Can Individuals' Beliefs Help Us Understand Non-Adherence to Malaria Test Results? Evidence from Rural Kenya

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Abstract

In malaria-endemic countries about a quarter of test-negative individuals take antimalarials (artemisinin-based combination therapies, ACTs). ACT overuse depletes scarce resources for subsidies and contributes to parasite resistance. As part of an experiment in Kenya that provided subsidies for rapid diagnostic test and/or for ACT conditionally on being positive, we study the association between beliefs on malaria status (prior and posterior the intervention), and the decisions to get tested and to purchase ACT. We find that prior beliefs do not explain the decision of getting tested (conditional on the price) and non-adherence to a negative test. However, test-negative individuals who purchase ACT report higher posterior beliefs than those who do not, consistent with a framework in which the formers revise beliefs upward, while the latters do not change or revise downward. We also do not find evidence that prior beliefs on ACT effectiveness and trust in test results play any major role in explaining testing or treatment behavior. Further research is needed to improve adherence to malaria-negative test results.

1. Introduction

Making decisions under uncertainty with imperfect information requires agents to rely on beliefs about uncertain events in the present and future (Delavande, 2008, van der Klaauw and Wolpin, 2008, Attanasio and Kauffman 2009, Delavande and Rohwedder, 2011, Kezdi and Willis, 2011, Arcidiacono et al., 2012, Shapira 2013, Zafar, 2013, McKenzie et al., 2013, de Paula et al. 2014, Delavande and Kohler, 2016). In the context of decisions related to health, where information asymmetry problems are acute (Arrow, 1963 and Sloan, 2001), agents might rely on their own beliefs about the state of their health, as well as form expectations about the probabilities of recovery or imminent complications. These beliefs, especially when they diverge from the true probabilities, can lead individuals to make choices that are not in their own self-interest. For example, when individuals systematically underestimate future risks, they might allocate resources and time inefficiently and also adopt inefficient levels of risky behavior. In addition to a broader literature in education (Attanasio and Kauffman 2009, Arcidiacono et al., 2012, Zafar, 2013), financial and labor markets (van der Klaauw and Wolpin, 2008, Delavande and Rohwedder, 2011, Kezdi and Willis, 2011, McKenzie et al., 2013), the literature on the economics of health has described how beliefs could affect choices about prevention and treatment in health settings. Most studies in this literature have focused on fertility choices (Shapira 2013), contraceptive behavior and risky behavior in the context of HIV (Delavande, 2008, de Paula et al. 2014, Delavande and Kohler, 2016), but there is no hard evidence on the role that beliefs play in explaining individual decisions related to other illness, such as malaria. Our study contributes to this literature by studying the

association between beliefs on malaria status and health behavior for diagnostic testing and treatment.

Each year, there are 215 million cases of malaria worldwide (WHO, 2015). Most of individuals with febrile illnesses seek care in the informal health sector, buying the most effective malaria drug (artemisinin-based combination therapies, ACTs), which is now publicly-subsidized in many malaria-endemic countries, including Kenya. However, poor targeting of ACTs to those in need, remains a concern. In fact, non-malaria febrile illnesses are common, and individuals with malaria-like symptoms purchase ACTs over the counter, without being diagnostically confirmed malaria positive. Even among those tested, a quarter of individuals tested negative still take ACTs (Briggs et al. 2014, Cohen et al. 2015). In our setting, rural Western Kenya, malaria testing is relatively uncommon with 43% of individuals reporting being malaria tested for their recent febrile illness. More than 70% of individuals with a recent fever reported taking ACT, nearly two thirds of which was sourced from the retail sector: 84% of those tested positive reported taking ACT; 60% of those untested and 34% of those tested negative also took ACT (Prudhomme O'Meara et al. 2018).

Understanding how people make their decisions in the context of testing and treatment of malaria is key to improve the appropriate use of ACTs. Specifically, knowing whether and how beliefs might guide these choices remain open empirical questions. Research examining the role of beliefs and malaria-related behavior has comprised primarily of qualitative studies examining drug purchases (Metta et al. 2014), and acceptability of rapid diagnostic test or trust in test results (Comoe' et al 2012, O'Neil et al. 2015), but we still lack rigorous quantitative evidence on the relationship between beliefs and malaria-related health behavior. Our study focuses on the role of beliefs in explaining individual non-adherence to a negative test result for malaria, a well-documented behavior that has not yet been explained empirically. Improving adherence to test results would reduce the wasteful use of publicly-funded ACTs and parasite resistance.

The data on malaria beliefs and health behavior come from an experiment in rural Western Kenya that offered randomized price subsidies to febrile individuals in order to get tested through a Rapid Diagnostic Test (RDT) for malaria by community health workers (CHW) and/or to receive conditional price subsidies for retail-sector purchase of

ACTs amongst those who test positive (Prudhomme O'Meara et al. 2016). By collecting data before and after the intervention, we examine whether the individual's prior beliefs about whether her fever is due to malaria are associated with the decision to get tested and to purchase ACT. We observe how beliefs change over time, and how these changes might differ depending on positive or negative malaria test results. We also analyze how the decisions are associated with posterior beliefs (one week after the intervention). We always control in our analysis for other prior beliefs such as ACT effectiveness and trust in a negative or positive test result.

We find that prior beliefs about the patient's illness are not associated with the choice to be tested for malaria, while the price of RDT remains the major driver of testing behavior. Furthermore, prior beliefs are not associated with ACT-purchasing decisions of individuals who tested negative for malaria. However, prior beliefs explain the decision to purchase ACT among those who did not get tested and those who tested positive. We also find that, amongst individuals who tested negative, posterior beliefs about whether the fever was due to malaria are associated with ACT-purchasing decisions for those who purchased ACT compared to individuals who did not purchase ACT. We do not find evidence that the prior beliefs on ACT effectiveness and trust in a negative or positive test result play any major role in explaining testing or treatment behavior.

The results indicate that in the context of healthcare for malaria in rural Kenya, prior beliefs do not explain the individual's decision to be tested for malaria (conditional on the price of RDT). Furthermore, prior beliefs do not explain non-adherence to a negative test result. Still, test-negative individuals revise their beliefs after purchasing an ACT. The positive difference between posterior beliefs of having malaria for negative individuals who purchased ACT relative to those who did not, is consistent with a conceptual framework in which test-negative individuals who purchase ACT revise their beliefs of having malaria upward, while those negatives who did not purchase ACT revise them downward or did not change them. This revision of beliefs after the choices of going for testing and purchasing ACT drugs could be explained by the following recovery process: the fever of those tested negative who purchased ACT might still have resolved by itself, with them attributing their recovery to the ACT drug they took; instead, those tested

negative who did not purchase ACT might have recovered either purchasing an other non-ACT drug which cured the true origin of their fever, or without taking any actions. Thus, while the recovery process of the former group reinforces their belief that the fever they had one week before was malaria (upward revision), the recovery through the non-ACT drug or lack of actions of the latter group either reinforce their belief that did not have malaria or did not change their beliefs (downward revision or no revision).

2. Background on Diagnostic Testing and Treatment for Malaria

In the last decades there has been a dramatic decline in the global malaria burden. Yet, in 2015, 215 million of cases and 438,000 deaths were attributed to malaria, and about 88% of those cases were concentrated in Sub-Saharan Africa (WHO, 2015). A unique challenge facing malaria control in endemic countries, such as Kenya, is that the majority of fevers are treated at retail drug stores. Fewer than 15% of potential malaria cases receive appropriate therapy, contributing to the global burden of disease and to the spread of resistance to antimalarial drugs (Laxminarayan, 2003, WHO, 2012; Lin et al. 2010).

In an effort to increase utilization of ACTs, the remaining most effective antimalarials, the Global Fund introduced quality-assured ACT in the retail sector at highly subsidized prices to eight pilot countries, including Kenya (Tougher et al. 2012). While higher utilization tied to Global Fund subsidies is widely seen as a public health success, it also leads to widespread overuse of ACTs by patients with malaria-like symptoms who do not have malaria. Such overuse of ACT not only depletes scarce public resources, it also contributes to resistance to artemisinin, which is already emerging in parts of South East Asia (Noedl et al. 2008, Phyo et al. 2012, Ashley et al. 2014).

In order to test an alternative model of targeting conditional subsidies to those individuals who test positive for malaria, Prudhomme O'Meara et al (2016) conducted a field experiment in Kenya that offered randomized price subsidies. Our study of the role of beliefs in explaining health behavior related to malaria is set within this context of experimental subsidies for RDT testing and ACT.

3. Methods, data and analysis

3.1. Setting and Study Participants

Our data was collected as part of a 2x2 factorial field experiment conducted in Bungoma County in western Kenya (Prudhomme O'Meara et al. 2016), where individuals were randomized to receive subsidies for RDT and/or subsidies for purchase of ACT[1], conditional on positive test results. Between July 2014 and June 2015, the study recruited individuals who had a malaria-like illness or history of symptoms in the last 24 hours, and had not yet received any testing, medicines or other treatment. Four hundred and forty-four individuals were enrolled in the study, and 98% of the respondents (adult patients or guardian if patient <18 year old) were interviewed at one-week follow-up. Over 60% of febrile patients were female, and 62% were children less than 18 years old. Therefore, the data about beliefs and expectations for the majority of our sample comes from respondents who were parents or guardians of these children. 84% of respondents are female with an average age of 37. Most completed primary education and are engaged in farming (Appendix 3 Table 1).

3.2. Data

Enumerators collected data on (prior) beliefs and subjective expectations, in addition to demographic details, health history, household characteristics, and level of knowledge about malaria. If the patient with malaria-like symptoms was a child (less than 18 years of age), the parent or guardian provided information on beliefs and expectations, and about actions taken. We therefore distinguish between patient (the individual with malaria-like symptoms) and respondent (the adult patient or the parent or guardian if the patient is a child less than 18 years old) in the reporting of results. Respondents were asked to describe their certainty about specific events by interacting directly with the touchscreen application hosted on android touchscreen tablets. They moved a "slider" back and forth to express more or less confidence in the probability of a specific event or condition (Appendix 1). Movement of the "slider" resulted in changes in the size of icons on both sides of the slider to give a visual interpretation of their choice. The slider tool

[1] The experiment randomized two levels of subsidy RDT for malaria (fully subsidized and free to the participant vs an unsubsidized test for which the participant paid US$0.50) and two levels of ACT subsidy (current retail price equivalent to no additional discount vs an additional discount of US$0.60 at the point of sale).

allowed us to record beliefs data along a scale from 0% to 100% (Maffioli and Mohanan, 2018). Our data includes respondents' assessments of the probability that the patient's illness is malaria[2], expectations about ACT effectiveness in curing malaria, and malaria test reliability under different scenarios of getting a positive and a negative test.

As part of the experimental intervention, patients were randomly assigned to one of four experimental conditions defined by two levels of RDT subsidies crossed with two levels of (conditional) ACT subsidies. One week after randomization, we collected follow-up data from respondents on beliefs and actions taken by, or for, the patient. In addition to collecting (self-reported) data on whether the patient was tested, test results, and drugs purchased, we elicited assessments of (posterior) beliefs about the malaria-like illness that made them eligible for the study, trust in a positive or negative malaria test result and ACT effectiveness. We were able to confirm respondent-reported testing results against documentation of the test result in nearly 90% of cases. We were not able to confirm ACT purchasing unless they used a study subsidy so that we can only rely on respondent-reported data in this latter case.

3.3. Hypothesis Testing and Empirical Analysis

We conceptualize treatment-seeking as two sequential decisions: whether (i) to get tested and (ii) to purchase ACT. First, individuals decide whether to get tested or not, and where to get tested (at a health facility or at a CHW). The decision is entirely up to the respondents, which could go to a health facility and receive a microscopy test, or to go to a CHW and receive a RDT. Second, individuals decide to purchase drugs (ACT versus other treatment options), taking into account the new information about being malaria negative or positive. If they choose to not get tested, they do not have access to the ACT subsidies, but they are still able to decide whether to purchase any drugs or not. The

[2] The analysis assumes that respondents have a basic understanding about malaria being caused by an infection that can be detected by a malaria test and treated with ACT. In our sample, 82% of respondents reported that malaria could be passed from one person to another and 79% of these respondents identified mosquitoes as the mode of transmission. In addition, 85% of respondents identified ACTs as a medicine that can be used to treat malaria. This suggests that respondents in our sample have a strong understanding of the biomedical basis of the disease.

decision of purchasing ACT would be the entirely up to the respondents if they decide to go to the informal sector to purchase a drug.[3]

In the first part of our analysis, we examine the association between respondents' prior beliefs and individual behavior. We are interested in the role that prior belief of having malaria has on (i) individual testing behavior and (ii) ACT purchasing behavior. We thus try to isolate the role of belief about having malaria, controlling for the general level of trust in a (negative or positive) test as well as a discrete measure of ACT effectiveness.[4] Ex-ante, it is not obvious what the relationship is between the prior belief of having malaria and the individual decision of going for testing. On the one hand, this association between beliefs and testing behavior could be expressed as a linear relationship. On the other hand, it could also be that those who feel certain about having (or not having) malaria (close to 100% and 0% probability respectively) are less likely to go for testing, compared to those who are uncertain about their status (around the 50% cut-off). In this latter case, an empirical model that allows for non-linearity could be more appropriate. While we test both possibilities, we report findings from empirically testing a linear relationship. We confirm that the results do not change if we use an alternative non-linear specification (Appendix 3 Table 2), which considers tertiles of the distribution to distinguish between respondents who are more certain to have (first tertile) or not have (third tertile) malaria, compared to those uncertain (second tertile).

We hypothesize that individuals with a higher prior belief of having malaria are more likely to go for testing (conditional on the price of RDT testing). We also estimate the effect of the price of the RDT test on testing behavior. Our basic model specification (Model 1) for individual i in community c is a linear probability model (LPM) with robust standard errors as follows:

[3] In our study, all participants could obtain an RDT (free or US$0.50, depending on the group) by reporting to the CHW, who provided the conditional ACT voucher when applicable. RDT-negative participants or those not tested could still access ACTs at the normal retail price. Participants could also choose to seek care at the nearest health facility where they would be treated according to normal patient protocols. Government facilities charged US$0.65 for a microscopy test but ACTs are free (O Meara Prudhomme at al. 2016).

[4] Trust in a malaria test and beliefs about ACT effectiveness might be important factors for individuals' decision of going for testing, in addition to the self-reported probability of having malaria. For example, these beliefs might matter more for individuals who are uncertain about their malaria status. Given our data limitation especially on ACT effectiveness belief, we simply add them as independent variables in the main empirical models. In separate analysis (not shown) we also explore the interaction between belief of having malaria and ACT effectiveness, but we do not find statistically significant results worthy to report. We also explore the interaction between belief of having malaria and trust in a negative or positive test result (not shown), and results are reported in footnotes 8 and 13.

$$y_{ic} = \alpha + \boldsymbol{\beta B_{ic}} + \boldsymbol{\gamma S_{ic}} + \theta_j + \mu_c + \varepsilon_{ic} \ (1)$$

where y_{ic} is an indicator equal to 1 if the individual got tested for malaria, regardless of the source of the test (at CHW or at health facility) or the type of test (RDT or microscopy), and equal to 0 otherwise. In equation (1) our regressor of interest is the individual prior belief as (self-reported) probability of having malaria, controlling for the (self-reported) probability that a positive or a negative malaria test results is correct ($\boldsymbol{B_{ic}}$ is a 3X1 vector of these prior beliefs). The basic specification also includes two indicators, one for ACT subsidy levels and one for RDT subsidy levels ($\boldsymbol{S_{ic}}$ is a 2X1 vector), enumerators (θ_j) and community fixed effects (μ_c) (three communities participated in the intervention). ε_{ic} is a normally-distributed random error term with mean of zero.

A second and a third specification (Model 2 and Model 3) include a vector of socio-demographic characteristics ($\boldsymbol{X_{ic}}$) and an additional vector of prior beliefs ($\boldsymbol{Z_{ic}}$)**.** Socio-demographic controls ($\boldsymbol{X_{ic}}$) include gender, age, occupation and education level of the respondent, household size, an indicator for wealth, gender of the patient, and an indicator for whether the respondent is the same as the patient. Additional beliefs variables ($\boldsymbol{Z_{ic}}$) include: (i) a binary variable indicating that the respondent thought ACT to be more effective than another common antimalarial drug, Sulfadoxine/Pyrimethamine (Fansidar, SP); (ii) a variable indicating the severity of a malaria illness, constructed as the mean probability of being admitted to the hospital in 2 days, 5 days, or 2 weeks after onset of illness; and (iii) a variable indicating the illness progression over time constructed as the difference between the reported probability of being admitted to the hospital in 2 weeks versus 2 days in the same hypothetical scenario. Our preferred specification over all models is the following:

$$y_{ic} = \alpha + \boldsymbol{\beta B_{ic}} + \boldsymbol{\gamma S_{ic}} + \boldsymbol{\delta X_{ic}} + \boldsymbol{\zeta Z_{ic}} + \theta_j + \mu_c + \varepsilon_{ic} \ (2)$$

where variables are defined as above.[5]

In the second part of the analysis, we test whether the prior belief of having malaria is associated with the decision of buying ACT, separately for individuals tested (negative or

[5] In Table 3 in Appendix 3 we also show estimates for the following specification which adds an interaction term between prior belief of having malaria and RDT/ACT discounts as follows: $y_{ic} = \alpha + \boldsymbol{\beta B_{ic}} + \boldsymbol{\gamma S_{ic}} + \boldsymbol{\delta X_{ic}} + \boldsymbol{\zeta Z_{ic}} + \boldsymbol{\psi B_{ic}} * \boldsymbol{S_{ic}} + \theta_j + \mu_c + \varepsilon_{ic}$ (4).

positive) and those not tested, controlling for all observable characteristics that might differentiate those who decided to go or not for testing. We empirically test the following hypothesis for each of the three sub-samples:

a) Individuals who tested positive

If individuals believe the positive test result, they should update their beliefs of having malaria upward after testing. Then, especially those with a higher prior belief of having malaria should receive the confirmation from a positive malaria test that their illness was malaria and revise their belief upward. Thus, we hypothesize a positive relationship between prior belief of having malaria and ACT purchasing behavior among individuals who tested positive. We test whether individuals tested positive who have higher prior belief of having malaria are **more** likely to buy ACT that those who have a lower prior belief of having malaria.

b) Individuals who tested negative

If individuals believe the negative test result, they should update their beliefs of having malaria downward after testing. It is however ex-ante unclear whether individuals with a higher prior belief of having malaria might revise their belief downward more or less relative to those with a lower prior belief, when they receive negative test results. We test empirically whether individuals who have higher prior belief of having malaria are **equally, more or less** likely to buy ACT than those who have a lower prior beliefs.

c) Individuals not tested

Among individuals who decided to not get tested, we assume that their prior beliefs remain unchanged since there is no new information from testing to update those priors. Thus, we hypothesize that among individuals not tested, those with higher prior beliefs of having malaria are **more** likely to buy ACT.

In the third part of the analysis, we examine the posterior belief of having malaria, and how this changed after individuals' behavior. Understanding how beliefs are shaped by actions is fundamental to learn about how to reinforce correct beliefs and thus improve health behavior. If changes in behavior lead to correct changes in posterior beliefs, these beliefs might then influence future individuals' choices and treatment behavior. Given the existing problem of tested negative individuals taking antimalarials, we are specifically interested in learning about whether ACT purchasing behavior, after the choice of being

tested and knowing the malaria status, is associated with the posterior belief of having malaria. This could affect whether individuals decide to go for testing for future illnesses and adhere to the test result.

Recall that individuals could have updated their beliefs at two points in time: one right after testing, and one after ACT purchasing and depending on whether and how they recover after taking the drug. Unfortunately, due to constraints in the implementation of the study, we were not able to collect information on updated belief of having malaria immediately after malaria testing. Thus, we do not observe updated beliefs at the first point in time. Instead, we observe beliefs after both actions – testing and purchase of ACT - are taken, one week after the intervention (posterior beliefs). Furthermore, due to limitations of data collection, we only have information on posterior belief of having malaria among individuals who were tested. Specifically, the analysis of associations between ACT purchase and posterior beliefs focuses on those who tested negative - a sub-sample that is critical for our study of overconsumption of ACT.[6] Finally, since we lack data on the timing of purchase of ACT relative to going for testing, and on the patients' health status one week after the intervention, we cannot determine how long individuals waited to purchase ACT after the test and then how long their illness lasted. Because of all these data limitations, this last set of results should be interpreted as suggestive compared to the other parts of the analysis. Appendix 2 Figure 1 pictures the belief updating process and data limitations.

Consider that the individual's recovery (or lack thereof) from febrile illness after consumption of ACT or other non-ACT drugs might influence their posterior beliefs. Also consider that ACT primarily cures malaria, and does not help with fevers of viral or bacterial origin, and that the majority of respondents (67%) have knowledge of this.[7] Still, there is some uncertainty about how individuals tested negative who purchased or

[6] Among individuals tested positive, it is unclear whether those individuals tested positive, which purchased ACT have a **similar, higher, or lower** posterior belief of having malaria, than those who did not purchase ACT. In fact, both groups are expected revise their beliefs upward (those who took ACT, get better and their recovery reinforce the belief of having malaria; those who do not take ACT, should not get better and their not recovery also reinforce the belief of having malaria). However, the difference in the upward revision of belief between those who purchased ACT and did not purchase ACT, among people tested positive, is unclear.

[7] Unfortunately, we did not asked directly respondents about whether they believe that ACT can cure non-malaria illnesses. However, we asked whether they believe ACT is more or less effective in curing malaria than other drugs, and 67% of the respondents reported ACT to be more effective.

did not purchase ACT recover after taking the drug, based on their true origin of fever. In sub-Saharan Africa fever remains a common symptom of several illnesses, and diagnosis remains a challenge, due to multiple causes of fevers and the lack available diagnostic tests (Meze et al. 2018). Recent studies in Kenya and Tanzania have demonstrated that most of the febrile illnesses are due to influenza or respiratory viruses (D'Acremont et al. 2014, Chipwaza et al. 2015, O Meara Prudhomme et al 2015), bacteraemia, such as brucellosis, leptospirosis, Q fever and rickettsiosis, or the origin still remain uncertain. While bacterial infections are treated with antibiotics, other drugs can help curing the common symptoms of viral infections, i.e. fever or cough or congestion. Because of the several factors influencing their recovery process, we describe here what we argue is the most likely scenario happening in our context.

In our data, among tested negative individuals, 19% purchased ACT, while the rest did not. Among those who did not purchase ACT, 38% purchased a non-ACT drug (mostly Panadol, fever-reducer, or Amoxyl, antibiotic), while 62% did not take any action. We argue that these individuals - tested negative individuals who did not purchase ACT - are more likely to either (i) get better because the non-ACT drug help curing the true origin of their fever or at least reduce it (38% of the cases), or (ii) potentially get better because their fever resolves by itself (62% of the cases), such as in a case of common cold. Thus, because of their recovery with non-ACT drugs or without taking any action reinforcing their belief that their fever one week before was not malaria, we expect these individuals to revise their beliefs downward. Instead, individuals tested negative who purchased ACT could:

a) Recover after taking the drug: It is still possible, as in the case of a common cold, that their fever resolves by itself in one-week time. Individuals tested negative who purchased ACT might still attribute their recovery to the drug they took, i.e. ACT. Then, we expect them to revise their belief of having malaria upward, since the recovery through ACT reinforces their belief that their fever one-week before was actually malaria.

b) Get worse after taking the drug: If the fever does not resolve by itself, the illness – that remained untreated – could worsen. Individuals tested negative who purchased ACT should attribute lack of effectiveness of ACT to the fact that their fever one week before was not malaria. Then, we expect them to revise their belief of having malaria downward.

c) Do not get better/worse: Individuals tested negative who purchased ACT should not revise their beliefs of having malaria.

For the same reasoning as above - because of the epidemiology of febrile illnesses which are not malaria (Meze et al.2018) - we argue that in our context individuals tested negative who purchased ACT are likely to get better in one-week window (scenario (a)). We then hypothesize that those individuals tested negative, which purchased ACT have a **higher** posterior belief of having malaria, than those who did not purchase ACT.

We test these hypotheses empirically, exploring whether and in which direction the respondents' decision to purchase ACT is associated with the posterior belief about the probability that the malaria-like symptoms they (or the patient) experienced one week before was due to malaria. Our specification is as follows:

$$y_{ic} = \alpha + \boldsymbol{\beta B_{ic}} + \boldsymbol{\gamma S_{ic}} + \boldsymbol{\delta X_{ic}} + \eta A_{ic} + \theta_j + \mu_c + \varepsilon_{ic} \quad (3)$$

where y_{ic} is a continuous posterior (self-reported) probability of having malaria. Our regressor of interest is an indicator about whether the individual purchased ACT (A_{ic}). All other controls are the same as described above.

3. Results

3.1 Beliefs

Respondents demonstrated good understanding of concepts of probability and nested probability. At baseline, respondents reported a mean (SD) probability of 73% (24%) that the fever or illness of the patient was due to malaria (Table 1). Looking at the distribution of the belief of having malaria (Appendix 2 Figure 2) it is also worthy to notice that, at baseline, few individuals assign very low levels of probability to having malaria, while most of the mass is around 50% and a good part is skewed toward 100%.

Table 1: Elicited beliefs and constructed variables at baseline for 444 respondents

	Mean	SD	p5	p25	p50	p75	p95
A. Beliefs							
Prob having malaria	73.1	24.5	40.0	50.0	74.0	100.0	100.0
Prob having malaria in district	60.6	24.1	25.0	49.0	52.0	77.0	100.0
Prob having malaria in village	66.9	24.3	34.0	50.0	62.0	96.0	100.0

Prob getting malaria in rainy season	83.2	17.8	50.0	72.0	88.0	100.0	100.0
Prob getting malaria in dry season	47.6	19.4	20.0	38.0	48.0	55.0	97.0
Prob - Admission to hospital in 2 days	38.3	23.2	0.0	25.0	39.0	50.0	84.0
Prob - Admission to hospital in 5 days	65.5	21.1	34.0	52.0	64.0	79.0	100.0
Prob - Admission to hospital in 2 weeks	92.1	12.9	66.0	88.5	99.0	100.0	100.0
Prob test negative correct	64.1	34.5	0.0	44.0	68.5	99.5	100.0
Prob test positive correct	71.4	32.7	0.0	51.0	85.5	100.0	100.0
B. Variables for analysis							
ACT more effective (binary) [§]	63.8	48.1	0.0	0.0	100.0	100.0	100.0
Prob - Admission to hospital (Severity)	65.3	15.2	40.7	55.3	65.0	74.2	93.3
Prob - Admission to hospital (Time progression)	53.7	24.3	10.0	39.0	53.0	68.5	100.0

Notes: This table presents moments of the distribution of beliefs (Panel A) and variables constructed for analysis (Panel B). The beliefs are collected from an adult patient or the guardian of child if the patient is under 18 years old. [§] A binary variable, therefore reported simply as a proportion. Panel A includes the probability that the individual's illness is malaria; the probability of getting malaria in their district; the probability of getting malaria in village; the probability of getting malaria in rainy season; the probability of getting malaria in dry season; the probability of being admitted to the hospital in 2 days, 5 days, or 2 weeks after onset of illness in the hypothetical case of an adult with malaria who did not take any medication; the probability that the malaria test was correct in the hypothetical scenario in which the respondent believes to have malaria, but the test shows she does not have malaria; the probability that the malaria test was correct in the hypothetical scenario in which the respondent believes to not have malaria, but the test shows she does have malaria. Panel B includes a binary indicator for whether the respondent believes ACTs are more effective than another common antimalarial drug, Sulfadoxine/Pyrimethamine (Fansidar, SP); two additional variables, both based on questions about the hypothetical case of an adult with malaria who did not take any medication: a variable indicating the severity of a malaria illness, constructed as the mean probability of being admitted to the hospital in 2 days, 5 days, or 2 weeks after onset of illness; and a variable indicating the illness progression over time constructed as the difference between the reported probability of being admitted to the hospital in 2 weeks versus 2 days in the same hypothetical scenario.

Respondents also believed that the probability that a fever in their village was caused by malaria is slightly higher than in the whole district. Further, they correctly believed that the probability of having malaria is higher in the rainy season than in the dry season, and that the probability of being admitted to the hospital increases over time in the hypothetical case of an adult with malaria who does not take any drug. When asked about their level of confidence in a negative or a positive malaria test result, respondents reported a mean (SD) probability of trusting a positive result of 71% (33%) if they thought themselves to be malaria negative, while they trusted a negative result less (mean: 64%, SD: 35%) if they believed they had malaria.

3.2 Uptake of malaria testing and ACT consumption

One week after being randomized to the intervention, 62% of respondents reported having received a diagnostic test from any source (either CHW or health facility) (Figure 1). Still, 90% of those tested were tested by a CHW with a RDT. Among those tested, 38% were found to be positive. Of those who tested positive, 75% reported taking an ACT compared to 19% of those who tested negative, and 26% of those who were not tested. The number of inappropriate users, i.e. individuals that buy ACT when tested negative, are less than what other studies report (Cohen et al. 2015, Prudhomme O'Meara 2018). Still, about one in five patients did not adhere to negative test results and purchased ACT when it was not necessary.

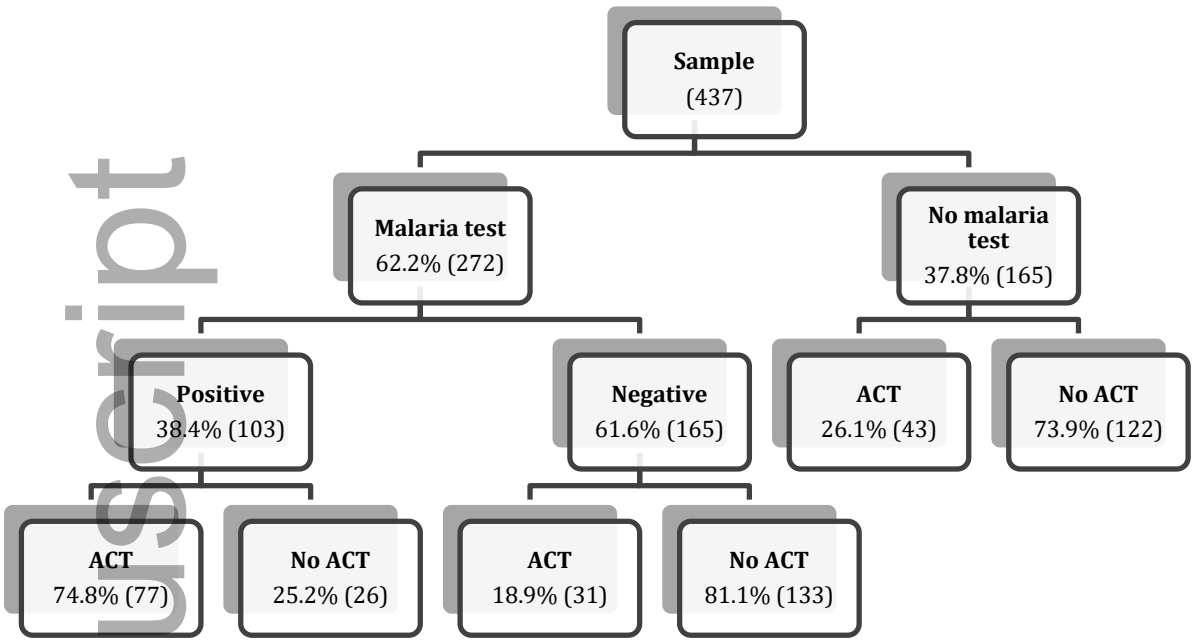
3.3. The association between prior beliefs and malaria testing uptake

Table 2 describes the association between prior belief of having malaria and getting tested for malaria, using a linear empirical specification. The estimates do not show evidence of a statistically significant association between prior beliefs and uptake of malaria testing. Across all model specifications, the assignment to RDT subsidy condition is the only statistically significant predictor (p-value<0.01) of testing uptake: individuals assigned to a RDT subsidy are about 23 percentage points more likely to go for testing. This indicates that price, rather than prior beliefs, is the major driving force behind the decision to be tested, and we can infer a causal effect of price on the decision due to the randomized nature of the experiment (Prudhomme O'Meara et al, 2016). In addition, none of the other beliefs on ACT effectiveness and trust in a positive or negative test result matter for the decision of going for testing.[8] [9]

Figure 1: Malaria testing and ACT purchasing behavior at follow-up for 437 study patients

[8] We find a similar positive association between RDT subsidy and going for testing in an alternative empirical specification which includes interaction terms between the prior belief of having malaria and trust in positive or negative test results. However, we find a positive association between the prior belief of having malaria and going for testing. Yet, those who have a higher prior belief of having malaria and have higher prior trust in a positive test result ("Prob having malaria X Prob test positive is correct") are less likely to go for testing. This suggests that those who are surer about having malaria and have higher trust in a positive test result might not have much to learn from the test, and thus they are more likely to not go for testing. Instead, we do not find any statistically significant effect for the interaction term between the prior belief of having malaria and the prior trust in a negative test result.

[9] The results remain similar if we look at children (under 5 years old, between 5 and 17 years old) or adults (18 years old and above) in the sample (Appendix 3 Table 4).



Notes: The figure presents means (observations) for testing and ACT purchasing behavior at follow-up. "Malaria test" includes any malaria test regardless of the source of the test (CHW or health facility) or the type of test (RDT or microscopy). Missing data on ACT purchasing behavior or test results explains why the number of observations in few sub groups does not always sum up perfectly.

The absence of a statistically significant association between prior belief of having malaria and the decision of getting tested is also confirmed when we specify a non-linear association, as shown by Table 2 in Appendix 3: neither individuals who have a very low belief of having malaria (probability of having malaria in the first tertile) nor those who strongly believe they have malaria (probability of having malaria in the third tertile) are more or less likely to go for testing than those who are uncertain about their status (probability of having malaria in the second tertile).

Table 2: Linear probability model estimates of the association between prior beliefs and malaria testing behavior (linear relationship between beliefs and behavior)

Dependent Variable: Had Any Malaria Test			
	Model 1	Model 2	Model 3
	(1)	(2)	(3)

Prob having malaria	-0.00511	0.0288	0.00813
	(0.110)	(0.113)	(0.116)
RDT subsidy	0.238***	0.232***	0.230***
	(0.0458)	(0.0462)	(0.0465)
ACT subsidy	-0.0245	-0.0287	-0.0313
	(0.0461)	(0.0465)	(0.0468)
Prob test negative correct	0.0890	0.0800	0.0899
	(0.0866)	(0.0890)	(0.0904)
Prob test positive correct	-0.00445	-0.0240	-0.0353
	(0.0855)	(0.0905)	(0.0926)
ACT more effective (dummy)			-0.000118
			(0.0506)
Admission to hospital - Severity			0.166
			(0.205)
Admission to hospital - Progression over time			0.0731
			(0.130)
Enumerator fixed effects	Yes	Yes	Yes
Community fixed effects	Yes	Yes	Yes
Socio-demographic controls	No	Yes	Yes
Dep Var Mean	0.622	0.622	0.622
N	421	413	412

Notes: This table presents linear probability model estimates of the association between prior beliefs and malaria testing behavior. Socio-demographic controls include age, gender, education level, occupation, wealth (in the lowest 40th percentile of income distribution) and household size of respondent (patient and guardian if patient <18years), gender of patient, and a dummy equal to 1 if respondent is the same as the patient. Enumerators fixed effects include a dummy per each of the 8 enumerators. Communities fixed effects include a dummy per each of the 3 communities. The variable "ACT more effective" is a binary indicator for whether the respondent believes ACTs are more effective than another common antimalarial drug, Sulfadoxine/Pyrimethamine (Fansidar, SP); The variable "Admission to hospital - Severity" is constructed as mean between probability of being admitted to the hospital in 2 days, 5 days, 2 weeks. The variable "Admission to hospital - Progression over time" is constructed as the difference between probability of being admitted to the hospital in 2 weeks and 2 days. Standard errors in parentheses. *p<0.1 ** p<0.05 *** p<0.01.

Table 3 in Appendix 3 confirms that even among people who did not receive a RDT discount, the prior belief of having malaria does not play a role in explaining the decision to go for testing (Model 3: coefficient 0.0146 and SE 0.193). Interacting the randomized discounts for RDT (or ACT) with prior belief of having malaria further confirms that

individuals with different prior beliefs do not react differently to subsidies for RDT (or ACT).

3.4. The association between prior beliefs and ACT purchase

We next examine the choice of purchasing ACT, conditional or not on getting tested for malaria and learning about the test result. Table 3 shows that the prior belief about having malaria is associated with ACT purchasing behavior, but only for specific sub-samples of the population. Among individuals tested positive, we find a statistically significant positive association between the prior belief of having malaria and ACT purchasing behavior. Specifically, a unit increase in the prior belief of having malaria is associated with a 0.50 unit change in likelihood of ACT purchase among those with a positive test result (Table 3, column 2). This corresponds to an increase of 12 percentage points in the probability of purchasing ACT for a standard deviation (1SD = 0.245, Table 1) increase in the prior belief that the illness is malaria. This positive association suggests that those with a higher prior belief of having malaria revise their belief upward, after confirming that they had malaria through the positive test. These individuals are then more likely to purchase ACT, compared to those with a lower prior belief. We also find a similar positive association for individuals not tested (coefficients (SE) of 0.311 (0.172) and 0.395 (0.166) in columns 5 and 6, respectively). Again, this result suggests that those who decided not to be tested, and thus did not get any novel information on their malaria status, are more likely to purchase ACT when their prior belief of having malaria is higher. In contrast, testing a similar relationship for those individuals who tested negative, we do not find associations that are statistically significant (column 3 and 4 show coefficients (SE) of -0.118 (0.161) and -0.0791 (0.177)). This might be consistent with the fact that those tested negative with higher prior belief of having malaria might not have revised their belief downward enough after testing, compared with individuals tested negative who already thought to have a low probability of having malaria to start with (Section 3). Thus, their ACT purchasing decision after their downward revision of beliefs immediately after testing (not observed) might not differ from the decision of

those with a lower prior belief.[10] It is also worthy to highlight that none of the other beliefs on ACT effectiveness and trust in a positive or negative test result strongly matter for the decision of purchasing ACT.[11]

Table 3: Linear probability model estimates of the association between prior beliefs and ACT purchasing behavior, among persons who were tested or not for malaria

	Dependent Variable: Purchased ACT

[10] Appendix 2 Figure 3 summarizes the mean belief of having malaria prior to the intervention by the decision of being tested, testing results, and ACT purchasing behavior. Red boxes highlight statistically significant associations (p-value<0.1) between prior belief of having malaria and the ACT purchasing behavior.

[11] Unfortunately, the sub-samples are not large enough to estimate similar results by age of the patient for malaria positive, malaria negative and non-tested individuals.

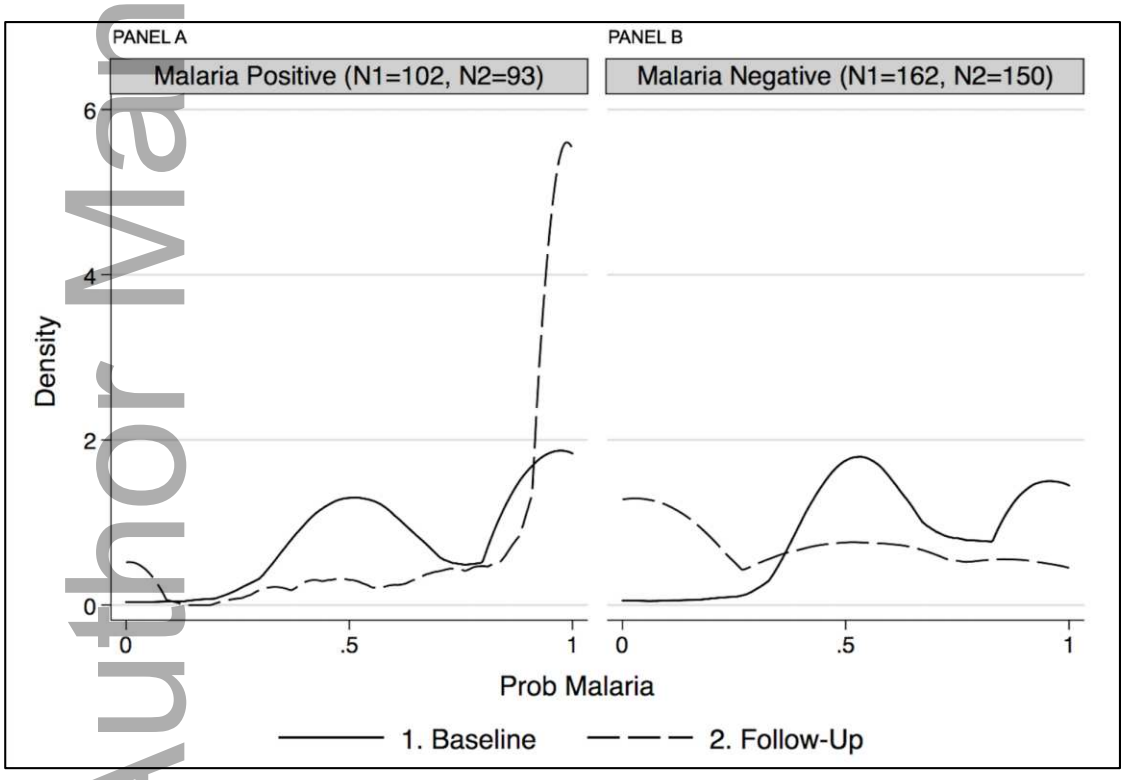
	Malaria Positive		Malaria Negative		Not tested	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	(1)	(2)	(3)	(4)	(5)	(6)
Prob having malaria	0.498**	0.498*	-0.118	-0.0791	0.311*	0.395**
	(0.227)	(0.269)	(0.161)	(0.177)	(0.172)	(0.166)
ACT subsidy	0.0921	0.0997	0.0477	0.0367	-0.101	-0.101
	(0.0937)	(0.105)	(0.0618)	(0.0664)	(0.0721)	(0.0698)
ACT more effective (Dummy)	-0.0171	0.0156	0.0316	0.0224	0.0266	-0.00576
	(0.102)	(0.113)	(0.0653)	(0.0737)	(0.0818)	(0.0789)
Prob test negative correct	0.0818	0.0785	-0.0814	-0.0870	-0.113	-0.101
	(0.144)	(0.177)	(0.126)	(0.132)	(0.141)	(0.144)
Prob test positive correct	-0.232*	-0.153	0.0753	0.0708	0.0529	0.130
	(0.125)	(0.138)	(0.143)	(0.161)	(0.151)	(0.150)
Enumerator fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Community fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Socio-demographic controls	No	Yes	No	Yes	No	Yes
Dep Var Mean	0.748	0.748	0.189	0.189	0.261	0.261
N	99	97	159	154	158	157

Notes: This table presents linear probability model estimates of the association between prior beliefs and ACT purchasing behavior. Socio-demographic controls include age, gender, education level, occupation, wealth (in the lowest 40th percentile of income distribution) and household size of respondent (patient and guardian if patient <18years), gender of patient, and a dummy equal to 1 if respondent is the same as the patient. Enumerators fixed effects include a dummy per each of the 8 enumerators. Communities fixed effects include a dummy per each of the 3 communities. The variable "ACT more effective" is a binary indicator for whether the respondent believes ACTs are more effective than another common antimalarial drug, Sulfadoxine/Pyrimethamine (Fansidar, SP). Standard errors in parentheses. *p<0.1 ** p<0.05 *** p<0.01.

3.5. The association between individual ACT purchasing behavior and posterior belief of having malaria, conditional on malaria testing

We start by describing the shifts in distribution of beliefs from baseline to follow up in Figure 2, separately among those who tested positive (Panel A) and who tested negative (Panel B) for malaria. We notice that among individuals who tested positive (Figure 2, Panel A), beliefs change in the one-week interval, seen as a large shift towards the right (higher probability of malaria). At baseline only 52% of individuals who subsequently tested positive expressed a probability of having malaria higher than 80%, while at follow-up 88% expressed a probability greater than 80%. Among malaria-negative individuals, the distribution of reported beliefs about having malaria shifted leftwards between baseline and follow-up (Figure 2, Panel B), with a smaller proportion reported a high probability (over 80%) of having malaria at follow-up compared to baseline.

Figure 2: Density of probability of believing having malaria by time, by malaria test result



Notes: This figure represents the density of the probability of believing having malaria, by malaria status (positive and negative) and by time of data collection (baseline and follow-up).

Table 4 reports estimates of the association between ACT purchasing behavior and posterior belief of having malaria among individuals who were tested for malaria. The decision to purchase ACT is associated with 37.4 percentage points higher posterior belief of having had malaria ($p<0.01$) (Table 4, column 6). In particular, among people who tested positive, the difference in the posterior belief between those who purchased ACT and those who did not – both of whom might have revised their belief of having malaria upward – is not statistically significant (Table 4, column 2, and Figure 3, Panel A). This finding could also be due to the fact that there might not be enough room for belief revision after positive testing. In fact, individuals who tested positive, regardless of whether they purchased ACT or not, reported very high probabilities of having had malaria at follow-up (mean of 85% in both cases).[12]

On the other hand, malaria negative people who purchase ACT on average express a 19.9 percentage points higher posterior belief of having malaria (columns 4 in Table 4, and Figure 3, Panel B) compared to those who did not buy ACT. This is consistent with the hypothized scenario in which those individuals tested negative who purchase ACT had their fever resolved by itself, attributing their recovery to the ACT drug they took, while those tested negatives who did not purchase ACT, either purchased non-ACT drug which potentially cured the true origin of their fever, or did not take any actions. While the former group revised the belief of having malaria upward, the latter group revised them downward or did not change beliefs. The difference in posterior belief of having malaria among those who purchase or not ACT is then positive and statistically significant. Overall, this lack of adherence to malaria negative test results and its positive association with the posterior belief of having malaria might have important implications for treatment behavior of future illnesses.

We do not find any evidence that the prior beliefs on ACT effectiveness and trust in a positive or negative test result explain the posterior belief that the illness was malaria.[13] [14]

[12] Figure 4 in Appendix 2 summarizes the means of the belief of having malaria, among individuals tested for malaria, after the intervention, by malaria status and ACT purchasing behavior. Red boxes highlight statistically significant association between individual ACT purchasing behavior and posterior belief of having malaria.

[13] We find similar results on the association between individual ACT purchasing behavior and posterior belief of having malaria in an alternative empirical specification which includes interaction terms between the prior belief of having malaria and trust in positive or negative test results. We also find that those who have a higher prior belief of having malaria and have higher prior trust in a negative test result ("Prob having malaria X Prob test negative is correct") are less likely to purchase ACT only among tested positive individuals. Instead, we do not find any statistically significant effect for the interaction term between the prior belief of having malaria and the prior trust in a positive test result.

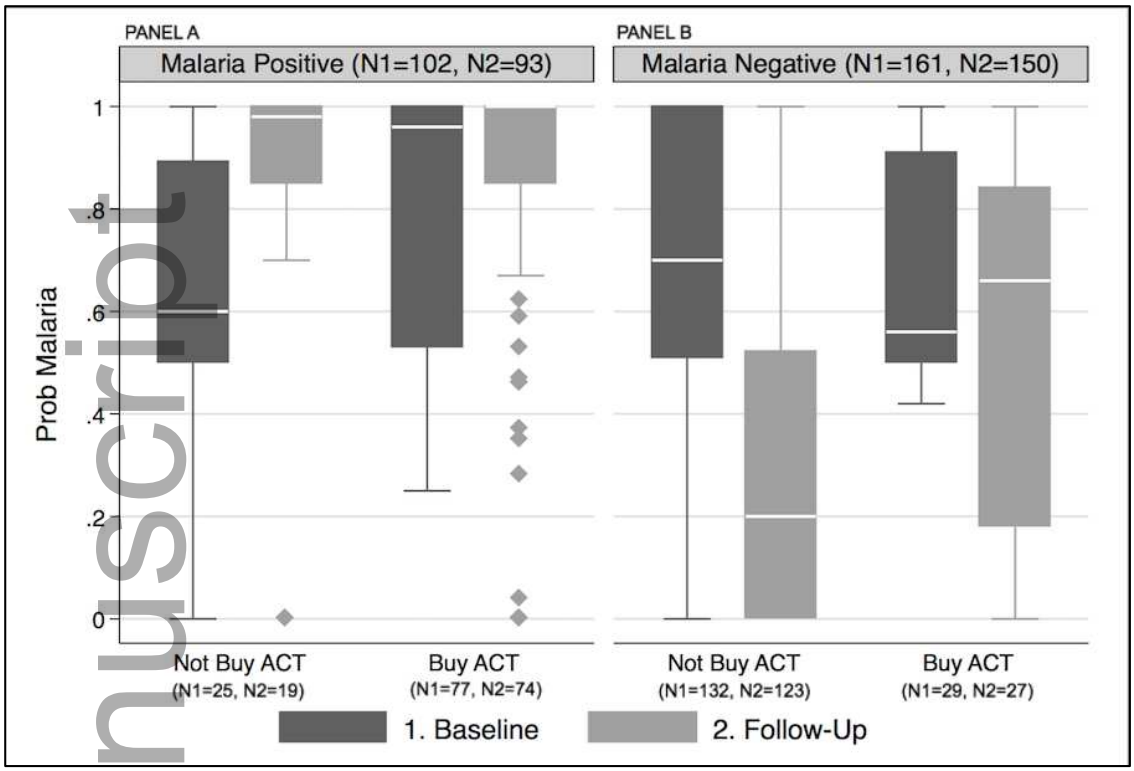
Table 4. Linear probability model estimates of the association between ACT purchasing behavior and posterior beliefs, among persons who were tested for malaria

Dependent Variable: Posterior Probability Illness Was Malaria						
	Malaria Positive		**Malaria Negative**		**All tested**	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	(1)	(2)	(3)	(4)	(5)	(6)
Purchased ACT	0.0179	0.0495	0.217***	0.199**	0.394***	0.374***
	(0.0587)	(0.0710)	(0.0779)	(0.0796)	(0.0468)	(0.0490)
Prob having malaria	-0.0727	-0.0614	-0.118	-0.104	-0.0259	-0.0222
	(0.136)	(0.174)	(0.133)	(0.149)	(0.112)	(0.116)
Prob test negative correct	0.0370	0.0181	0.0404	0.0677	0.0685	0.0901
	(0.0888)	(0.108)	(0.120)	(0.129)	(0.0827)	(0.0857)
Prob test positive correct	0.125	0.146	-0.0872	-0.131	-0.0300	-0.00434
	(0.0946)	(0.105)	(0.112)	(0.120)	(0.0794)	(0.0828)
ACT subsidy	0.0660	0.0340	0.0535	0.0460	0.0346	0.0235
	(0.0575)	(0.0627)	(0.0527)	(0.0573)	(0.0452)	(0.0473)
Enumerator fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Community fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Socio-demographic controls	No	Yes	No	Yes	No	Yes
Dep Var Mean	0.850	0.850	0.356	0.356	0.538	0.538
Observations	90	88	147	143	240	234

[14] Unfortunately, the sub-samples are not large enough to estimate similar results by age of the patient for malaria positive, malaria negative and all tested individuals.

Notes: This table presents linear probability model estimates of the association between ACT purchasing behavior and posterior belief that illness one week before was malaria, among persons who were tested for malaria. Socio-demographic controls include age, gender, education level, occupation, wealth (in the lowest 40^{th} percentile of income distribution) and household size of respondent (patient and guardian if patient <18years), gender of patient, and a dummy equal to 1 if respondent is the same as the patient. Enumerators fixed effects include a dummy per each of the 8 enumerators. Communities fixed effects include a dummy per each of the 3 communities. Standard errors in parentheses. *p<0.1 ** p<0.05 *** p<0.01.

Figure 3: Box plot of probability of believing having malaria among tested individuals, by ACT purchasing behavior and malaria test result



Notes: This figure represents the probability of believing having malaria among tested individuals, by ACT purchasing behavior and by malaria status (positive and negative). Missing data on ACT purchasing behavior or test results explains why the number of observations in few sub groups does not always sum up perfectly to the number of observations in Figure 3.

4. Discussion

We study the relationship between beliefs about the illness being malaria and decisions about malaria testing and treatment in rural Western Kenya, examining how these beliefs change with new information on malaria status from rapid diagnostic tests (RDT).

Our first finding that prior beliefs do not play an important role in explaining the individual decision of getting tested (conditional on the price of RDT) or in explaining non-adherence to a negative test, is significantly different from previous research (Delavande, 2008, de Paula et al. 2014, Delavande and Kohler, 2016) in which beliefs were found to be good predictors of individual behavior. The lack of relationship between prior beliefs and behavior could be due to contextual factors that are specific to malaria testing and treatment, as well as to our setting in Kenya. The RDT is a new technology that was introduced in the parent study, and it is still becoming more widely available in

rural areas of Kenya. It is possible that the decision to get tested might respond differently to beliefs once the RDT is better known and trusted. In fact, we also note that our measures of trust in test results do not explain testing decisions. Furthermore, in our setting, the testing was conveniently done by a CHW in the village and we offer ACT subsidies to those tested positive. However, the findings might be different in other contexts where testing might be available primarily at health facilities.

We also argue that our second finding - individuals tested negative, which purchased ACT have a higher posterior belief of having malaria than those who did not purchase ACT - could be consistent with the hypothetical scenario in which individuals tested negative who purchased ACT had their fever resolved by itself (upward revision of beliefs), while those tested negative who did not purchase ACT, either recovered because of non-ACT drugs curing their illness or did not take any actions (downward or no revision of beliefs). Still, due to the lack of data on the individual recovery process in one-week time window, we are unable to confirm that this is the exact case in our study setting. Our results however underscore the importance of price mechanisms in policy responses to current challenges in malaria control, and they highlight the difficulties in implementing information-based strategies that might aim to changing beliefs.

Finally, our study highlights how in our setting of rural Western Kenya, still 18.9% of people tested negative purchased ACT, even after an intervention aimed at improving adherence to testing and treatment. This figure is lower than what other studies reported in similar contexts (Briggs et al. 2014, Cohen et al. 2015, Prudhomme O'Meara et al. 2018), but it sheds light on how non-adherence to negative test results remains a problem which should be further addressed.

Our findings are subject to several limitations. Ideally, we would want to isolate the effect of new information on beliefs. The follow up data collection was conducted one week after baseline to minimize recall biases and to collect data on beliefs soon after decisions related to testing and purchasing antimalarial drugs. Yet, factors other than the individual actions considered in the analysis might influence beliefs at the one-week follow-up, thus limiting our ability to draw causal inferences. In addition, the key competing explanation for high ex-post beliefs about malaria among individuals who purchased ACT in spite of negative test results is ex-post rationalization: those

individuals tested negative who purchased ACT reported a higher posterior belief of having malaria than those who did not purchase ACT, at the time of follow-up data collection to justify their choice of ACT purchasing at the eye of the enumerators. This remains a competitive explanation that we are not able to rule out. Finally, we only collected beliefs data on the probability of having malaria for people who were tested. Unfortunately, we cannot infer how the posterior beliefs of those who were tested compared to those who decided not to get tested.

Our findings and limitations point towards future research opportunities. Since the prior belief of having malaria did not explain the individuals' decision of testing, this might be a good opportunity for policy makers to use other factors such as the RDT price to influence behavior. If then behavior is associated with correct posterior beliefs, these beliefs might further drive appropriate behavior. More studies should analyze a longer-term relationship between beliefs and health-behavior. Moreover, since the outcome of the illness after ACT purchasing behavior is associated with posterior beliefs among tested-negative individuals, this suggests that there might be scope for future policy efforts to increase individuals' adherence to malaria test results, for example by improving confidence in malaria testing as well as improving ACT targeting. Finally, finding that beliefs on malaria status do change over a very short time period in response to different actions should encourage researchers to understand better how to reinforce correct beliefs to improve health seeking behavior. Appropriate policies in the health sector depend on individuals recognizing the risks they face and making informed decisions based on their own expectations of the future. Further and more in-depth research on how beliefs are shaped and how actions shape beliefs is needed, in order to improve utilization of information from malaria testing and treatment, and to improve adherence to test results.

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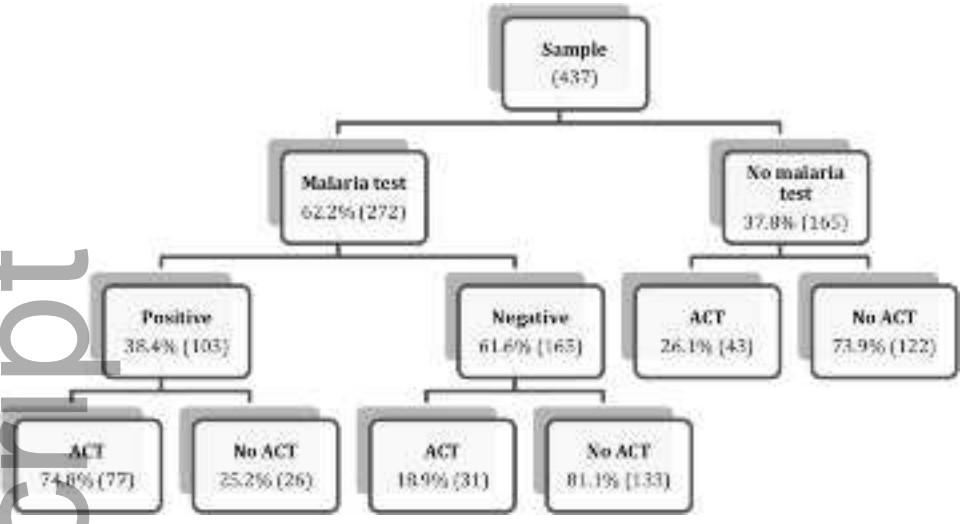

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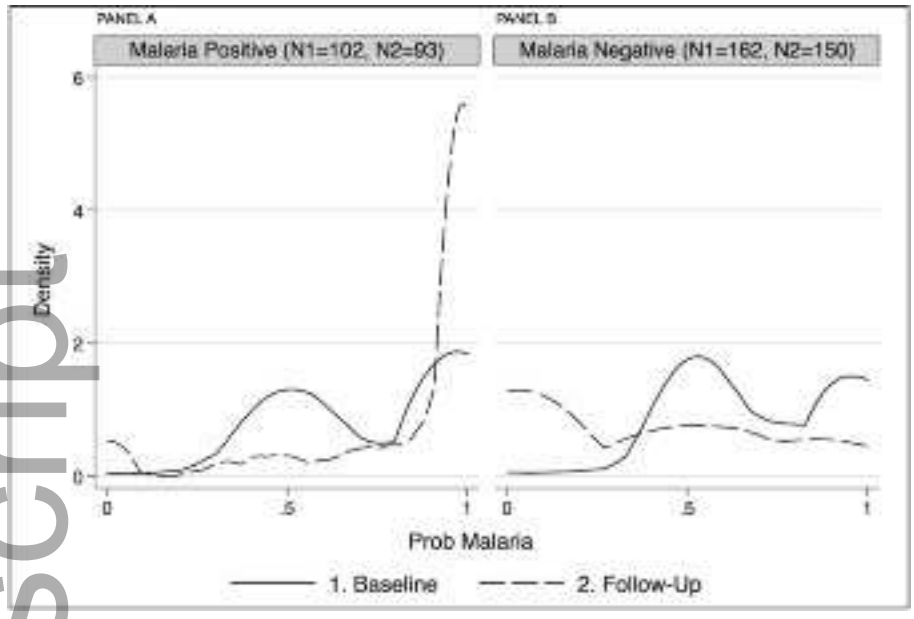

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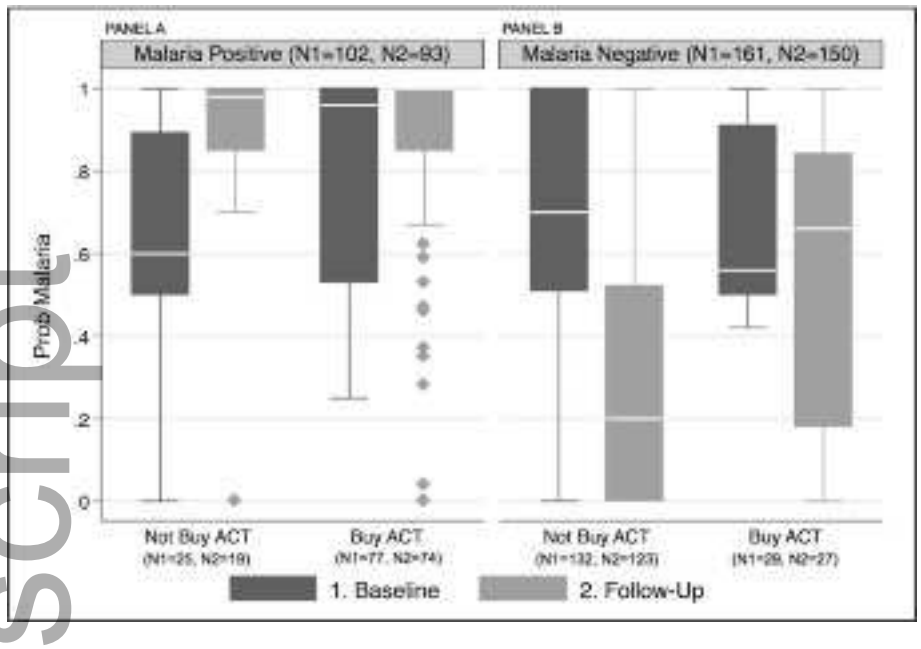

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