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Abstract

One of the most serious problems in the fight against malaria, especially in Africa, is the fact that many individuals suffering from malaria do not have easy access to effective antimalarials while at the same time a large proportion of people receiving antimalarials do not suffer from malaria. In order to improve access, a global price subsidy of 95% has been proposed for the most effective antimalarial, artemisinin-based combination therapy (ACT). The objective of this proposal is to lower the consumer price on effective malaria medicine to increase access for, in particular, poor consumers. However, treatment of patients not suffering from malaria with antimalarials including ACTs has been proven widespread and a subsidy is likely to increase this over-treatment. This means waste of resources and will result in inflating the subsidy funds required. In addition, as has happened with older types of malaria medicine, treating non-malarial fevers with malaria medicine may increase the risk of artemisinin resistance development. Diagnostic tests for malaria may have the potential for reducing over-treatment, but tests are expensive for the typical malaria treatment-seeking individual. In order to both increase access and reduce over-treatment we propose a subsidy on rapid diagnostic tests (RDTs) together with the ACT subsidy. The main objective of the paper is to investigate the optimal combination of subsidies that incentivises individuals suspecting themselves to have malaria to always test before buying an effective drug. We present a model that describes the health seeking behaviour of a representative individual using an expected utility framework. Based on numerical simulations of our model we find that a price reduction on RDTs is necessary to incentivise testing while at the same time, the subsidy on ACT can be lower than the proposed 95% without compromising access. The least-cost policy of the health policy maker is to subsidise both ACT and RDT, redirecting some of the subsidy money from ACT to RDT.

Keywords: Health and economic development, public health, medical subsidy programmes, malaria, drug resistance.
JEL codes: I15, O15, H51

Dansk resumé

En af de største udfordringer i bekæmpelsen af malaria i Afrika er at mange malariasmittede ikke har adgang til effektiv behandling, mens der samtidig findes et stort antal personer, som er under behandling med malariamedicin uden at have malaria men blot har malarialignende symptomer. For at forbedre adgangen til malariamedicin, især for de fattigste, har et nyt tiltag foreslået et 95% subsidie på det mest effektive malariamiddel, en såkaldt artemisinin-baseret kombinationsbehandling (ACT). Men behandling af individer uden malaria, bl.a. med ACT, er særdeles udbredt, og et subsidie vil potentielt øge denne over-behandling. Det betyder spild af knappe ressourcer og vil drive de nødvendige midler til subsidier i vejret. Desuden, som det er sket med ældre typer af malariamedicin, betyder overbehandling med ACT, at malariaparasitten hurtigere udvikler resistens. Test for malaria kan potentielt reducere overbehandlingen, men en test er dyr for den typiske behandlingssøgende. Med det formål både at øge adgangen til effektiv malariamedicin og mindske over-behandling og resistensudvikling foreslår vi ikke kun at subsidiere ACT men også at subsidiere de såkaldt rapid diagnostic tests (RDTs). Hovedformålet med denne artikel er at undersøge den optimale kombination af subsidier, der giver individer, der har mistanke om at være smittet med malaria, et incitament til altid at lade sig teste før behandling og kun behandle, hvis testen er positiv. Vi opstiller en forventet nyttemodel, der beskriver et repræsentativt individs sundhedsadfærd. Baseret på numeriske simulationer af vores model finder vi, at en prisreduktion på RDTs er nødvendig for at tilskynde brugen af diagnosticerende test. ACT-subsidiet kan desuden være lavere end de foreslåede 95% uden at det går negativt ud over adgangen til behandling. Den omkostningsminimerende policyanbefaling er at subsidiere både ACT og RDT, hvor subsidiemidler kan overføres fra ACT til RDT uden at den samlede omkostning stiger.

Introduction

Malaria is a disease that can be both prevented and treated. Still, malaria figures high on the list of deadly communicable diseases killing more than 600,000 people and causing more than 200 million cases of malaria in 2010 (WHO 2013). Malaria is a mosquito-borne disease caused by the parasite Plasmodium and transmitted between humans via mosquito bites. The disease burden is highest in the African region with 80% of all cases and 90% of all deaths. The majority (86%) of all deaths are children below the age of five. Despite the fact that malaria mortality rates have fallen by 25% globally and 33% in Africa since 2000, the share of the total global disease burden attributable to malaria is still around 3% which corresponds to a loss of 40 million DALYs every year (Skolnik 2011). The economic costs of malaria to both individuals and society are high (Gallup & Sachs 2001, Sachs & Malaney 2002) and the disease harms earnings, health budgets and the potential for economic growth.

The tragedy of malaria is that effective tools for prevention and treatment exist but for a number of reasons the tools are not used sufficiently or correctly. Elimination of malaria has been successful in some areas but has failed as a global strategy (WHO, 2013). The current strategy for malaria control builds on prevention and prompt treatment. The main preventive tools are insecticide treated mosquito nets (ITNs) and indoor residual spraying (IRS) with insecticides. Chloroquine and other types of monotherapy drugs have been used for decades as treatment for malaria symptoms and have been both cheap and effective, but the parasite has largely developed resistance rendering older antimalarials ineffective. Because of the low cost of antimalarials like chloroquine there has been a tendency for overuse where all fevers, caused by malaria or not, have been treated with antimalarials without a parasitological diagnostic confirmation first. This has contributed to speeding resistance development. Artemisinin-based combination therapies (ACTs) are currently the only highly effective treatment of the most common malaria parasite many places on the African continent (Whitty et al. 2008, WHO 2012). Unlike older antimalarials, ACTs are very expensive. In Africa where poverty is common, public health systems are underdeveloped, private sector drug shops are first point of care and the majority of medical purchases are made out of pocket, the high cost of ACT means low access to effective treatment for a large part of the population. In Africa today less than 60% of confirmed malaria cases are treated with ACTs. Instead people rely on cheaper but less effective antimalarials or are not treated at all (WHO 2012).

To increase access to ACTs in malaria-endemic areas, the idea of a global subsidy on ACTs was presented in 2004 (Arrow et al. 2004) through the so-called Affordable Medicines Facility - malaria (AMFm). The aim of this facility was to reduce the price of ACTs through a price subsidy at the factory gate. This idea of subsidising ACT was tested in eight pilot countries in 2009-11 resulting in first-line buyers paying 80% less than they did before 2009 (The Global Fund 2013). The final price to consumers is unrestricted but the aim is that subsidies in the top of the supply chain should

affect consumer prices making them so low that access increases and ACT prices become competitive to the price on less effective monotherapies (MTs) including artemisinin monotherapy and crowd them out. The original goal of the AMFm was a 95% subsidy. AMFm has negotiated with drug manufacturers so that sales prices are the same for both public and private sector buyers, which is important considering the large role played by e.g. private drug shops in many malaria endemic countries[1]. AMFm has currently subsidised over 300 million ACT treatments[2].

Though the AMFm initiative increases access to ACT, especially for the poorest, a potential problem of a subsidy on ACT is that it increases demand both among people who suffer from malaria but also among people who will not benefit from ACT treatment because they suffer from a non-malarial febrile illness (Cohen et al. 2013). This potentially leads to over-consumption and resistance development– as was the case for monotherapies such as chloroquine that have been used for many years (see e.g. Reyburn et al. 2004, Perkins & Bell 2008, and Cohen et al. 2013 for studies that document over-use of antimalarials). A few incidences of artemisinin-resistance (where artemisinin was given as a monotherapy drug) have recently been reported and over-use thus becomes a pressing concern if one wants to slow down resistance development[3]. What complicates matters is that over-treatment may be optimal from the individual's point of view since individuals do not consider the possible externality their consumption implies, namely that over-treatment has negative societal spill-over effects by speeding the process of resistance development in the parasites that cause malaria. A subsidy like the one AMFm provides makes the individual's decision to over-use ACT affordable and therefore it has the potential to speed up resistance development.

Parasitological testing is the most accurate method for diagnosing malaria. The first-best response to reduce over-treatment would therefore be to make ACT purchase contingent on testing positive for malaria but this is likely impossible to enforce due to physician and drug shop agency issues (Hamer et al. 2007, Cohen et al. 2013, Hansen et al. 2013)[4]. However, diagnostic testing may still be feasible if it impacts individual behaviour. Until recently, diagnostic testing needed advanced microscopic equipment and trained health professionals rendering testing difficult in rural settings. Today reliable rapid diagnostic tests (RDTs) for malaria can be performed. The patient gets the result immediately and the test procedure does not require much training so RDTs could feasibly be sold in drug shops and other private sector outlets without professionally trained health care staff. However, only very few people (most often less than 50% but only 10% of children) who receive antimalarials had a parasitological confirmation prior to treatment (WHO

[1]This does not mean that consumer prices are equal in the public and private sector. Typically, add-on costs further down the supply chain are higher in the private sector, but the subsidy lowers the price.
[2] http://www.theglobalfund.org/en/amfm/independentevaluation/
[3]This is also done by only giving artemisinin as part of a combination therapy.
[4] There is anecdotal evidence of doctors and drug shop owners prescribing antimalarials even when the patient tests negative for malaria, both because people require medicine but also because other types of medicine which may be more appropriate are not available and "something is better than nothing".

2012). WHO (2012) estimated that the positivity rate in most African areas is below 50%. The ratio of number of tests to number of ACTs should then be equal to or above 2 and not 0.5 as is the case today. If medicines, and subsidies, could be targeted towards those who have the disease, the cost of subsidising could be substantially lowered. Previous studies have shown that the uptake of malaria tests is slow in part because of the relatively high price of tests (Cohen et al. 2013). The average price of a RDT is US$3-4 but willingness to pay was found to be only US$0.5-1.0 in two African countries (Uzochukwu et al. 2010, Hansen et al. 2013).

Since 2010 when the WHO started recommending that all suspected malaria cases should be confirmed with a diagnostic test before treatment, there has been an interest in incentivising the use of RDTs in the private sector. We argue that the uptake of testing could be encouraged by the same mechanism as treatment, namely a price subsidy. We thus speculate that by redirecting some of the subsidy money from ACT to rapid diagnostic tests (RDTs) it will be possible to improve targeting of subsidy resources and at the same time reduce and slow down the resistance development that arises from overuse. The main purpose of this paper is to investigate the optimal subsidy levels for ACT and RDT. Based on an expected utility model we describe the optimal health seeking behaviour of a representative individual with suspected malaria and we show how this behaviour may conflict with the optimal behaviour from a health planner's point of view. While the health planner wants the individual always to test if he or she suspects a fever to be caused by malaria and only buy ACT if the test is positive, it will often be optimal for the individual not to test, buy cheaper MTs or perhaps take treatment even though the test is negative. With numerical simulations based on reasonable parameter values from published studies on prices, effectiveness of drugs, prevalence, consumer beliefs and willingness to pay we investigate the optimal mix of subsidies to RDTs and ACTs. Our results show that only subsidising ACTs, which is what the AMFm currently does, is in general not sufficient for incentivising the health planner's desired health behaviour. A price reduction on RDTs is necessary as well. Our results show that it is feasible to lower the subsidy on ACT and redirect the funds to a subsidy on RDT with the outcome being a more efficient use of subsidy resources and better health.

The structure of the paper is as follow. After this introduction we provide some detailed background information and briefly review the literature that is related to our paper to put the paper into context. We then outline our theoretical model in section 3 which gives the basis for our numerical simulations in section 4. We present the results in section 5. Section 6 discusses and outlines some potential policy implications. Section 7 concludes. Mathematical derivations are provided in the Appendices.

Related literature

Encouragement of correct preventive and curative health behaviour through cost-reducing incentives has gained much attention in the global health arena in recent years. A well-known example is the PROGRESA/Oportunidades program in Mexico where conditional cash transfers (CCTs) were used to encourage better health and nutrition of children. Lagarde et al. (2007) review a number of CCT programs in developing countries and find a consistent beneficial impact on the uptake of health services and changes in health behaviour. Cohen & Dupas (2010) find that the take-up of bed nets by pregnant women is almost 100% when the nets are distributed for free, but if instead the nets are sold at the highly subsidised price of US$0.60 only 40% will buy a net. Similarly, Ashraf et al. (2010a) find that the use of water-treatment products falls from 80% to 50% when price increases from US$0.10 to US$0.25. Kremer & Miguel (2007) find in a study in Kenya that the demand for de-worming medication is highly price elastic. When medicine is provided through schools for free take-up is close to 80% but when price is raised to US$0.30 take-up falls to 20%. Other examples of price incentives to influence health behaviour includes distribution of free condoms, vouchers for HIV testing and counselling (Thornton 2008) and for contraceptives (Ashraf et al. 2010b), food for immunisation (Banerjee et al. 2010), conditional cash transfers for avoiding sexually transmitted diseases (Medlin & DeWalque 2008) and many more.

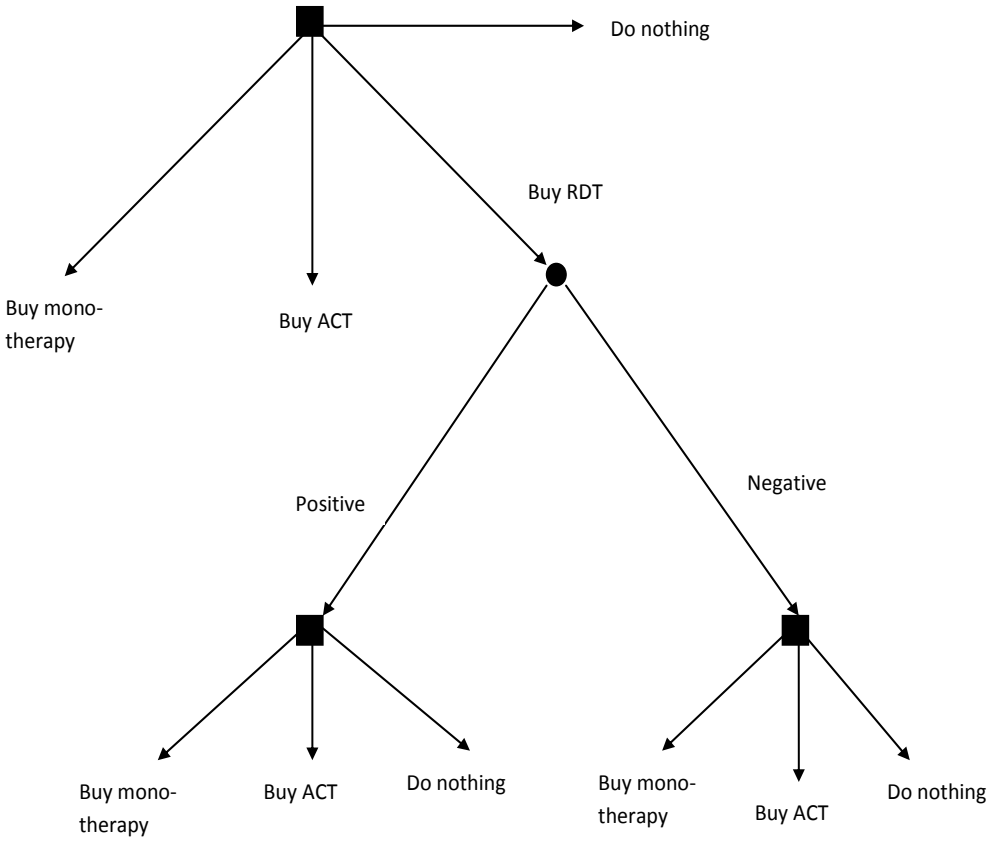
In this study we focus on one price incentive: price subsidies for malaria management. Since funding for subsidies is not unlimited it is essential that subsidy money be spent where they have the largest impact. Especially one paper, namely Cohen et al. (2013), is related to our work and gives it an empirical perspective. In their paper, Cohen et al. test in a randomised controlled trial in rural Kenya the impact of changing RDT and ACT prices. They test three different subsidy levels for ACT as part of a pilot study for the AMFm initiative – the highest being 90% which is slightly below the original 95% target of the AMFm. What they find is that ACT use increased 59% in presence of a subsidy of 90% - but only 56% of those buying ACT test positive for malaria. Over-treatment and resistance development is therefore a true concern. However, they also find that right “targeting”, meaning that only those with a positive diagnostic test bought ACT, increased to 81% when the subsidy for ACT was slightly reduced (from 90% to 80%) and the freed resources directed to an RDT subsidy instead. This increased the testing rate more than 50% and had no significantly negative effect on ACT uptake. Hence, both access and targeting was improved when some of the ACT subsidy was transformed into an RDT subsidy. Cohen et al. find that people are extremely interested in testing if only the test is made available over the counter in drug shops at a sufficiently low price. Combining this with evidence from Hansen et al. (2013) and Uzochukwu et al. (2010) that people are willing to pay for RDT shows that there must be a potential for upscaling the sale of RDTs in the private sector.

Model of consumer behaviour in malaria treatment seeking in the private sector

In most malaria endemic areas the private health sector is substantial and private sector outlets play an important role in the provision of antimalarials. The private retail sector accounts for 40-97% of all antimalarial sales in Africa (Patouillard et al. 2010). Drug shops are often located closer to home than public facilities and they have a wide range of antimalarials available (Patouillard et al. 2010). In some areas of Africa up to 70% diagnose and treat at home with drugs from local drug shops paid out-of-pocket (Amexo et al. 2004). Drug shops are thus typically the first point of care for those seeking treatment (Cohen & Dickens 2012).

We develop an individual level decision model where a representative, febrile individual who wants to maximise expected utility can choose among a range of possible strategies involving choice of drugs and whether to take a parasitological test before treatment. One possible strategy is to do nothing about his fever if he thinks it is self-resolving (strategy S_{NO}) or to go to a drug shop to seek treatment if he believes the fever to be caused by malaria. In the drug shop, the individual faces the following options: a) buy cheap, less effective monotherapy (MT) malaria treatment (strategy S_{MT}), b) buy more effective but also more expensive ACT (strategy S_{ACT}) or c) buy a rapid diagnostic test (RDT) and let the subsequent decision of buying ACT, MT or nothing depend on the result of the test (strategy S_{RDT}). The latter strategy will lead to nine possible sub-strategies. One example of a sub-strategy is where the individual purchases ACT if the RDT is positive and purchases a cheap antimalarial if the RDT is negative (strategy $S_{RDT(ACT,MT)}$). Another example of a sub-strategy is where the individual purchases a cheap antimalarial if the RDT is positive and does not buy any drugs if the RDT is negative (strategy $S_{RDT(MT,NO)}$), etc. The individual's possible strategies are represented graphically in Figure 1.

Figure 1: Treatment-seeking strategies



The individual attaches utility to each of the possible strategies and a rational individual will choose the strategy giving him/her the highest utility. All strategies involve risky outcomes (malaria and full health) and it is assumed that the individual evaluates all alternatives and chooses the strategy with the highest utility following the framework of expected utility theory. We assume two possible health states: "Malaria" and "Not malaria". If the fever turns out to be malaria, the individual assigns a utility value of 0 to the health state whereas a utility value of 1 is assigned to the health state "Not malaria", which will be the result of a self-resolving fever[5]. The individual does not know for certain whether the fever is malaria or a self-resolving health problem but assigns a subjective probability *p* that the fever is malaria. Utility further depends on the probability of the treatment to cure malaria, E_{MT} and E_{ACT} where $E_{ACT} > E_{MT}$, the cost of treatment, C_{MT} and C_{ACT} where $C_{ACT} > C_{MT}$, as well as the cost of RDT, C_{RDT}. Assuming quasi-linear utility, we can write the individual's utility for each strategy as follows:

Utility of buying no drugs and without having a test.

[5]For the health state "Not malaria" we ignore the possibility that the illness is not self-resolving but e.g. requires treatment with antibiotics. We are aware of the importance of such a scenario but for the simplicity of the model we choose not to include it formally.

$$U(S_{NO}) = (1 - p)$$

Utility of buying a cheap antimalarial monotherapy without having a test.

$$U(S_{MT}) = pE_{MT} + (1 - p) - C_{MT}$$

Utility of buying an ACT without having a test.

$$U(S_{ACT}) = pE_{ACT} + (1 - p) - C_{ACT}$$

Before formulating the utility of the strategies that involves taking an RDT first, we define two subjective probabilities held by the individual related to the RDT. Define p_p as the subjective probability that a fever is malaria having observed that the RDT result is positive whereas p_n is the subjective probability that a fever is malaria having observed that the RDT result is negative. It is assumed that

$$p_n < p < p_p$$

so that both a positive and a negative RDT result will influence the individual's belief of malaria status. If the individual has complete confidence in the accuracy of the test, then p_p will be equal to 1 and p_n will be equal to 0. From p, p_p and p_n we can deduce the subjective probability p^* that the test result is positive as $p = p^* p_p + (1 - p^*)p_n$, which gives us

$$p^* = (p - p_n)/(p_p - p_n)$$

The probability p^* may not necessarily be equal to p if for instance the individual is concerned that the RDT will occasionally miss positive malaria cases (false negatives) in which case p^* will be lower than p. An example of a utility function for a strategy involving a test is

$$U\big(S_{RDT(ACT,NO)}\big) = p^*[p_p E_{ACT} + \big(1 - p_p\big) - C_{ACT}] + (1 - p^*)(1 - p_n) - C_{RDT}$$

which is the utility of buying an RDT and having a strategy of buying an ACT if the test is positive and not purchase any drugs if the test is negative. For the remaining strategies see Appendix 1.

Some of the strategies are clearly not rational. For example, it is irrational for an individual to consider a strategy consisting of first purchasing an RDT associated with a decision to purchase an ACT if the test is positive and also purchasing an ACT if the test is negative ($S_{RDT(ACT,ACT)}$). Effectively, the individual sees no value in the result of the test and will always choose to buy an ACT irrespective of the test result. It would therefore make more sense to save the money for purchasing an RDT and instead go directly to acquiring an ACT. Indeed it is easy to show that within the model framework developed, the strategy $S_{RDT(ACT,ACT)}$ is dominated by the strategy S_{ACT} . Similarly, the strategies $S_{RDT(MT,MT)}$ and $S_{RDT(NO,NO)}$ are dominanted by S_{MT} and S_{NO}

respectively. More interestingly, the three strategies $S_{RDT(MT,ACT)}$, $S_{RDT(NO,MT)}$ and $S_{RDT(NO,ACT)}$ are also dominated by other strategies within this framework (see Appendix 2 for further details). The remaining non-dominated strategies are

S_{ACT}, S_{MT}, S_{NO}, $S_{RDT(ACT,NO)}$, $S_{RDT(MT,NO)}$ and $S_{RDT(ACT,MT)}$

and these are the only strategies that a rational individual would choose among in this framework.

The objective of the health planner

We now introduce a health policy maker who has the objective that all suspected malaria cases should be diagnosed with a parasitological test before treatment and that patients with confirmed malaria should be treated with ACT while patients with a negative test should not receive any antimalarial. Patients visiting drug shops do not necessarily behave according to the aims of the health policy maker. Since purchasing antimalarials in drug shops is not contingent on a positive test, the health planner must try to influence behaviour among drug shop customers and it is assumed that the instrument available to the health policy maker is an ability to change the prices of ACT and the RDT (C_{ACT} and C_{RDT}) via a subsidy. The health planner's problem is thus to find the right set of subsidies for ACT and RDT that ensures that the individual prefers strategy $S_{RDT(ACT,NO)}$ to any of the other strategies and doing it at the lowest possible cost. Formally, the health planner minimises total subsidy costs

$$\beta^{ACT} * \tilde{p} + \beta^{RDT}$$

where β^{ACT} is the subsidy cost per ACT course, β^{RDT} is the subsidy cost per RDT and $\tilde{p}$ is the probability that an RDT will be positive which depends on the true prevalence among drug shop customers and the accuracy of the RDT. Positive RDT results will include both true and false positives and $\tilde{p}$ can be written as

$$\tilde{p} = \bar{p} * ss^{RDT} + (1 - \bar{p}) * (1 - sp^{RDT})$$

where $\bar{p}$ is the true malaria prevalence among febrile patients, and ss^{RDT} and sp^{RDT} is the RDT's sensitivity and specificity. The health planner minimises costs subject to the constraint that the utility of the individual from following strategy $S_{RDT(ACT,NO)}$ is higher than all other strategies (see Appendix 3 for formal representation).

Inspection of the incentive constraints reveals that none of these hold for all possible values of the parameters meaning that the individual does not generally prefer strategy $S_{RDT(ACT,NO)}$ within this framework. Hence, we need to investigate for which parameter values the health planner's objective is fulfilled.

Table 1: Parameter values

Variable	Best estimate	Lower bound	Upper bound	Source
C_{MT}	US$ 0.3	US$ 0.01	US$ 1.6	IDPIG* (2010), Goodman et al. (2009)
C_{ACT}	US$ 3.5	US$ 1	US$ 10	ACTwatch (2012), Whitty et al. (2008)
C_{RDT}	US$ 1.8	US$ 0.5	US$ 2.93	ACTwatch (2012), IDPIG (2010)
E_{MT}	50%	20%	70%	Morel et al. (2005), Mueller et al. (2004)
E_{ACT}	95%	90%	99%	Sinclair et al. (2009)
ss^{RDT}	95%	86%	99%	Björkman & Mårtensson (2010), Bisoffi et al. (2010)
sp^{RDT}	95%	75%	99.8%	Bisoffi et al. (2010)

*International Drug Price Indicator Guide. As recommended in a report from the Medicines for Malaria Venture (2008), the reported estimates include transportation costs and mark-up corresponding to about 100% of the product's price.

Consumer types and numerical simulations

To gain intuition on the subsidy sizes that are needed to fulfil the health planner's objective we develop some numerical examples or simulations based on linear programming using the incentive constraints derived in Appendix 3. We start out by setting the parameters of the model in such a way that the individual prefers purchasing ACT or monotherapy directly without testing first. We then change C_{ACT} and C_{RDT} to ensure that the individual prefers the strategy $S_{RDT(ACT,NO)}$. A series of numerical examples will give indications on what combination of ACT and RDT price changes (subsidies) is the cheapest. We use the estimates in Table 1 for our simulation, where all costs refer to an adult dose.

To our knowledge, there are no studies that have assessed malaria drug consumers' subjective beliefs of drug effectiveness. We therefore rely on "true" effectiveness measures. Anecdotal evidence says that consumers have high belief in the effectiveness of ACT, so the subjective and the true effectiveness are very close. However, as the effectiveness of MT varies a lot between regions it may be more difficult for individuals to know the true effectiveness. We therefore apply a number of different MT effectiveness estimates for sensitivity analysis.

Table 2: Examples of consumer types

Consumer type	Low true malaria prevalence $\bar{p}$		
a	High p	High p_p	Low p_n
b	Low p	High p_p	Low p_n
c	Low p	High p_p	High p_n
d	High p	High p_p	High p_n
	High true malaria prevalence $\bar{p}$		
e	High p	High p_p	Low p_n
f	Low p	High p_p	Low p_n
g	Low p	High p_p	High p_n
h	High p	High p_p	High p_n

To convert actual prices into a cost comparable to the 0-1 normalised utility model we use a linear transformation where we divide the price with the individual's willingness to pay (WTP) for avoiding malaria illness to create a utility normalised drug price. Unfortunately, at least to our best knowledge, an empirical estimate of such a WTP does not exist. Instead we rely on a study by Hansen et al. (2013) who measure the WTP for ACT (US$ 2.05) as a proxy. Because this is a WTP for a specific drug to cure malaria and not as such a WTP to avoid malaria in the first place, we consider this estimate as a lower bound and use a WTP of US$3 as our best guess. For sensitivity analysis we also apply higher estimates. A higher WTP to avoid malaria will, all else equal, make it cheaper to incentivise consumers to adopt the desired behaviour.

To guide our analysis we construct a number of consumer types, where each type differs by their pre- and post-test beliefs of having malaria as well as with the degree to which they believe in the test result. There is evidence that people have strong beliefs in a positive test result but the belief in a negative test result typically varies and can be quite low. Each consumer type lives in an area with a given true malaria prevalence which is not directly linked to the beliefs of the consumer (though it may rationally be) but affects the total subsidy costs for the health planner. Table 2 presents eight examples of consumer types. For instance, consumer type a is a consumer living in an area with low true malaria prevalence, but the consumer has a high belief that his fever is caused by malaria. He has high confidence in the accuracy of RDTs. This distinguishes him from consumer type d who does not have much faith in a negative test results, meaning that he still believes that his fever could be caused by malaria even when the test is negative. A full overview of all our constructed consumer types as well as a list of parameter values used in the simulation exercise describing the behaviour of each consumer type is given in Appendix 4. We will use the 8 consumer types from Table 2 to illustrate some general insights in the next section.

Results

Figure 2 shows a graphical illustration of the possible and optimal combinations of subsidies on ACT and RDT that ensure that the consumer behaves in accordance with the health planner's objective. For example the consumer in panel (a) of Figure 2 has a strong belief that the fever is malaria, high trust in a positive RDT result and low trust in an RDT result if it is negative. Such an individual may be incentivised to always purchase an RDT before treatment and buy an ACT only if the RDT is positive (appropriate behaviour) if the subsidy on a course of ACT, the RDT or a combination is at the right level. The blue line in panel (a) shows the different possible combinations of subsidies on ACT and RDT that will ensure appropriate behaviour of this consumer. As displayed by this figure, the consumer will only behave appropriately if the RDT subsidy is at least 90% and any RDT subsidy below this value will lead to inappropriate behaviour irrespective of the level of subsidy on the ACT. The green line in the figure is a 'subsidy isocost line' showing combinations of ACT and RDT subsidies giving the same total subsidy cost in US$ (the sum of subsidy cost of ACT and RDT). The further to the south-west this line is situated, the lower the total subsidy cost. The optimal combination of subsidies in panel (a) of Figure 2 is a 90% subsidy on the RDT and a 61% subsidy on the ACT since this will at the same time ensure appropriate behaviour in the individual at the lowest possible subsidy expenditure of the health policy maker. Similar comments may be made to the other panels in Figure 2. Each illustration corresponds to a consumer type in Table 2. The examples use the "best estimate" of parameter values from Table 1. A key observation is that for no consumer type is it possible to ensure appropriate behaviour by only subsidising ACT or RDT. The subsidy must be a combined subsidy. From Figure 2 it is evident that a certain level of RDT subsidies is required and cannot be replaced by increasing the ACT subsidy since a lower relative ACT price increases the consumer's incentive to buy ACT directly without an RDT first. However, a certain level of ACT subsidies is also required. Even if RDTs were given away for free would the price of ACT (compared to MT) still be too high for consumers to adopt the desired behaviour. Note that there is no solution for the two consumer types d and h. These types are characterised by a strong prior belief in being malaria positive and a weak belief in a negative test result. No matter how high the subsidies are, these individuals will never choose to test before treating.

Figure 2: Optimal combinations of subsidies depending on consumer type

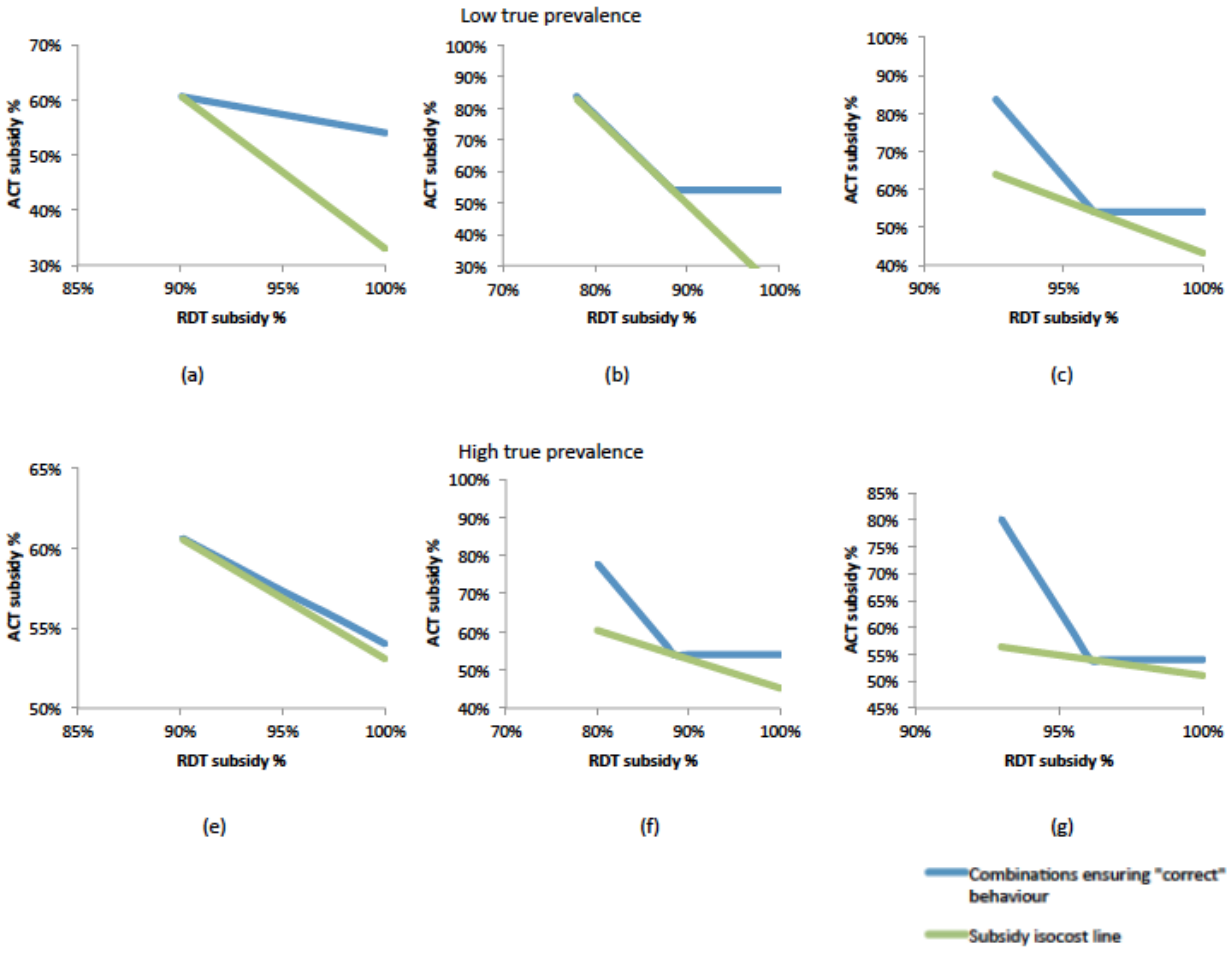


Table 3 shows the optimal (least cost) combinations of RDT and ACT subsidies for the eight consumer types that ensures appropriate behaviour. The optimal combination is also illustrated in Figure 2 as the tangent between the green subsidy isocost line and the blue line. Note that subsidy sizes and hence consumer behaviour is unaffected by the true prevalence rate. Prevalence only affects health planner's costs. In all our cases, the optimal subsidy on RDT must be a larger percentage of the price than the subsidy on ACT. However, since the price on RDT is lower than the price on ACT the RDT subsidy is cheaper in absolute terms. And because the ACT subsidy can be substantially lower than the 95% that was the target of AMFm (corresponding to a cost per treatment-seeking individual of US$3.33) the total cost of the combined subsidy is lower than the cost of only subsidising ACT, even in high prevalence areas. Our results thus show a potential for redirecting subsidy money from ACT to RDT. This can lead to a cost reduction and at the same time increase targeting of ACT and reduce the waste of subsidy money and potential resistance development.

Table 3: Optimal combinations of ACT and RDT subsidies and subsidy costs

	Optimal combination of ACT and RDT subsidies and health planner's costs			AMFm regime: Subsidising ACT 95%
Consumer type	ACT %	RDT %	US$ per consumer	US$ per consumer
a	60.6	90.1	2.01	3.33
b	54	88.4	1.94	
c	54	96.1	2.08	
d	No solution			
e	60.6	90.1	3.06	
f	54	88.4	2.88	
g	54	96.1	3.02	
h	No solution			

Sensitivity analysis

The subsidy structure and costs depend on the beliefs of consumers. We have in this paper focused particularly on the beliefs regarding the probability that a fever is caused by malaria or is self-resolving and the probability that malaria RDTs are accurate. The beliefs of consumers may be close or far from the actual probabilities. Consumers have a tendency to over- rather than under-estimate true risks of malaria. The larger the difference between perceived and true prevalence, the higher subsidies are required and the more costly it will be to incentivise appropriate consumer behaviour. Further, the disbelief in negative test results that has been documented in e.g. Cohen et al. (2013) also makes it difficult and expensive to incentivise appropriate behaviour. In addition to the beliefs described above, sensitivity analyses have been performed using the lower and upper bound parameter values in Table 1. The general picture from Figure 2 seems robust with higher retail prices of ACTs and RDTs leading to higher subsidy costs. We considered the WTP to avoid malaria of US$3 as a quite low estimate. Increasing the WTP lowers the required subsidies and costs, especially for ACT, but only for consumers with a high trust in negative test results. For consumers with a low belief in negative test results, an increase in WTP makes it hard to find a subsidy combination that ensures correct behaviour, because the consumer tends to go directly to buying ACT. There may thus be a challenge in incentivising correct behaviour among wealthier individuals, however, wealthier individuals are often better educated and hence in a better position to understand test probabilities.

The effectiveness of MTs varies a lot from area to area in Africa due to different levels of resistance development (WHO 2012) and consumers tend to overestimate their effectiveness. We also investigate how changes in MT effectiveness affect the results. A lower effectiveness of MT will, all else equal, make it less attractive for the consumer to buy MT and thus easier for the health planner to incentivise the use of ACT. However, the effect of MT effectiveness on RDT uptake is not so straightforward as a higher relative (perceived) effectiveness of ACT means that

the consumer needs a larger incentive to buy an RDT before buying ACT. The beliefs of the relative effectiveness of the different treatment types are therefore also important for reducing total subsidy costs.

Discussion

By modelling the behaviour of a representative consumer and how this behaviour may be in conflict with optimal behaviour from the health planner's point of view we have shown that a combination subsidy lowering the retail price of both ACT and RDT leads to an outcome with lower total subsidy costs and less potential for resistance development. A clear policy implication of our study is thus to redirect funds from the ACT subsidy to an RDT subsidy - in contrast to the AMFm which currently proposes a subsidy on ACT alone. In our model we disregarded any agency issues related to the drug shop. However, the drug shop is likely to be an important actor in the private sector and depending on market power and prevalence beliefs, drug shops may not act according to the health planner's wish. Because the drug shops operate in the private market and because the consumer price on RDT (as well as ACT) is not restricted, drug shops are not obliged to pass the entire subsidy on to the final consumer. Further, because drug shops make money on selling ACT as well as other antimalarials they may not have much of an incentive to sell cheap RDTs since costumers who test negative will not buy ACT – at least not if they adhere to the test result. Cohen & Dickens (2012) argue that subsidising antimalarials increases consumers' perception of the risk of malaria infection, and - combined with the low trust in test results and lack of treatment options for non-malarial fever - profit maximising drug shops may encourage people to buy ACT when they do not need it. However, Cohen & Dickens show that an RDT subsidy may reduce the drug shop's incentive to undersupply tests if the subsidy is combined with information campaigns to customers about the true malaria prevalence. More research on the supply side is definitely called for. Incorporating the drug shop as a third agent in the model would be a topic for future research.

Also more research on consumer beliefs is needed to guide policy. As mentioned, wrong beliefs are costly and without perfect compliance with test results caused by wrong beliefs, subsidising RDTs may not be cost-effective. However, even without perfect compliance, an RDT subsidy that encourages more people to test can have two other beneficial effects: 1) RDTs may increase the chance that non-malarial fevers receive appropriate treatment with e.g. antibiotics sooner, and 2) RDTs contribute to a learning effect whereby individuals become able to assess the effectiveness of ACT and other antimalarials (Cohen et al. 2013). Presently, there is a tendency of fever patients to 'diagnose' their fever by trying different drugs including antimalarials and see what works (Chandler et al. 2011). Cost-effectiveness of subsidising RDTs is therefore likely to increase in the longer run. A full set of policies to maximise uptake of RDTs and correct use of ACTs consists of subsidies for RDTs and ACTs as well as information campaigns to "correct" individuals' beliefs. Training of drug shop owners in using RDTs is also necessary, but because RDTs are so easy to use, these costs are likely to be limited.

Conclusion

Limiting over- and under-treatment of infectious diseases such as malaria is a key health policy concern across the world but improving both problems at the same time is a challenge. A subsidy for treatment of malaria with the highly effective ACT will reduce under-treatment which is important to avoid the 600,000 yearly deaths from the disease, but the subsidy may also increase over-treatment, especially when consumers' information on true malaria risks is missing or incomplete. Over-treatment may increase the risk of resistance development towards artemisinin and its partner drug in the combination therapy. In particular it is important to delay resistance to artemisinin, the most effective antimalarial on the market today. A rapid diagnostic test improves consumers' knowledge of malaria status. However, tests are expensive, and since malaria is highly prevalent in the world's poorest areas, ability to pay for a test is insufficient. Further, lack of faith in test results due to inaccurate older test types leading to imperfect compliance with test results makes testing more unattractive for treatment-seeking consumers.

We suggest a subsidy on rapid diagnostic tests as a supplement to the AMFm subsidy on ACTs. We find that a combination subsidy is the only way in which we can incentivise consumers to adopt a strategy of always buying a test before deciding on a treatment type. A combined subsidy is necessary to ensure that consumers only buy ACT when they test positive for malaria – and not buy any antimalarial when they test negative. Redirecting subsidy money from the current ACT subsidy to a combined subsidy including RDTs will be both cost-reducing and limit resistance development that eventually results from over-treatment. Consumer beliefs about malaria risk and treatment effectiveness are important for the (cost-) effectiveness of a combination subsidy. Information campaigns may therefore potentially be a cost-effective supporting policy.

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Literature

ACTwatch (2012). http://www.actwatch.info/results/

Amexo, M., Talhurst, R., Barnish, G., & Bates, I. (2004). Malaria misdiagnosis: effects on the poor and vulnerable. Lancet, 364: 1896-98.

Ashraf, N., Beryy, J., & Shapiro, J. M. (2010a). Can Higher Prices Stimulate Product Use? Evidence from a Field Experiment in Zambia. American Economic Review, 100, 2382-2413.

Ashraf, N., Field, E., & Lee, J. (2010b). Household Bargaining and Excess Fertility: An experimental Study in Zambia. Unpublished Manuscript, Harvard University.

Banerjee A, Duflo E, Glennerster R, Kothari D. 2010. Improving immunization coverage in rural India: a clustered randomized controlled evaluation of immunization campaigns with and without incentives. BMJ 340:c2220

Bisoffi, Z., Sirima, S. B., Menten, J., Pattero, C., Angheben, A., Gobbi, F., Tinto, H., Lodesani, C., Neya, B., Gobbo, M. & Van den Ende, F. (2010). Accuracy of a rapid diagnostic test on the diagnosis of malaria infection and of malaria-attributable fever during low and high transmission season in Burkina Faso. Malaria Journal 9:192.

Björkman, A. & Mårtensson, A. (2010). Risks and Benefits of targeted Malaria Treatment Based on Rapid Diagnostic Test Results. Clinical Infectious Diseases 51.

Cohen, J., & Dupas, P. (2010). Free Distribution or Cost-Sharing? Evidence from a Randomized Malaria Prevention Experiment. Quarterly Journal of Economics, 125(1), 1.

Cohen, J., Dupas, P., & Schaner, S. G. (2013). Price Subsidies, Diagnostic Tests, and Targeting of Malaria Treatment: Evidence from a Randomized Controlled Trial. National Bureau of Economic Research.

Cohen, J. L., & Dickens, W. T. (2012). Adoption of Over-the-Counter Malaria Diagnostics in Africa: The Role of Subsidies, Beliefs, Externalities, and Competition. The Value of Information, 173–191.

Gallup, J. & Sachs, J (2001). The economic burden of malaria. American. Journal of Tropical Medicine and Hygiene. 64(1,2)S, 85–96.

Goodman, C., Kachur, S. P., Abdulla, S., Bloland, P. & Mills, A. (2009): Concentration and drug prices in the retail market for malaria treatment in rural Tanzania. Health Economics, 18:727-742.

Hamer, D. H., Ndhlovu, M., Zurovac, D., Fox, M., Yeboah-Antwi, K., Chanda, P. Sipilinyambe, N., Simon, J. L. & Snow, R. W. (2007). Improved Diagnostic Testing and Malaria Treatment Practices in Zambia. JAMA 297: 2227-2231

Hansen, K. S., Pedrazzoli, D., Mbonye, A., Clarke, S., Cundill, B., Magnussen, P., & Yeung, S. (2013). Willingness-to-pay for a rapid malaria diagnostic test and artemisinin-based combination therapy from private drug shops in Mukono district, Uganda. Health Policy and Planning.

Kremer M, Miguel E. 2007. The illusion of sustainability. Quarterly Journal of Economics, 112, 1007–65

Lagarde M, Haines A, Palmer N. (2007). Conditional cash transfers for improving uptakeof health interventions in low- and middle-income countries: a systematic review. JAMA 298:1900–10

Management Science for Health (2010). International Drug Price Indicator List.

Medlin, C., & de Walque, D. (2008). Potential Applications of Conditional Cash Transfers for Prevention of Sexually Transmitted Infections and HIV in Sub-Saharan Africa. World Bank Policy Research Paper 4673.

Morel, C. M., Lauer, J. A. & Evans, D. B. (2005). Cost effectiveness analysis of strategies to combat malaria in developing countries. BMJ, doi:10.1136/bmj.38639.702384.AE

Mueller, O., Razum, O., Traore, C. & Kouyate, B. (2004). Community effectiveness of chloroquine and traditional remedies in the treatment of young children with falciparum malaria in rural Burkina Faso. Malaria Journal 3:36.

Patouillard, E., Hanson, K. G., & Goodman, C. A. (2010). Retail sector distribution chains for malaria treatment in the developing world: a review of the literature. Malaria Journal 9:50.

Perkins, M. D., & Bell, D. R. (2008). Working without a blindfold: the critical role of diagnostics in malaria control. Malaria Journal, 7(Suppl 1), S5.

Rafael, M. E., Taylor, T., Magill, A., Lim, Y. W., Girosi, F., & Allan, R. (2006). Reducing the burden of childhood malaria in Africa: the role of improved diagnostics. Nature, 444, 39–48.

Reyburn, H., Mbatia, R., Drakeley, C., Carneiro, I., Mwakasungula, E., Mwerinde, O., Saganda, K., et al. (2004). Overdiagnosis of malaria in patients with severe febrile illness in Tanzania: a prospective study. BMJ: British Medical Journal, 329(7476), 1212.

Sachs, J. & Malaney, P. (2002). The economic and social burden of malaria. Nature, 415.

Sinclair, D., Zani, B., Donegan, S., Olliaro, P. & Garner, P. (2009). Artemisinin-based combination therapy for treating uncomplicated malaria. The Cochrane database of systematic reviews. Issue 3.

Skolnik, R. (2011). Global health 101. Jones & Bartlett Learning.

The Global Fund (2013): http://www.theglobalfund.org/en/amfm/

Thornton, RL. 2008. The demand for, and impact of, learning HIV status. American Economic Review, 98:1829–63.

Uzochukwu, B. S., Onwujekwe, O. E., Uguru, N. P., Ughasoro, M. D., & Ezeoke, O. P. (2010). Willingness to pay for rapid diagnostic tests for the diagnosis and treatment of malaria in southeast Nigeria: ex post and ex ante. International Journal for Equity in Health, 9(1).

Whitty, C. J. M., Chandler, C. Anshah, E. Leslie, T. & Staedke, S. G. (2008). Deployment of ACT antimalarials for treatment of malaria: challenges and opprtunities. Malaria Journal 7(Suppl I):S7

WHO (2011). World malaria report 2011

WHO (2012). World malaria report 2012

WHO (2013). Malaria fact sheet no 94.
http://www.who.int/mediacentre/factsheets/fs094/en/index.html

Appendix 1

Utility of strategies involving taking an RDT first:

Utility of buying an RDT and having a strategy of buying an antimalarial monotherapy if the test is positive and not purchase any drugs if the test is negative.

$$U\left(S_{RDT(MT,NO)}\right) = p^*[p_p E_{MT} + \left(1 - p_p\right) - C_{MT}] + (1 - p^*)(1 - p_n) - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying an antimalarial monotherapy if the test is positive and also buy monotherapy if the test is negative.

$$U\left(S_{RDT(MT,MT)}\right) = p^*[p_p E_{MT} + \left(1 - p_p\right) - C_{MT}] + (1 - p^*)[p_n E_{MT} + (1 - p_n) - C_{MT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying an ACT if the test is positive and also buy an ACT if the test is negative.

$$U\left(S_{RDT(ACT,ACT)}\right) = p^*[p_p E_{ACT} + \left(1 - p_p\right) - C_{ACT}] + (1 - p^*)[p_n E_{ACT} + (1 - p_n) - C_{ACT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying an ACT if the test is positive and also buy an antimalarial monotherapy if the test is negative.

$$U\left(S_{RDT(ACT,MT)}\right) = p^*[p_p E_{ACT} + \left(1 - p_p\right) - C_{ACT}] + (1 - p^*)[p_n E_{MT} + (1 - p_n) - C_{MT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying an antimalarial monotherapy if the test is positive and buy an ACT if the test is negative.

$$U\left(S_{RDT(MT,ACT)}\right) = p^*[p_p E_{MT} + \left(1 - p_p\right) - C_{MT}] + (1 - p^*)[p_n E_{ACT} + (1 - p_n) - C_{ACT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying no drugs if the test is positive and buy an antimalarial monotherapy if the test is negative.

$$U\left(S_{RDT(NO,MT)}\right) = p^*(1 - p_p) + (1 - p^*)[p_n E_{MT} + (1 - p_n) - C_{MT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying no drugs if the test is positive and buy an ACT if the test is negative.

$$U\left(S_{RDT(NO,ACT)}\right) = p^*(1-p_p) + (1-p^*)[p_n E_{ACT} + (1-p_n) - C_{ACT}] - C_{RDT}$$

Utility of buying an RDT and having a strategy of buying no drugs if the test is positive and also buying no drugs if the test is negative.

$$U\left(S_{RDT(NO,NO)}\right) = p^*(1-p_p) + (1-p^*)(1-p_n) - C_{RDT}$$

Appendix 2

[1] $S_{RDT(MT,MT)}$ is dominated by S_{MT}.

$$U(S_{MT}) \geq U(S_{RDT(MT,MT)}) \Leftrightarrow$$

$$pE_{MT} + (1-p) - C_{MT} \geq p^*[p_pE_{MT} + (1-p_p) - C_{MT}] + (1-p^*)[p_nE_{MT} + (1-p_n) - C_{MT}] - C_{RDT} \Leftrightarrow$$

$$[p^*p_p + (1-p^*)p_n]E_{MT} + [1 - p^*p_p - (1-p^*)p_n] - C_{MT} \geq p^*[p_pE_{MT} + (1-p_p) - C_{MT}] + (1-p^*)[p_nE_{MT} + (1-p_n) - C_{MT}] - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{MT} + p_nE_{MT} - p^*p_nE_{MT} + 1 - p^*p_p - p_n + p^*p_n - C_{MT} \geq p^*p_pE_{MT} + p^* - p^*p_p - p^*C_{MT} + p_nE_{MT} + 1 - p_n - C_{MT} - p^*p_nE_{MT} - p^* + p^*p_n + p^*C_{MT} - C_{RDT} \Leftrightarrow$$

$C_{RDT} \geq 0$ which is true.

[2] $S_{RDT(NO,NO)}$ is dominated by S_{NO}.

$$U(S_{NO}) \geq U(S_{RDT(NO,NO)}) \Leftrightarrow$$

$$(1-p) \geq p^*(1-p_p) + (1-p^*)(1-p_n) - C_{RDT} \Leftrightarrow$$

$$1 - p^*p_p - (1-p^*)p_n \geq p^*(1-p_p) + (1-p^*)(1-p_n) - C_{RDT} \Leftrightarrow$$

$$1 - p^*p_p - p_n + p^*p_n \geq p^* - p^*p_p + 1 - p_n - p^* + p^*p_n - C_{RDT} \Leftrightarrow$$

$C_{RDT} \geq 0$ which is true.

[3] *] $S_{RDT(ACT,ACT)}$ is dominated by S_{ACT}.*

$U(S_{ACT}) > U(S_{RDT(ACT,ACT)}) \Leftrightarrow$

$$pE_{ACT} + (1-p) - C_{ACT} > p^*\{p_pE_{ACT} + (1-p_p) - C_{ACT}\} + (1-p^*)\{p_nE_{ACT} + (1-p_n) - C_{ACT}\} - C_{RDT} \Leftrightarrow$$

$$\{p^*p_p + (1-p^*)p_n\}E_{ACT} + \{1 - p^*p_p - (1-p^*)p_n\} - C_{ACT} > p^*\{p_pE_{ACT} + (1-p_p) - C_{ACT}\} + (1-p^*)\{p_nE_{ACT} + (1-p_n) - C_{ACT}\} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + p_nE_{ACT} - p^*p_nE_{ACT} + 1 - p^*p_p - p_n + p^*p_n - C_{ACT} > p^*p_pE_{ACT} + p^* - p^*p_p - p^*C_{ACT} + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} > 0$$

[4] $S_{RDT(MT,ACT)}$ is dominated by either S_{ACT} or S_{MT}.

First we investigate when $S_{RDT(MT,ACT)}$ is dominated by S_{ACT} :

$$U(S_{ACT}) \geq U(S_{RDT(MT,ACT)}) \Leftrightarrow$$

$$pE_{ACT} + (1-p) - C_{ACT} \geq p^*[p_pE_{MT} + (1-p_p) - C_{MT}] + (1-p^*)[p_nE_{ACT} + (1-p_n) - C_{ACT}] - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} + 1 - p^*p_p - (1-p^*)p_n - C_{ACT} \geq p^*p_pE_{MT} + p^*(1-p_p) - p^*C_{MT} + p_nE_{ACT} + (1-p_n) - C_{ACT} - p^*p_nE_{ACT} - p^*(1-p_n) + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} + 1 - p^*p_p - (1-p^*)p_n - C_{ACT} \geq p^*p_pE_{MT} + p^*(1-p_p) - p^*C_{MT} + p_nE_{ACT} + (1-p_n) - C_{ACT} - p^*p_nE_{ACT} - p^*(1-p_n) + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} + 1 - p^*p_p - p_n + p^*p_n - C_{ACT} \geq p^*p_pE_{MT} + p^* - p^*p_p - p^*C_{MT} + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} \geq p^*p_pE_{MT} - p^*C_{MT} + p_nE_{ACT} - p^*p_nE_{ACT} + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} \geq p^*p_pE_{MT} - p^*C_{MT} + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq p^*[(C_{ACT} - C_{MT}) - p_p(E_{ACT} - E_{MT})].$$

We proceed by investigating when $S_{RDT(MT,ACT)}$ is dominated by S_{MT} :

$$U(S_{MT}) \geq U(S_{RDT(MT,ACT)}) \Leftrightarrow$$

$$pE_{MT} + (1-p) - C_{MT} \geq p^*[p_pE_{MT} + (1-p_p) - C_{MT}] + (1-p^*)[p_nE_{ACT} + (1-p_n) - C_{ACT}] - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{MT} + (1-p^*)p_nE_{MT} + 1 - p^*p_p - (1-p^*)p_n - C_{MT} \geq p^*p_pE_{MT} + p^*(1-p_p) - p^*C_{MT} + p_nE_{ACT} + (1-p_n) - C_{ACT} - p^*p_nE_{ACT} - p^*(1-p_n) + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{MT} + (1-p^*)p_nE_{MT} + 1 - p^*p_p - p_n + p^*p_n - C_{MT} \geq p^*p_pE_{MT} + p^* - p^*p_p - p^*C_{MT} + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p_nE_{MT} - p^*p_nE_{MT} - C_{MT} \geq -p^*C_{MT} + p_nE_{ACT} - C_{ACT} - p^*p_nE_{ACT} + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq -(1-p^*)[(C_{ACT} - C_{MT}) - p_n(E_{ACT} - E_{MT}).$$

We note from above that if S_{ACT} does not dominate $S_{RDT(MT,ACT)}$ then we have $(C_{ACT} - C_{MT}) \geq p_p(E_{ACT} - E_{MT})$. Since $p_n < p_p$ this implies that $(C_{ACT} - C_{MT}) > p_n(E_{ACT} - E_{MT})$. This means that $-(1-p^*)[(C_{ACT} - C_{MT}) - p_n(E_{ACT} - E_{MT})] < 0$ implying instead that S_{MT} dominates $S_{RDT(MT,ACT)}$. In other words, if $S_{RDT(MT,ACT)}$ is not dominated by S_{ACT} then it will instead be dominated by S_{MT}.

[5] $S_{RDT(NO,ACT)}$ is dominated by either S_{ACT} or S_{NO}.

We investigate when $S_{RDT(NO,ACT)}$ is dominated by S_{ACT} :

$$U(S_{ACT}) \geq U(S_{RDT(NO,ACT)}) \Leftrightarrow$$

$$pE_{ACT} + (1-p) - C_{ACT} \geq p^*(1-p_p) + (1-p^*)[p_nE_{ACT} + (1-p_n) - C_{ACT}] - C_{RDT} \Leftrightarrow$$

$$pE_{ACT} + (1-p) - C_{ACT} \geq p^* - p^*p_p + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$(p^*p_p + (1-p^*)p_n)E_{ACT} + (1-(p^*p_p + (1-p^*)p_n)) - C_{ACT} \geq p^* - p^*p_p + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} + 1 - p^*p_p - (1-p^*)p_n - C_{ACT} \geq p^* - p^*p_p + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + (1-p^*)p_nE_{ACT} - (1-p^*)p_n - C_{ACT} \geq p_nE_{ACT} - p_n - C_{ACT} - p^*p_nE_{ACT} + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$p^*p_pE_{ACT} + p_nE_{ACT} - p^*p_nE_{ACT} + p^*p_n - p_n - C_{ACT} \geq p_nE_{ACT} - p_n - C_{ACT} - p^*p_nE_{ACT} + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq p^*(C_{ACT} - p_pE_{ACT}).$$

We proceed by investigating when $S_{RDT(NO,ACT)}$ is dominated by S_{NO} :

$$U(S_{NO}) \geq U(S_{RDT(NO,ACT)}) \Leftrightarrow$$

$$(1-p) \geq p^*(1-p_p) + (1-p^*)[p_nE_{ACT} + (1-p_n) - C_{ACT}] - C_{RDT} \Leftrightarrow$$

$$1 - p^*p_p - (1-p^*)p_n \geq p^* - p^*p_p + p_nE_{ACT} + (1-p_n) - C_{ACT} - p^*p_nE_{ACT} - p^*(1-p_n) + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$1 - p^*p_p - p_n + p^*p_n \geq p^* - p^*p_p + p_nE_{ACT} + 1 - p_n - C_{ACT} - p^*p_nE_{ACT} - p^* + p^*p_n + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$0 \geq p_nE_{ACT} - C_{ACT} - p^*p_nE_{ACT} + p^*C_{ACT} - C_{RDT} \Leftrightarrow$$

$$0 \geq (1-p^*)p_nE_{ACT} - (1-p^*)C_{ACT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq -(1-p^*)[C_{ACT} - p_nE_{ACT}].$$

We note that the strategy $S_{RDT(NO,ACT)}$ can be eliminated, since we always have that either S_{ACT} or S_{NO} is better. To see this, note that if $S_{RDT(NO,ACT)}$ is not dominated by S_{ACT}, then we have

$p^*(C_{ACT} - p_p E_{ACT}) \geq C_{RDT}$and hence $(C_{ACT} - p_p E_{ACT}) \geq 0$. But since $p_n < p_p$ we then have $(C_{ACT} - p_n E_{ACT}) \geq 0$ and also that $-(1-p^*)[C_{ACT} - p_n E_{ACT}] < 0$ implying that S_{NO} dominates $S_{RDT(NO,ACT)}$.

[6] $S_{RDT(NO,MT)}$ is dominated by either S_{MT} or S_{NO}.

We investigate when $S_{RDT(NO,MT)}$ is dominated by S_{MT} :

$$U(S_{MT}) \geq U(S_{RDT(NO,MT)}) \Leftrightarrow$$

$$pE_{MT} + (1-p) - C_{MT} \geq p^*(1-p_p) + (1-p^*)[p_n E_{MT} + (1-p_n) - C_{MT}] - C_{RDT} \Leftrightarrow$$

$$p^* p_p E_{MT} + (1-p^*)p_n E_{MT} + 1 - p^* p_p - (1-p^*)p_n - C_{MT} \geq p^* - p^* p_p + p_n E_{MT} + 1 - p_n - C_{MT} - p^* p_n E_{MT} - p^* + p^* p_n + p^* C_{MT} - C_{RDT} \Leftrightarrow$$

$$p^* p_p E_{MT} + (1-p^*)p_n E_{MT} \geq p_n E_{MT} - p^* p_n E_{MT} + p^* C_{MT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq p^*(C_{MT} - p_p E_{MT}).$$

We proceed by investigating if $S_{RDT(NO,MT)}$ is dominated by S_{NO} :

$$U(S_{NO}) \geq U(S_{RDT(NO,MT)}) \Leftrightarrow$$

$$(1-p) \geq p^*(1-p_p) + (1-p^*)[p_n E_{MT} + (1-p_n) - C_{MT}] - C_{RDT} \Leftrightarrow$$

$$1 - p^* p_p - (1-p^*)p_n \geq p^* - p^* p_p + p_n E_{MT} + (1-p_n) - C_{MT} - p^* p_n E_{MT} - p^*(1-p_n) + p^* C_{MT} - C_{RDT} \Leftrightarrow$$

$$1 - p^* p_p - p_n + p^* p_n \geq p^* - p^* p_p + p_n E_{MT} + 1 - p_n - C_{MT} - p^* p_n E_{MT} - p^* + p^* p_n + p^* C_{MT} - C_{RDT} \Leftrightarrow$$

$$0 \geq p_n E_{MT} - C_{MT} - p^* p_n E_{MT} + p^* C_{MT} - C_{RDT} \Leftrightarrow$$

$$C_{RDT} \geq -(1-p^*)\{C_{MT} - p_n E_{MT}\}.$$

We note that the strategy $S_{RDT(NO,MT)}$ can be eliminated, since we always have that *either* S_{MT} or S_{NO} is better. If $S_{RDT(NO,MT)}$ is not dominated by S_{MT}, we have that $(C_{MT} - p_p E_{MT}) \geq 0$. But since $p_n < p_p$ we then also have $(C_{MT} - p_n E_{MT}) \geq 0$ and further that $-(1-p^*)\{C_{MT} - p_n E_{MT}\} < 0$ implying that S_{NO} dominates $S_{RDT(NO,MT)}$.

Appendix 3

The individual will prefer strategy $S_{RDT(ACT,NO)}$ to strategy S_{ACT} if the following condition holds:

[1]

$$U(S_{RDT(ACT,NO)}) \geq U(S_{ACT}) \Leftrightarrow$$

$$p^*[p_p E_{ACT} + (1-p_p) - C_{ACT}] + (1-p^*)(1-p_n) - C_{RDT} \geq pE_{ACT} + (1-p) - C_{ACT} \Leftrightarrow$$

$$p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \geq p^* p_p E_{ACT} + p_n E_{ACT} - p^* p_n E_{ACT} + 1 - p^* p_p - p_n + p^* p_n - C_{ACT} \Leftrightarrow$$

$$p^* p_p E_{ACT} - p^* C_{ACT} - C_{RDT} \geq p^* p_p E_{ACT} + p_n E_{ACT} - p^* p_n E_{ACT} - C_{ACT} \Leftrightarrow$$

$$(1-p^*)C_{ACT} - C_{RDT} \geq (1-p^*)p_n E_{ACT}$$

The remaining incentive compatibility conditions are as follows:

[2]

$$U(S_{RDT(ACT,NO)}) \geq U(S_{MT}) \Leftrightarrow$$

$$p^*[p_p E_{ACT} + (1-p_p) - C_{ACT}] + (1-p^*)(1-p_n) - C_{RDT} \geq pE_{MT} + (1-p) - C_{MT} \Leftrightarrow$$

$$p^*[p_p E_{ACT} + (1-p_p) - C_{ACT}] + (1-p^*)(1-p_n) - C_{RDT} \geq p^* p_p E_{MT} + (1-p^*)p_n E_{MT} + 1 - p^* p_p - (1-p^*)p_n - C_{MT} \Leftrightarrow$$

$$p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \geq p^* p_p E_{MT} + p_n E_{MT} - p^* p_n E_{MT} + 1 - p^* p_p - p_n + p^* p_n - C_{MT} \Leftrightarrow$$

$$p^* p_p E_{ACT} - p^* C_{ACT} - C_{RDT} \geq p^* p_p E_{MT} + p_n E_{MT} - p^* p_n E_{MT} - C_{MT} \Leftrightarrow$$

$$C_{MT} - p^* C_{ACT} - C_{RDT} \geq (1 - p^*) p_n E_{MT} + p^* p_p (E_{MT} - E_{ACT}) \Leftrightarrow$$

$$p^* p_p E_{ACT} - \{p^* p_p + (1 - p^*) p_n\} E_{MT} \geq C_{RDT} + p^* C_{ACT} - C_{MT}$$

[3]

$$U(S_{RDT(ACT,NO)}) \geq U(S_{NO}) \Leftrightarrow$$

$$p^* [p_p E_{ACT} + (1 - p_p) - C_{ACT}] + (1 - p^*)(1 - p_n) - C_{RDT} \geq (1 - p) \Leftrightarrow$$

$$p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \geq 1 - p^* p_p - p_n + p^* p_n \Leftrightarrow$$

$$p^* p_p E_{ACT} \geq C_{RDT} + p^* C_{ACT}$$

[4]

$$U(S_{RDT(ACT,NO)}) \geq U(S_{RDT(ACT,MT)}) \Leftrightarrow$$

$$\begin{aligned} p^* [p_p E_{ACT} + (1 - p_p) - C_{ACT}] + (1 - p^*)(1 - p_n) - C_{RDT} \\ \geq p^* [p_p E_{ACT} + (1 - p_p) - C_{ACT}] + (1 - p^*)[p_n E_{MT} + (1 - p_n) - C_{MT}] - C_{RDT} \Leftrightarrow \end{aligned}$$

$$\begin{aligned} p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \\ \geq p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + p_n E_{MT} + 1 - p_n - C_{MT} - p^* p_n E_{MT} - p^* \\ + p^* p_n + p^* C_{MT} - C_{RDT} \Leftrightarrow \end{aligned}$$

$$0 \geq p_n E_{MT} - C_{MT} - p^* p_n E_{MT} + p^* C_{MT} \Leftrightarrow$$

$$-(1 - p^*) p_n E_{MT} \geq -(1 - p^*) C_{MT} \Leftrightarrow$$

$$(1 - p^*) C_{MT} \geq (1 - p^*) p_n E_{MT} \Leftrightarrow$$

$$C_{MT} \geq p_n E_{MT}$$

[5]

$$U(S_{RDT(ACT,NO)}) \geq U(S_{RDT(MT,NO)}) \Leftrightarrow$$

$$p^*[p_p E_{ACT} + (1 - p_p) - C_{ACT}] + (1 - p^*)(1 - p_n) - C_{RDT} \geq p^*[p_p E_{MT} + (1 - p_p) - C_{MT}] + (1 - p^*)(1 - p_n) - C_{RDT} \Leftrightarrow$$

$$p^* p_p E_{ACT} + p^* - p^* p_p - p^* C_{ACT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \geq p^* p_p E_{MT} + p^* - p^* p_p - p^* C_{MT} + 1 - p_n - p^* + p^* p_n - C_{RDT} \Leftrightarrow$$

$$p^* p_p E_{ACT} - p^* C_{ACT} \geq p^* p_p E_{MT} - p^* C_{MT} \Leftrightarrow$$

$$p_p(E_{ACT} - E_{MT}) \geq (C_{ACT} - C_{MT})$$

Appendix 4

All combinations of values in the table below was used to create 32 different consumer types which we combine with estimates from Table 1.

parameter description	Parameter				
degree of certainty fever is malaria	p	0,20	0,40	0,60	0,80
low belief in RDT negative	p_n	0,15	0,35	0,55	0,75
high belief in RDT negative	p_n	0,03	0,10	0,15	0,20
belief in RDT positive	p_p	0,97	0,97	0,97	0,97
true malaria prevalence among drug shop customers	$\tilde{p}$	0,15	0,35	0,50	0,70