Chapter 7
Adoption of Over-the-Counter Malaria Diagnostics in Africa: The Role of Subsidies, Beliefs, Externalities, and Competition

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Abstract Plans for the wide-scale distribution and subsidy of artemisinin combination therapies (ACTs), an antimalarial treatment, pose two problems for public health planning. First, many people seeking malaria treatment do not have the disease. If ACT subsidies could be targeted toward those with malaria, the cost of subsidies could fall. Second, the inappropriate use of antimalarial drugs may contribute to the emergence of drug-resistant parasites. Rapid diagnostic tests (RDTs) for malaria could help with both problems, but drug shop owners may have few financial incentives to sell them, given profits from overtreatment for malaria. A model of the provision of RDTs by profit-maximizing drug shops shows that if all parties know the probability of having malaria and if there are no subsidies for drugs and no external costs to inappropriate treatment, both monopolistic and competitive drug shop owners will provide RDTs under the same circumstances that a social welfare maximizing planner would. However, since drugs will be subsidized, customers overestimate their likelihood of having malaria, and since there are external costs to the misuse of antimalarials, profit-maximizing drug shops will likely underprovide RDTs. We show that a subsidy for RDTs can increase provision and, under adequate competition, induce everyone to use RDTs optimally. The results also highlight the importance of educating customers about the true prevalence of malaria and promoting competition among drug providers.

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7.1 Introduction

According to the 2009 World Malaria Report (2010), only 15% of children are treated for malaria with artemisinin combination therapies (ACTs)—currently, the only antimalarials that are effective against the disease.[1] The rest are treated with medicines to which the malaria parasite has acquired resistance. At $6–$7 for an adult dose, ACTs are considerably more expensive than the older, less effective antimalarials, the costs of which range from $.20 to $1 a dose (ACT Watch, PSI 2010).[2] The very low uptake of ACTs is attributed to the high price of these life-saving medicines in the private retail sector (where most Africans first seek treatment for malaria), combined with poorly functioning public sector facilities and supply chains. In an effort to increase access to ACTs, as well as crowd out artemisinin monotherapy and stem the development of resistance, efforts are under way to subsidize roughly 95% of their cost.[3]

Plans for wide-scale distribution and subsidies are likely to dramatically increase access to ACTs, but they are also likely to significantly increase the use of ACTs for nonmalarial illnesses. This is because most people seeking treatment for malaria either self-diagnose and purchase medicine at drug shops, or go to a public facility where they are diagnosed based on clinical symptoms but without a formal blood test.[4] Thus a large share of malaria treatment goes to people without malaria. In a recent randomized trial with rural Kenyan drug shops, Cohen et al. (2012) show that more than half of older children and adults purchasing subsidized ACTs do not have malaria. In another example, from Tanzania, only 46% of people receiving in-patient hospital care for "severe malaria" actually tested positive for malaria, the same rate as the general population (Reyburn et al. 2004). Because of acquired

[1] Artemisinin monotherapy is effective against malaria as well, but the World Health Organization and others in the global health community have pushed for artemisinin to be manufactured and sold in combination with other treatments with longer half-lives to preserve its efficacy (Arrow et al. 2004).

[2] ACT Watch Outlet Surveys, conducted by Population Services International, are available at http://www.actwatch.info/home/home.asp

[3] The Global Fund currently grants funds for ACTs in the public sector. The Affordable Medicines Facility–malaria (AMFm), funded by the Gates Foundation, the U.K. Department for International Development, and others (and hosted by the Global Fund), is being piloted in eight countries and will subsidize the cost of ACTs to first-line buyers (NGOs, wholesalers, governments, etc.) by roughly 95%. AMFm has negotiated the price of ACTs with manufacturers down to around $1 a dose. Details about AMFm are at http://www.theglobalfund.org/en/amfm/

[4] According to the 2009 World Malaria Report, only 22% of suspected malaria cases that present at public health centers are confirmed with a test. In most African countries, more than 50% of people seek treatment for malaria outside the public sector (ACT Watch 2010).

immunity, the chances that a patient with a fever (the symptom most commonly associated with malaria) has parasites declines rapidly after age 5, and thus overtreatment is much more likely among older children and adults (Reyburn et al. 2004). In a Tanzania study with drug shop customers, only 18% of those five and over buying antimalarials were parasitemic (Kachur et al. 2006). Parasite prevalence in the area for this age group was 9%, suggesting that symptom-based self-diagnosis in this context was not much better than a random draw from the population.

Without improved targeting, such high rates of overtreatment mean that a large amount of ACT subsidy money will be spent on people without malaria. High rates of overtreatment have other downsides as well, including delaying proper treatment for the true cause of illness (a dangerous example is pneumonia in young children) and accelerating the development of drug resistance (Rafael et al. 2006; Perkins and Bell 2008). If people take ACT when they don't have malaria, it could also preclude learning about the effectiveness of ACTs over other antimalarials (Advaryu 2012).

A potential solution to those problems of ACT targeting would be to improve access to rapid diagnostic tests (RDTs) for malaria. Recent experimental results in Cohen et al. (2012) suggest that those seeking treatment for malaria are extremely interested in being tested for the disease and that drug shop customers may be willing to pay for an RDT. Combined with nonexperimental results on willingness to pay for RDTs (Uzochukwu et al. 2010), the results in Cohen et al. (2012) are an encouraging indication that, if RDTs are priced low enough and made available over the counter, consumer demand for malaria diagnostics may be substantial. We briefly describe the results of that experiment below.

The question then is whether drug shop owners would be willing to sell the tests. It is possible that, since sales of antimalarial drugs are a major source of revenue for drug shops, they would not want to offer the tests because they would not be able to sell antimalarials to customers who test negative. In this chapter we show that in the absence of subsidies or misperception of malaria frequency among drug shop customers, this is not the case. In fact, if there are no subsidies or externalities, if all those needing treatment are treated, and if both customers and drug shop owners correctly perceive the probability of malaria (conditional on symptoms), both monopolistic and competitive drug shops will provide tests in the same circumstances as would a social welfare–maximizing central planner.

We then explore how RDT provision is affected by ACT subsidies and by incorrect perceptions by consumers of the likelihood of malaria conditional on malaria-like symptoms. As noted above, ACTs are currently being subsidized in eight countries through the AMFm, and this could have major implications for the feasibility of RDT adoption in drug shops. We show that under ACT subsidies, there will be a tendency for underprovision of testing. Though not definitive, the fact that the majority of teenage and adult ACT buyers in Cohen et al. (2012) actually do not have malaria suggests that the probability of malaria infection conditional on symptoms is commonly overestimated. We show that if customers overestimate the likelihood that they have malaria, testing will not take place in circumstances where it should. Finally, we show that if there are externalities to mistreatment with antimalarials—for example, because it hastens the emergence of

parasite resistance—provision of RDTs by drug shops will be suboptimal. All of these problems can be overcome to some degree by subsidizing RDTs.

7.2 Demand for RDTs: Consumers

The first experimental evidence on demand for RDTs among drug shop customers comes from a randomized controlled trial in western Kenya. Cohen et al. (2012) distributed vouchers to just under 3,000 households in the catchment area (4-km radius) of four rural drug shops. A sub-sample of households received vouchers for subsidized ACTs and for subsidized RDTs, and another sub-sample received vouchers for the subsidized ACTs only. ACT prices were randomly assigned and ranged from $.50 to $6, spanning the range of prices for alternative antimalarials available in drug shops. Households receiving RDT vouchers were randomly assigned to three treatment groups: free, $.20, or $.20 with the possibility of a refund. This last group had to pay $.20 for the RDT, but if they tested positive and went on to buy an ACT, they were refunded the cost of the test. The group receiving an offer for free RDTs or for $.20 RDTs with a refund had the strongest financial incentives to be tested for malaria prior to ACT purchase.

Among those with subsidized ACTs only (i.e., with no RDT voucher), a sub-sample of households were given "surprise" RDTs. That is, on purchase of ACTs, they were asked whether they would be willing to take a malaria test. Cohen et al. (2012) find that, although nearly all young children for whom ACTs were being purchased tested positive, less than 40% of older children and adults buying ACTs had malaria. Further, they find that the fraction of ACT buyers who have malaria diminishes as ACT prices go down (i.e., as ACT subsidies go up). This suggests that an ACT subsidy policy could exacerbate targeting problems. They then go on to show that subsidized RDTs, available over the counter alongside subsidized ACTs, can to some extent improve targeting.

Cohen et al. (2010, 2012) find some evidence that demand for RDTs is substantial. They find that, among those with RDT vouchers, more than 80% of people coming to buy ACTs took an RDT first. In other words, very few people choose to buy the medicine without first being tested. Further, they find that demand for RDTs was the same among those offered the test free and those who had to pay $.20. Although this RDT price is quite low, the study was conducted in an area where the daily wage is equivalent to $1.50, so the finding that demand for RDTs does not drop at all when the price increases from $0 to $.20 suggests that consumer valuation and willingness to pay for RDTs are notable.

Cohen et al. (2010, 2012) present encouraging evidence of significant demand for RDTs in drug shops. However, this study completely controlled the supply side, not allowing drug shop owners to choose whether RDTs were offered or at what price. Thus, the crucial next step in understanding whether RDTs can improve targeting of malaria medicine is exploring the conditions under which drug shops will find it profitable to make them available and affordable. We now turn to the supplier decision.

7.3 Supply of RDTs: Profit-Maximizing Drug Shops

Consider a simple framework where individuals periodically suffer from fevers, and some fraction m of fevers are caused by malaria. Drug shops have access to three products: an antimalarial drug, a rapid diagnostic test, and an alternative drug that is effective for nonmalaria-related fevers (e.g., an antipyretic or antibiotic).

7.3.1 Monopolistic Drug Shop

Define P^{NT} ("price no test") as the price a monopolist will charge for antimalarial treatment if RDTs aren't offered, and P^{WT} ("price with test") as the price the monopolist will charge if RDTs are offered. Define P^T ("price of test") as the price the monopolist will charge for the RDT if it is offered. We will assume that those who test negative for malaria will all purchase an alternative treatment at some price P^A (which we will treat as given).[5] The drug seller faces a constant unsubsidized cost for the antimalarial drug, the tests, and an alternative drug, which we denote C^D, C^T, and C^A, respectively.[6] Finally, the drug seller is assumed to expect that a fraction m^D of those seeking treatment for malaria will test positive.

We assume that the cost of antimalarials, whether or not tests are offered, is low enough relative to the expected value of treatment that all people who suspect they have malaria purchase an antimalarial. That is, we abstract (for now) from any potential effect of the tests on the decision to seek treatment at the drug shop, an assumption consistent with results in Cohen et al. (2010, 2012).[7]

Under these assumptions, when the test is not offered, we can write the expected profit per customer as

$$E\left(r^{NT}\right) = P^{NT} - C^D. \tag{7.1}$$

If RDTs are offered for sale in drug shops, the potential payoffs change. Individuals who test positive will be sold both the RDT and the antimalarial. Individuals who test negative will be sold both the RDT and the alternative treatment. Although the shop owner does not know the exact number of his customers who will test positive, the

[5] We treat the price of the alternative therapy as exogenously given because we assume that the market for it is much larger than those testing negative for malaria, so the cost of malaria medication and the availability of tests for malaria will have no effect on the price charged. We have in mind antipyretic drugs.

[6] If there is no alternative treatment, then $C^A = P^A = 0$.

[7] Cohen et al. (2010) find that people who are offered a subsidized RDT in addition to a subsidized ACT are no more likely to show up at the drug shop for treatment than those offered a subsidized ACT only.

expectation is that a fraction m^D will do so, and thus the expected payoff per customer if the test is offered is

$$\mathrm{E}\left(r^{WT}\right) = \left[P^T - C^T\right] + m^D\left[P^{WT} - C^D\right] + \left(1 - m^D\right)\left[P^A - C^A\right], \tag{7.2}$$

where the expressions in the squared brackets reflect the margins the shop makes on each of the three products sold.

Profit-maximizing drug shops will offer RDTs for sale if expected profits are higher with the sales of RDTs—that is, if $\mathrm{E}(r^{WT}) > \mathrm{E}(r^{NT})$. Combining (7.1) and (7.2) and rearranging terms, we can see that this is true as long as

$$m^D\left(P^{WT} - P^{NT}\right) + \left[P^T - C^T\right] + \left(1 - m^D\right)\left(\left[P^A - C^A\right] - \left[P^{NT} - C^D\right]\right) > 0. \tag{7.3}$$

From Eq. (7.3) we can see that three factors contribute to a monopolistic drug shop's willingness to offer the test. First, the shop could charge more for the drug when people are certain they have malaria. This is intuitive since the drug will be effective only when the person actually has malaria.[8] Even if this is not understood initially, over time, willingness to pay should increase as people discover that recovery is more likely when the drug is taken after a positive test. Second, the higher the markup on the test, the more likely the shop is to offer the test. Finally, if the margin on the alternative treatment is larger than the margin on the antimalarial if no test is offered, shops are more likely to offer the tests. This is unlikely to be the case, since the majority of alternative treatment purchases will be antipyretics, which are extremely inexpensive in Africa and are available widely in general stores, markets, and other outlets. To know when it will be in shops' interest to offer RDTs, we need to know what prices monopoly drug shops can charge. This requires an analysis of consumers' willingness to pay.

7.3.2 *Consumers' Decision to Buy Test*

The value to consumers of taking an antimalarial has two components. The first is the value of the improvement in health if they actually have malaria and receive the treatment for it. We designate that as W^M, where the W stands for willingness to pay for effective treatment. People know from experience that the treatment is not always effective, and they may understand that the reason is that other illnesses may appear symptomatically like malaria. Thus the second component of the value of treatment to a customer is the perceived probability that their symptoms are caused

[8] Some older antimalarials, such as chloroquine, have an antipyretic effect as well—so a person who had fever but not malaria and took an antimalarial might experience some benefit—but for the newer antimalarials, this is not the case.

by malaria, which we designate m^C. Thus their willingness to pay for the antimalarial drug in the absence of definitive test results is

$$\mathrm{E}\left(U^{NT}\right) = m^C W^M = P^{NT} \tag{7.4}$$

or the expected value to them of treatment when malarial infection is uncertain. Since drug shops want to maximize profits, a monopolist will charge the maximum price people are willing to pay for the drug if RDTs are not offered for sale ($m^C W^M$).

On the other hand, if a test is offered, consumers' expected value is the sum of the benefit if they test positive for malaria and if they test negative. Denoting W^A the willingness to pay for alternative treatment, the expected benefit if tested is

$$\mathrm{E}\left(U^{WT}\right) = m^C W^M + \left(1 - m^C\right) W^A \tag{7.5}$$

and customers will be willing to pay up to this amount in expected costs for treatment if tests are available. Their expected costs if tests are available and are purchased are

$$\mathrm{E}\left(C^{WT}\right) = P^T + m^C P^{WT} + \left(1 - m^C\right) P^A. \tag{7.6}$$

Even if tests are available, consumers may still choose to purchase the medicine without purchasing a test. Consumers will use the tests only if their expected welfare (benefits minus costs) is at least as great with the tests as without. That will be the case if

$$\begin{aligned} m^C W^M - P^{WT} &\leq m^C \left(W^M - P^{WT}\right) + \left(1 - m^C\right)\left(W^A - P^A\right) - P^T \\ &\Rightarrow P^T \leq \left(1 - m^C\right)\left[P^{WT} + W^A - P^A\right]. \end{aligned} \tag{7.7}$$

If people choose not to be tested, they always pay for the drug but receive the benefit only a fraction m^C of the time. If they choose to be tested, they always pay for the test but pay for the antimalarial only if the test is positive. If the test is negative, they purchase the alternative treatment and receive consumer surplus $W^A - P^A$. Thus people are more likely to want to use the test (1) the lower the price of the test; (2) the less certain they are that they have malaria; (3) the more expensive the antimalarial drug is; and (4) the greater the consumer surplus from alternative treatment ($W^A - P^A$) if they do not have malaria.

Figure 7.1 portrays the actions consumers will take with different combinations of prices for the test and antimalarial drug. The consumer is choosing among being tested (and buying the appropriate drug conditional on test result), being presumptively treated (buying the antimalarial without the test), and doing nothing (buying no drug or test).

If the expected consumer surplus from buying the test and then the appropriate drug ($\mathrm{E}(U^{WT})$) is less than or equal to the expected cost ($\mathrm{E}(C^{WT})$), and the value of the test is above its price, then consumers will purchase the test and appropriate drug.

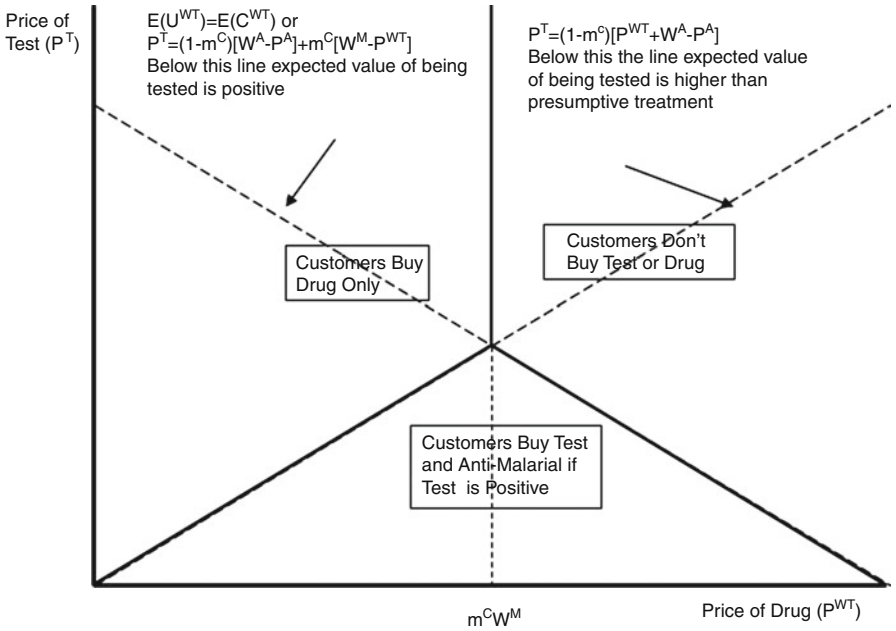

Fig. 7.1 Customer choices with different prices for tests and antimalarial drugs

This will be true anywhere in the lower triangle formed by the upward- and downward-sloping lines depicting the boundaries for the two conditions.

If the expected total cost with the test is above its value (the price of the test is above the upward-sloping line) but the price of the antimalarial is at or below the consumer's expected value of presumptive treatment with the antimalarial, then consumers will buy the drug but not the test. Finally, if the expected cost of the test and drugs is greater than the expected value of treatment with the test, and the cost of the antimalarial is above the expected value of taking it without knowing whether one has malaria ($m^C W^M$), then customers will buy neither the test nor the drug.

7.3.3 Monopolist's Decision to Offer Test

If the monopolist is going to offer the test, he will maximize profit by setting the prices for the antimalarial and the test such that customers' expected costs (from Eq. (7.6)) are just equal to the expected benefits (from Eq. (7.5)). Setting $E(U^{WT}) = E(C^{WT})$ and solving for P^T yields

$$P^T = \left(1 - m^C\right)\left[W^A - P^A\right] + m^C\left[W^M - P^{WT}\right]. \tag{7.8}$$

Substituting that into the equation for the firm's profit if the test is sold, we get

$$\mathrm{E}\left(r^{WT}\right) = \left(1 - m^{C}\right)\left[W^{A} - P^{A}\right] + m^{C}\left[W^{M} - P^{WT}\right] - C^{T} + m^{D}\left[P^{WT} - C^{D}\right] + \left(1 - m^{D}\right)\left[P^{A} - C^{A}\right]. \tag{7.9}$$

That will be greater than profits without offering the test if

$$\begin{aligned}\mathrm{E}\left(r^{WT}\right) - \mathrm{E}\left(r^{NT}\right) = {} & \left(m^{D} - m^{C}\right)\left[P^{WT} - P^{A}\right] \\ & + \left[\left(1 - m^{C}\right)W^{A} - \left(1 - m^{D}\right)C^{A}\right] \\ & + \left[\left(1 - m^{D}\right)C^{D} - C^{T}\right] > 0.\end{aligned} \tag{7.10}$$

Note that if both the drug shop owners and the customers correctly perceive the probability that a sick person has malaria ($m^{D} = m^{C} = m$) and if there is no alternative treatment ($W^{A} = C^{A} = 0$), the monopolist offers the test so long as it saves on costs. That is, the monopolist will offer the test if the cost of the test (C^{T}) is less than or equal to the savings from the times the drug will not be purchased because the customer is not sick ($(1-m^{D})C^{D}$). If an alternative treatment is available, then even if the cost of the test is greater than the savings from not having to buy the drug, the monopolist may still offer the test if the expected gain from being able to provide the alternative treatment when appropriate ($(1-m^{D})[W^{A}-C^{A}]$) is sufficiently large. As we will see, this is the same condition under which the test will be provided by the competitive market and the same conditions under which a social welfare–maximizing planner would choose to make the tests available.

7.3.4 Perfect Competition

We've seen the conditions under which a monopolist will offer the test for sale, but under what conditions will profit-maximizing drug shops that face competition offer them? In a competitive market all prices are driven down to cost, and shops that don't offer the most attractive products to their customers will be driven out of business. Thus, RDTs will be offered so long as their costs are less than their benefits to consumers. With both drugs and the RDTs being offered at cost, customers of competitive drug shops will earn surplus

$$\mathrm{E}\left(U^{NT}\right) = m^{C}W^{M} - C^{D} \tag{7.11}$$

if they don't purchase an RDT. If they do purchase a test, their expected surplus will be

$$\mathrm{E}\left(U^{WT}\right) = m^{C}\left(W^{M} - C^{D}\right) + \left(1 - m^{C}\right)\left(W^{A} - C^{A}\right) - C^{T}. \tag{7.12}$$

Thus in a perfectly competitive market, RDTs will be offered and purchased if and only if

$$\mathrm{E}\left(U^{WT}\right) - \mathrm{E}\left(U^{NT}\right) = \left(1 - m^{C}\right)C^{D} + \left(1 - m^{C}\right)\left(W^{A} - C^{A}\right) - C^{T} > 0. \quad (7.13)$$

RDTs will be offered and purchased so long as the cost is less than the expected savings from not buying the antimalarial when customers are not sick plus the extra benefit of getting a more appropriate therapy in that case. Note that if consumers' perceptions of the probability that they have malaria (m^{C}) are equal to the drug shop owners' perceptions (m^{D}), then the condition for the competitive market (Eq. (7.13)) is identical to that with a monopolist (Eq. (7.10)).

7.4 Optimal Provision of RDTs

We've seen that both monopolistic and perfectly competitive drug shops will sell RDTs under certain circumstances. How do those circumstances compare with what a social planner would deem optimal? The planner would want the tests to be sold and used if total social welfare was higher with use of the tests than without. We define social welfare or value when RDTs are not used as

$$V^{NT} = m\left(W^{M} + B^{M}\right) - C^{D} - (1 - m)C^{O} \quad (7.14)$$

where B^{M} is the external benefits of malaria treatment and C^{O} is the social cost of treatment of someone who is not sick with malaria with antimalarials, above and beyond the cost of the drugs. There are external benefits of malaria treatment to the extent that it reduces risks of infection to others. There are costs of treatment in excess of the cost of the drug if inappropriate treatment increases the rate at which malaria parasites become resistant to therapy. When tests are used, social welfare or value is

$$V^{WT} = m\left(W^{M} + B^{M} - C^{D}\right) + (1 - m)\left(W^{A} - C^{A}\right) - C^{T}. \quad (7.15)$$

A social planner would want the tests to be used when $V^{WT} > V^{NT}$ or when

$$(1 - m)\left(W^{A} - C^{A}\right) + (1 - m)\left(C^{D} + C^{O}\right) - C^{T} > 0. \quad (7.16)$$

Note that the existence of consumption externalities to taking the antimalarial if one is sick (B^{M}) has no effect on the optimal choice (since everyone who is sick is taking it under all conditions), but the social desirability of tests is higher if there are external costs to use of the drugs when they are not needed.

Comparing (7.16) with (7.13) and (7.10), we see that if there are no externalities to mistreatment ($C^{O} = 0$), and if there are no misperceptions of the likelihood of

malaria ($m^D = m^C = m$), then both the competitive shop and the monopolist will supply the test in exactly the same conditions in which the social planner would provide them.

However, since neither the monopolist nor the consumer takes into account the costs of inappropriate treatment, the presence of such externalities can lead them to fail to provide tests in circumstances where the social planner would like to see them provided. Similarly, misperceptions of the true likelihood that a customer seeking treatment for malaria actually has malaria can lead to RDTs being provided in situations when they shouldn't be or not being sold in situations where they should be. We consider another possible source of this problem as well as a possible solution next.

7.5 Role of Subsidies, Beliefs, and Competition in Optimal Provision of RDTs

Consider now how the analysis changes if governments and NGOs want to make treatment for malaria and RDTs more affordable by subsidizing their prices. As noted in the introduction, there are many benefits to subsidizing ACTs (particularly in the context of credit constraints and disease externalities) that we don't consider here. Rather, our purpose is to ask whether subsidized RDTs, if made available alongside subsidized ACTs, would be sold by drug shops in a way that is welfare enhancing.

Define C'^T as the production cost of tests, which is equal to the subsidy plus the cost to drug shops, or $C'^T = C^T + S^T$, and define the production cost of the antimalarial drug analogously as $C'^D = C^D + S^D$. We can now rewrite the social planner's problem (Eqs. (7.14), (7.15) and (7.16)) as

$$\begin{aligned} V^{NT} &= m\left(W^M + B^M\right) - C'^D - (1-m)C^O \\ &= m\left(W^M + B^M\right) - C^D - S^D - (1-m)C^O, \end{aligned} \tag{7.14'}$$

$$\begin{aligned} V^{WT} &= m\left(W^M + B^M - C'^D\right) + (1-m)\left(W^A - C^A\right) - C'^T \\ &= m\left(W^M + B^M - C^D - S^D\right) + (1-m)(W^A - C^A) - C^T - S^T, \end{aligned} \tag{7.15'}$$

and the condition $V^{NT} < V^{WT}$

$$\begin{aligned} &(1-m)\left(W^A - C^A\right) + (1-m)\left(C'^M + C^O\right) - C'^T \\ &= (1-m)\left(W^A - C^A\right) + (1-m)\left(C^D + S^D + C^O\right) - C^T - S^T > 0. \end{aligned} \tag{7.16'}$$

Note that even if there are no costs to inappropriate treatment ($C^O = 0$) and no misperceptions ($m^C = m^D = m$), subsidizing antimalarial treatment can create situations where both the competitive market and the monopolist will fail to provide

the tests when it would be best to do so. This happens because the subsidy reduces the cost of antimalarials to the drug shops and thus lowers the cost-saving value of the test to them and to consumers, but it has no effect on the true social cost of the drug.

This problem, and the others previously described, could be overcome if it was possible to align the interests of private actors with the public purpose represented by the social planner's objective function. Is it possible to incentivize private drug shops to behave optimally? Yes, as long as private drug shops can be made to offer tests in the same circumstances as the social planner. To see whether this is possible, we look at the difference between the objective function of the social planner and that of the private drug shop.

A perfectly competitive drug shop will make the same choices as the social planner if the left-hand side of Eq. (7.13) is equal to the left-hand side of Eq. (7.16′), or if

$$\begin{aligned}&\left(1-m^C\right)\left(W^A-C^A\right)+\left(1-m^C\right)C^D-C^T\\&\quad=(1-m)\left(W^A-C^A\right)+(1-m)\left(C^D+S^D+C^O\right)-C^T-S^{*T}\end{aligned}\tag{7.17}$$

where S^{*T} is the subsidy to the cost of the RDT that will cause the competitive drug shop to offer RDTs under the same conditions the social planner would. Rearranging terms, we see that this will be happen if

$$S^{*T}=\left(m^C-m\right)\left[W^A-C^A+C^D\right]+(1-m)\left[S^D+C^O\right].\tag{7.18}$$

If there are no errors in perception, then an optimal RDT subsidy will be equal to the proportion of customers without malaria times the drug subsidy plus the external cost of inappropriate treatment. If customers misperceive the probability that they have malaria, then there is an additional term.

Given how frequently people seeking treatment for malaria test negative for the parasite—studies noted in the introduction find this to be the case 35–80% of the time—if there are errors in perception, customers probably overestimate the probability they have malaria. If so, the RDT subsidy will have to compensate for this. To the extent the probability is overstated, the subsidy will have to be larger in proportion to the surplus from the alternative treatment plus the cost of the antimalarial drug.

The monopolistic drug shop will make the same choices as the social planner if the right-hand side of Eq. (7.10) is equal to the right-hand side of Eq. (7.16′), or if

$$\begin{aligned}&\left(m^D-m^C\right)\left[P^{WT}-P^A\right]+\left[\left(1-m^C\right)W^A-\left(1-m^D\right)C^A\right]+\left[\left(1-m^D\right)C^D-C^T\right]\\&=(1-m)\left(W^A-C^A\right)+(1-m)\left(C^D+S^D+C^O\right)-C^T-S^{*'T}.\end{aligned}\tag{7.19}$$

Rearranging terms, we see that this will be true if $S^{*'T}$ is set as

$$\begin{aligned}S^{*'T}=&\left(m^C-m^D\right)\left(P^{WT}-P^A\right)+\left[\left(m^C-m\right)W^A-\left(m^D-m\right)C^A\right]\\&+\left(m^D-m\right)C^D+(1-m)\left(S^D+C^O\right).\end{aligned}\tag{7.20}$$

Once again, in the absence of any misperceptions ($m^C = m^D = m$), a subsidy equal to the probability the customer does not have malaria times the cost of the antimalarial drug plus the external cost of inappropriate treatment will align the behavior of the drug shop with that of the social planner. If customers and drug shop owners misperceive the likelihood of malaria to the same extent ($m^C = m^D$), then (7.20) is identical to (7.18), and both the monopolist and the perfect competitor will behave like the social planner if the subsidy for the RDT is set optimally.

However, if drug shop owners and customers have different perceptions of the probability that customers are sick with malaria, monopolists will behave differently from competitive drug shops. Monopolistic drug shops will be less likely to want to offer tests to their customers if the owners think customers overestimate the probability that they are sick. Such customers will be willing to pay more for the drug than they would if they shared the drug shop owners' views, and the owners may not want to disabuse them of such views. Alternatively, if the customers view themselves as less likely to be sick than drug shop owners do, the drug shops will have an interest in promoting the test to increase the sale of the drug and the price they can charge for it (since people will consider the antimalarial more likely to be efficacious if they know they have the disease).

To see how much of a difference this will make for the optimal subsidy, we need to know what drug shops will charge for the antimalarial drug if they offer it with the test. Equation (7.9) shows what the monopolistic drug shop's profits will be as a function of the price of the antimalarial, assuming that the price of the test is set low enough that customers are just willing to seek treatment at the shop. Rearranging the terms in (7.9), we get that expected profits are

$$\mathrm{E}\left(r^{WT}\right) = \left(1 - m^C\right)\left[W^A - P^A\right] + m^C W^M - C^T - m^D C^D + \left(1 - m^D\right) \times \left[P^A - C^A\right] + \left(m^D - m^C\right)P^{WT}. \tag{7.9'}$$

We see from the last term that if the drug shop owner's perceived probability that the customer is infected is higher than that of the customer ($m^D > m^C$), then the drug shop will want to set the highest price for the antimalarial that it can (and thus the lowest price it can for the test).[9] On the other hand, if the shop owner sees the probability of a customer's being infected as lower than the customer does, they will want to set the price of the antimalarial as low as possible and the price of the test as high as possible if the shop is going to offer the test.

From Fig. 7.1 we can see what prices these will be. If the monopolist shop wishes to offer the test and to maximize profits, it will choose the price of the RDT and the antimalarial that is on the solid section of the downward-sloping line. If at the same

[9] If customers and drug shop owners have the same perceived probability of infection ($m^D = m^C$), then any choice of the price of the antimalarial and the RDT that satisfy the constraint that the customer expects that the test will save money (Eq. (7.7)) will maximize profit. In Fig. 7.1 this is any combination of the two prices on the solid section of the downward sloping line.

price for the RDT a lower price is charged for the antimalarial, profits will be lower. If the price of the RDT is increased beyond the maximum value on the solid part of that line, customers either won't purchase the RDT or won't seek treatment. From Fig. 7.1 we can see that the maximum price of the drug consistent with profit maximization corresponds to a zero price for the test. Thus if customers think it less likely that they have malaria than the drug shop owners, drug shops will give the tests away for free to identify those who have malaria and then charge as much as they can for the antimalarial—and still get customers to come to the shop.[10]

In the more likely case that customers perceive the probability that they have malaria to be higher than the drug shop owner does, the drug shop will want to charge as high a price as it can for the test. That price is given by the intersection of the upward- and downward-sloping lines in Fig. 7.1, and that can be found by solving Eq. (7.13) for P^T and setting it equal to the value for P^T given by Eq. (7.7). In this case $P^{WT} = m^C W^M$, and this is the value that should be used in computing the optimal subsidy in Eq. (7.20).

7.6 Discussion

We have shown that profit-maximizing drug shops have several incentives to offer their customers RDTs, and that in the absence of errors in perceptions, subsidies, or externalities, they will offer them in the same circumstances as would a planner who chooses whether to offer the test to maximize social welfare. However, there likely are externalities to inappropriate treatment, customers seem to perceive themselves as having malaria very frequently when they do not, and ACTs are being heavily subsidized in some countries. Thus in the absence of policy interventions, the private market will almost certainly under provide RDTs.

We have seen that a subsidy may be able to overcome the problem of under provision. How big would the subsidy have to be? Consider that the subsidy for the test that equates the interests of a drug shop owner and the social welfare–maximizing planner must be at least equal to the fraction of people seeking treatment who do not have malaria times the value of the subsidy to the antimalarial. Given that, on average, 65% of older children and 82% of adults seeking treatment for malaria test negative (Cohen et al. (2010, 2012); Kachur et al. 2006), and that an expected subsidy of 95% for ACTs with production costs of roughly $1, just this one component of the optimal subsidy would be nearly the entire cost of the typical RDT ($.60).

Thus a subsidy for RDTs may help but may not be a complete solution to the problem. From Eq. (7.13), we can see that if the price of the test is made low

[10] Drug shops would never pay people to take the test, since even those who did not think they might be ill would take the test just to get the payment.

enough with subsidies, consumers will always purchase them in a competitive marketplace.[11] The necessary subsidy may be quite large, and the best policy may be to give the tests to drug shops for free. However, in the absence of competition, monopolists may not offer the tests even if they are given to them at no cost. From Eq. (7.10), we can see that if consumers perceive the likelihood that they have malaria to be higher than the drug shop owners do, then profits from offering the test can be less than profits when the RDT is not sold, even if RDTs are given to shops for free. This observation suggests the importance of both educating customers about the prevalence of malaria and promoting competition among drug shops. The latter policy would have the additional benefit of reducing the cost of tests and drugs, thus making treatment accessible to more people (a factor we have not considered in our modeling). A full set of policies to maximize the benefits that RDTs might provide may require subsidies for the tests, education of consumers, and policies to promote competition among drug shops. These could be accomplished as part of a campaign to promote the use of ACTs.

[11] If Eq. (7.18) dictates a subsidy larger than the cost of the test to equate the behavior of the competitive drug shop and the social planner, the social planner would chose to offer the test at any production cost less than S^{*T}, and thus giving the tests away for free (in which case they will be used) is adequate.

7. Commentary: How to Solve One Problem Without Creating Another

Anup Malani

Two challenges motivate Cohen and Dickens in "Adoption of Over-the-Counter Malaria Diagnostics in Africa." First, individuals with malaria use the wrong malaria drug to treat their illness. They use monotherapies rather than combination therapies, specifically artemisinin combination therapies (ACTs), and the use of monotherapies is more likely to lead to drug resistance. Second, individuals use malaria treatments even when they do not have malaria. Specifically, individuals with fevers take malaria treatment even if they do not have malaria and either an antipyretic or antibiotic would be more effective. This too exacerbates drug resistance.

The favored policy response to the first problem, suboptimal malaria treatment, has been to subsidize the cost of ACTs. Unfortunately, this subsidy does not solve the second problem. Indeed, it may worsen it—a point to which I will return later. The proper policy response to the second problem, excessive malaria treatment, is to get individuals to take rapid diagnostic tests (RDTs) to verify that they have malaria before they take malaria treatments. Of course that is easier said than done. In a pair of papers, Cohen has taken up the question of how one can get individuals to take RDTs.

In a separate paper with Dupas and Schaner, Cohen reports on the results of an experiment in which individuals were randomized to subsidized ACTs and RDTs at different prices. The salient findings are two. First, subsidizing the price of ACTs appears to increase the degree of ACT use by individuals—especially older children and adults—who do not have malaria. Second, demand for RDTs is relatively inelastic. Specifically, demand is the same whether RDTs have zero price or a price equivalent to almost one-seventh of the subjects' daily wage. The results suggest that, if local pharmacies offer consumers RDTs for sale, those RDTs will be purchased, and the second problem—overuse—will be solved.[12]

[12] Although it is tangential to my main comments on the present paper, I am puzzled by this result in the predicate paper. For very few products in the world is demand truly inelastic. It is particularly surprising that demand for tests is inelastic given the high rate at which individuals take malaria medication even without verification they have malaria. Therefore, I suspect that some sort of crude Hawthorne effect may be responsible for the remarkable finding that price did not affect demand for RDTs. If I am correct, however, this means that the theory in the paper on which I am commenting is even more important. We must understand when drug sellers would also sell RDTs and when consumers would use them. The only change my suspicion would imply is that consumer demand for tests is more sensitive than the model in the theory paper assumes.

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This volume's chapter by Cohen and Dickens takes up the natural question that follows: under what conditions will firms offer RDTs for sale, at least to the same extent that a social planner would want them to? The long answer is that it depends on several factors, including the beliefs of drug sellers and individuals about the prevalence of malaria and the externalities from excessive use of ACTs. But the useful normative policy proposal that emerges is that appropriate subsidies for RDTs may encourage RDT use and solve the problem that malaria drugs are overused.

In this comment I want to highlight two points that Cohen and Dickens make but do not stress and yet are very important for policymakers to understand. Moreover, I want to raise some more complications that they ought to consider in future research.

The first point I want to stress is that the policy designed to get people to use ACTs rather than monotherapies—ACT subsidies—exacerbates the second, overuse problem. By reducing the gap between the price of ACTs and the drug that individuals should take (antipyretics or antibiotics) if they know they do not have malaria, ACT subsidies also reduce the incentive of individuals to use RDTs and identify the proper drug to treat their illness. Indeed, to the extent that ACTs are more effective at treating malaria than monotherapies because they are less likely to be resistant, they will actually worsen the overuse problem after equating the price of ACTs and monotherapies. The implication is not that ACT subsidies are a bad idea. Rather, it is that the return to such subsidies is lower than expected.[13]

The second point is that a critical factor in evaluating the efficacy of any subsidy for RDTs is determining how they affect both sellers' and consumers' beliefs about malaria prevalence. As Cohen and Dickens acknowledge, if monopoly sellers think that malaria prevalence is lower than consumers think it is, then they would be reluctant to sell RDTs (or would require a higher subsidy to sell RDTs) because, through RDTs, consumers may learn that prevalence is lower and thus they may demand fewer ACTs. What I want to stress is that even if monopolist sellers were uncertain whether consumers thought prevalence was higher than it actually is, the risk that they might would actually encourage monopolists to at least delay selling RDTs. Once consumers learn that malaria risk is lower than they previously thought, that belief cannot be reversed. Thus the decision to sell RDTs has real option value.

The problem is even thornier if the monopolist seller starts wondering why an NGO or the government is subsidizing RDTs. If everyone who currently sought treatment actually had malaria, then there would be no need for RDTs. RDT subsidies are only required if individuals underuse ACTs or if they overuse it. If they underuse ACTs, an alternative solution is to further subsidize ACTs. If they overuse it, the RDT subsidies are required. Thus it is plausible that sellers will infer from RDT subsidies that malaria is lower than consumers suspect. But this very signal will

[13] To be even more clear, the blame ought to be placed not on ACT or ACT subsidies but on the low price of monotherapies. It is that low price that forces the use of subsidies for ACT to reduce the rate at which antimalarials generate resistance. However, if subsidies that equate the price of ACT and monotherapies increase use, then that too will generate resistance, a negative externality.

discourage monopolist sellers from offering RDTs in their stores. The one consolation, however, is that this should not affect the behavior of competitive sellers.

Beyond this point I want to recommend some topics for future research on RDT subsidies. The model that Cohen and Dickens present is purposely simplified to convey the basic intuition behind an RDT subsidy. All the comments that follow are meant to complicate that model to make it more realistic and help craft a more appropriate subsidy.

First, and most important, the present model assumes that individuals believe the RDT works. If they are uncertain of RDT accuracy, then they will have lower demand for RDTs. This has two consequences. One is that it is important to model how individuals update their beliefs about the accuracy of tests. From Gentzkow and Shapiro (2006), we know that individuals will judge tests partly by their priors and hence will be slow to learn about the accuracy of tests—at least without successful use of antimalarials to verify tests. Another consequence is that slow learning will require higher subsidies to encourage individuals to use RDTs.

A second topic for research is whether the subsidies for RDTs are so large that firms (or consumers) will face a negative price for RDTs. That raises the problem that governments and NGOs must monitor the use of RDTs; otherwise firms or consumers will simply order and dispose or take duplicative tests just to obtain income from the subsidy. That will increase subsidy costs without benefit.

Third, the present model assumes that individuals do not currently purchase diagnostic tests. But the fact is that they do. Buying an antimalarial is also the purchase of a diagnostic test. If the antimalarial does not work, people know either the antimalarial does not work or they do not have malaria.[14] As a result, the product choice they face is not an antimalarial or a test (the RDT). Rather, it is an antimalarial with a diagnostic test or a diagnostic test by itself (the RDT). This will change the equilibrium price for antimalarials, the demand for RDTs, and the magnitude of the subsidy required for the RDT.

Finally, the present model assumes that all individuals have identical beliefs about whether they have malaria and identical valuation for a cure conditional on having malaria. Of course both values will vary among the population. As a result, sellers face a downward-sloping demand for ACTs and RDTs even among people with fevers or with malaria. So a monopolist will sell fewer RDTs than the social planner desires and fewer than a competitive firm would sell, even if there were common knowledge about aggregate malaria prevalence and no externalities from mistreatment, contrary to the conclusion at the end of Sect. 7.4.

In summary, the chapter by Cohen and Dickens in this volume, combined with the companion piece by Cohen, Dupas, and Schaner, is an important step in addressing the problem of antimalarial overuse. The lesson—RDTs must be subsidized along with ACTs—is an important one for policymakers to learn. Further work is required to fine-tune the RDT subsidy amount, but that should not detract from the main lesson.

[14] If the individual does not have malaria but infers that the antimalarial does not work, one could say the antimalarial diagnostic suffered a false negative.

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