The effect of malaria prevalence on usage of mosquito nets and ACT for children under 5 in Sub-Saharan Africa[1]

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Abstract

This paper seeks to determine, for children under the age of five living in selected Sub-Saharan African countries, the elasticity of demand for the malaria-preventive behaviors of sleeping under a mosquito net, an insecticide-treated net and when infected, the use of artemisinin-combination therapy as treatment, with respect to the local malaria prevalence. Using individual behavior and demographic information from recent Demographic and Health Surveys as well as the Malaria Atlas Project's spatial distribution of the *Plasmodium falciparum* Parasite Rate, our logistic analysis indicates the existence of prevalence elasticity, which is to say that as malaria prevalence increases, the demand for these preventive behaviors in this vulnerable subgroup of the population increases more than proportionally. In contrast to the epidemiological theory which ignores the incentivized preventive response that individuals may take when faced with an increased risk, these findings, along with evidence supporting the controlling effect that these preventive behaviors have on the prevailing prevalence of malaria as well as the current status of decline of this disease in many areas, suggest that it may be imperative for the preventive behavior response to be maintained at levels at least as high as the prevailing parasite rate to ensure a resurgence does not occur in the absence of adequate prevention.

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Introduction

During the last five years there has been significant progress in the fight to prevent avoidable deaths due to malaria in Sub-Saharan Africa. The Roll Back Malaria (RBM) Partnership estimates that 1.1 million malaria related deaths were averted during the last 10 years due to these efforts (RBM 2011). Much of the progress in reducing the malaria burden was accomplished with funding from international donors that increased from $100 million in 2000 to $1.5 billion in 2010 (RBM 2011). Two of the most important interventions to prevent and treat malaria for the most vulnerable population, children under five, are sleeping under an insecticide treated mosquito net (ITN) and prompt treatment of malaria using artemisinin-combination-therapy (ACT) (RBM 2011, WHO 2011). RBM considers ITN ownership and ACT availability to be public goods and recommends ITNs to be distributed free of charge to achieve full coverage by the end of 2010 (RBM 2011). Free access to ACT in health care facilities for those diagnosed with malaria is also recommended (WHO 2011). However, each country is responsible for designing and implementing the distribution of the resources provided to them by the international community. There is a great variation across countries on the "scaling up" of their programs to achieve universal coverage.

One of the main contributions of economics to epidemiology was to recognize the importance of changes in preventive behaviors in response to a change in the infectious disease rate. Few studies have analyzed the importance of malaria prevalence on malaria preventive behaviors taken by individuals such as sleeping under an ITN (Pattanayak et al. 2006 and 2009). If individuals' preventive behaviors are highly responsive to changes in the prevalence rate, then improvement in malaria conditions may be limited since individuals will be less likely to continue using malaria preventive interventions (should we add something here about how this is what we mean when we say it will become “increasingly expensive to control malaria”?). This is particularly of concern if funding for malaria prevention and control subsidies decline in future years as discussed in the 2011 World Malaria Report. This paper utilizes a spatial model of malaria endemicity to determine whether the prevalence of malaria appears to affect the odds of the specific malaria-preventive behaviors of sleeping under a mosquito net or an ITN and usage of ACT by children under the age of five.

We find that malaria prevalence is highly positively correlated with usage of mosquito nets, ITNs and ACT. The size of the effects suggest that the elasticity of malaria prevalence is slightly larger than one, implying that efforts to achieve continuous gains in controlling malaria will become progressively more expensive since widespread adoption of ITNs and ACT will reduce the number of vectors (mosquitoes) and infected individuals, causing a reduction of malaria cases. However, in future periods, malaria prevalence will affect the decision of sleeping under an ITN or ACT treatment.

Methods

The behavioral and demographic data for this analysis come from the Demographic and Health Surveys (DHS), Malaria Indicator Surveys (MIS) and AIDS Indicator Surveys (AIS) for 11 countries in Sub-Saharan Africa between 2008 and 2011. The Demographic and Health Survey's goal is to monitor the population and health situations of the target countries and it is part of the Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) project. DHS data contain detailed information on health and preventive health behaviors for children, women and men. Starting in 2000, DHS began collecting information on the ownership and use of mosquito nets, including whether the net owned and used is an ITN, and ACT treatment of fever for children. The Malaria Indicator

Survey (MIS) and AIDS Indicator Survey (AIS) are also part of the MEASURE DHS project. Fortunately, DHS, AIS and MIS pose the same basic malaria questions, making comparisons between and within countries using the various surveys straightforward.

DHS/MIS/AIS samples are nationally representative of the population, but they are drawn from geographical clusters. Clusters vary in size and population but typically contain around 500 individuals. In rural areas a cluster is usually a village or group of villages and in urban areas it is approximately a city block. For many surveys DHS includes the latitude and longitude of the centroid of the cluster. Using this latitude and longitude we were able to "geocode" the DHS/MIS/AIS clusters into the Geographic Information Systems (GIS, ESRI's ArcMap) mapping software. We then merged this information with the 2010 Malaria Atlas Project (MAP) *Plasmodium falciparum* Parasite Rate (PfPR) database (Hay et al., 2009). The PfPR is an age-standardized measure of the proportion of people sampled (children between the ages of 2 and 10) showing detectable parasites in the peripheral blood. This is an objective and common index of malaria transmission intensity and will be our main explanatory variable, the measure of the malaria prevalence in the cluster where the individual lives. See Hay et al. for a description of the calculation of this index.

Our sample consists of all children less than 5 years of age for which we have information on malaria preventive behaviors from the DHS/MIS/AIS surveys. We restrict the analysis sample to post-2008 years and surveys that we were able to merge with MAP leaving us with 12 surveys in 11 countries which are described in Table 1.   There is great variation in the mean of our measure of malaria intensity (PfPR) across countries where average malaria prevalence ranges from 0.096 to 0.473. Only post-2008 survey years were included to reduce the probability that widespread ITN usage for a long period of time reduced the PfPR measure in

2010 (elaborate? Is this the first time we address the relationship going the other direction (i.e. prevention→malaria prevalence)? Saying that the 2010 PfPR might be representative of preventive behaviors of the past (i.e. pre-2008) so only more recent past (i.e. post-2008 years) to reduce the likelihood of reverse causality?). However, an analysis including pre-2008 surveys does not change the reported conclusions (true, right?).

Our dependent variables are binaries indicating: 1) whether the child slept under a mosquito net the previous night, 2) whether the child slept under an insecticide-treated mosquito net the previous night and 3) whether a child who had a fever during the previous 2 weeks before the survey received ACT treatment. We estimate logit models and report the odds ratio. Sleeping under an ITN is the most cost-effective intervention to prevent malaria in Sub-Saharan Africa and in 2008 World Health Organization (WHO) recommended that all children under the age of five should sleep under an ITN (Roll Back Malaria 2008). Prompt treatment of fever for children under 5 with malaria using ACT is also one of the main policy recommendations of WHO.

The main explanatory variable in our analysis is the PfPR for the cluster where the child lives. This is our measure of malaria prevalence and, in agreement with the epidemiological economic theory, we expect this variable to have a positive effect on all of our dependent variables which represent demand for prevention. Other explanatory variables include whether their mother has obtained at least secondary education, mother's age, age of child, gender, whether the child is the child of the head of the household, household size, whether the house has piped water, household wealth in quintiles, whether the individual has a car or truck and whether the house is located in an urban environment. If better-educated mothers are more likely to be informed of and value the benefits of these interventions, mother education should be positively correlated with each of our dependent variables.. We expect the child's age to have a negative sign since the risk of dying for malaria decreases with the age of the child. Household size should proxy competition for resources and we expect it to have a negative effect on sleeping under a net. In addition to households in which existing children are the biological children of the head of household, extended households are also prevalent in sub-Saharan Africa. Extended households may include as children the biological grandchildren of the head of household or cousins of the biological children of the head, for example. The child of head variable measures whether there is preferential treatment toward the biological children of the head of the household. Finally, wealth, piped water, and having a car represent availability of resources in the household where the child lives and we expect these variables to have a positive effect on prevention.

We also control for country, year and month of the interview fixed effects. There is great variation in the malaria control policies across countries and years. For example it is not yet national policy for Uganda and Mali to distribute ITNs or LLINs (long-lasting insecticidal nets) to all age groups regardless of risk whereas in Nigeria this is national policy (WHO “country profiles”). The fixed effects will control for these variations. Month of the interview will control for differences in temperature and rainfall that affect the number of mosquitos and therefore the risk of malaria at the time of the interview.

Results

Despite the 2008 WHO recommendation that all children under 5 sleep under an ITN, in our sample of xxx children, only 42% slept under any net (treated or untreated) and 32.5% slept under an ITN (Table 2). These numbers are well short of universal usage. It is worth noticing that 62% of children in our sample live in households (mean size 7.65 people) that have at least one mosquito net and 16.5% of children who had a fever during the 2 weeks prior to the survey took ACT. Most children live in areas where the prevalence of malaria is very high (the mean of PfPR is 0.336). 7.5% have piped water in their house, 23% live in urban areas and only 20% of the mothers complete secondary education.

Table 3 presents the results of the logistic model in the form of odds ratios. The coefficient on PfPR is greater than one and statistically significant for all of the specifications. With relatively large effects,it is the main predictor for all of the dependent variables.. An increase of 10 percentage points in PfPR increases the odds of a child sleeping under a net by 16% and sleeping under a treated net by 15% (OR 1.16 and 1.15, respectively). If there is no reverse causation or omitted variable bias, these results imply that the prevalence elasticity for sleeping under a net or an ITN is elastic. To acknowledge the possibility that in the previous analysis some households may not utilize a net simply because they do not own one or one is otherwise unavailable to them, we also estimate the model with a restricted sample of only those families who have a net. For this specification, a 10 percentage point increase in PfPR remains a positive influential factor on the odds a child sleeping under a net but now implies a less than proportional increase in the odds ratio (OR 1.09). Similarly, a 10 percentage point increase in PfPR increases the odds of a child with a fever in the previous two weeks having ACT by 12% (OR 1.12).

In general the other explanatory variables have the expected sign and they are significant. Whether the child’s mother has at least secondary level education increases the odds of a child under five sleeping under a net (OR 1.10) and sleeping under an ITN (OR 1.11). However, conditional on owning a net, a mother’s educational attainment appears not to have an effect on a child sleeping under a net, which could indicate that the effects of a mother’s education on net-prevention behavior are potentially somehow related (perhaps through wealth) to access to resources or, more specifically, mosquito nets. A child of the head of household is more likely to use a mosquito net the previous night for all net-behavior specifications, but this relationship has no impact on the odds of ACT uptake. For all net-related preventive behaviors (but not ACT uptake) household size is statistically significant, decreasing the odds of mosquito net prevention by children. As limited availability of sufficient nets is likely to pose an issue for households of more members, these results are not surprising.

For children under the age of five, age is shown to decrease the odds of sleeping under a net, whether conditional on owning a net or whether, for all households, the net is treated or untreated (OR 0.97, 0.90 and 0.96, respectively) indicating that as children develop immunity they are less likely to sleep under nets. Conversely, age increases the odds of those children having a fever taking ACT (OR 1.12), perhaps because older children are more able to identify and communicate their symptoms. Compared to being a female, being a male decreases the odds of a child sleeping under an ITN (OR 0.97) and being male also decreases the odds of a child sleeping under a net conditional on owning one (OR 0.97). Child's gender does not appear to be influential in the all-household sample for the behaviors of child slept under a net the previous night or child with a fever took ACT indicating gender equality in these preventive behaviors among children. ACT behavior is influenced by whether the household has a car or truck, increasing the odds of uptake (OR 1.52) while car or truck ownership has no effect on net-related prevention methods. This is likely due to the widespread distribution and availability of mosquito nets whereas ACT uptake occurs at clinics in which case transportation may be necessary.

Discussion

Malaria prevalence, as measured by the PfPR 2010 estimates from the Malaria Atlas Project, appears to be the main predictor of the primary malaria prevention behaviors practiced by children under five including usage of mosquito nets and uptake of ACT when necessary. This implies that children with the highest risks of contracting malaria are more likely to use malaria preventive measures, and consistent with the main predictions of the theory of economic epidemiology, individuals respond rationally to changes in malaria prevalence or intensity. However, malaria-preventive behaviors, such as the use of ITNs, will also affect malaria prevalence over time. For example, Lengeler finds that in areas of stable malaria, compared with absence of mosquito nets, usage of ITNs has 13% protective efficacy on the parasite prevalence (2004). So as improvements are made regarding malaria control and eradication and as malaria prevalence declines, it may be necessary to establish a plan to ensure that the preventive behaviors do not diminish more quickly than the prevalence rate. Otherwise the gains in controlling malaria will be difficult to sustain. Policy makers need to understand that achieving and maintaining the Millennium Development Goal 6 of reducing malaria child mortality to near zero by the end 2015 will be progressively more expensive.

There are several caveats that we must acknowledge. First, ITN usage is highly correlated with net ownership, which is a function of country specific policies on distribution of nets. Although, the goal of the Roll Back Malaria Partnership is to achieve universal coverage it is likely that areas with higher prevalence of malaria received more resources earlier. We have addressed this problem by including country and year fixed effects to our specifications. Thus we control for differences in resources across countries at the time of the survey. We estimated a specification using only children who live in households that have at least one ITN and obtain similar results. Second, the measure of malaria prevalence, PfPR endemicity from the Malaria

Atlas Project, provides a single value for a given location that originates from generally sparse and clustered data throughout Africa in a Bayesian geostatistical framework (Patil et al. 2011). Thus, while this measure of malaria prevalence is arguably the best data available, it is not without consideration that the true measure of malaria prevalence for any given location may vary even significantly at any given time from the value used in this analysis.

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Table 1 - Description of Data

Country	Survey	Number of Clusters	Range of PfPR
Angola	MIS 2011	239	[0, .6221527]
Ghana	DHS 2008	411	[0, .6874862]
Kenya	DHS 2008-09	400	[0, .6550676]
Liberia	MIS 2009	156	[0, .6040976]
Madagascar	DHS 2008-09	598	[0, .6389704]
Malawi	DHS 2010	849	[0, .64401543]
Mali	Special 2010	109	[0, .7113904]
Nigeria	DHS 2008	1125	[0, .7131584]
	MIS 2010		[0, .6692404]
Senegal	MIS 2008-09	330	[0, .4481814]
Tanzania	DHS 2010	484	[0, .6267124]
Uganda	MIS 2009	170	[0, .6463038]

TABLE 2 - DESCRIPTIVE STATISTICS

	Mean	(Standard Dev.)
Dependent		
Child slept under net	0.420	(0.493)
Child slept under ITN	0.325	(0.468)
Child took ACT	0.165	(0.371)
Independent		
PfPR	0.336	(0.192)
Age (child)	2.011	(1.423)
Gender	0.504	(0.500)
Household size	7.656	(4.999)
Household wealth	2.729	(1.392)
Water in household	0.074	(0.262)
Owns car/truck	0.042	(0.201)
Urban residence	0.229	(0.420)
Child of Head	0.762	(0.426)
Mother's age	28.811	(7.011)
Mother's education	0.199	(0.399)

TABLE 3 - DETERMINANTS OF NET USAGE AND ACT UPTAKE BY CHILDREN - LOGIT

	Child slept under net		Child slept under ITN		Child slept under net (conditional)		Child took ATC	
PfPR 2010	1.1637	***	1.1447	***	1.0908	***	1.1159	***
	(0.01)		(0.01)		(0.01)		(0.01)	
Age	0.9556	***	0.8960	***	0.9737	***	1.1179	***
	(0.00)		(0.00)		(0.01)		(0.01)	
Male	0.9792		0.9728	*	0.9673	*	1.0328	
	(0.01)		(0.01)		(0.02)		(0.03)	
HH size	0.9870	***	0.9738	***	0.9671	***	0.9945	
	(0.00)		(0.00)		(0.00)		(0.01)	
HH has water	1.0982	***	1.1405	***	1.1438	***	0.8429	*
	(0.03)		(0.03)		(0.04)		(0.07)	
HH wealth	1.1179	***	1.1082	***	1.0395	***	0.9939	
	(0.01)		(0.01)		(0.01)		(0.01)	
HH has car/truck	0.9961		0.9605		0.8903		1.5193	***
	(0.04)		(0.04)		(0.04)		(0.15)	
Mother's education	1.1037	***	1.1150	***	1.0080		1.0704	
	(0.02)		(0.02)		(0.03)		(0.06)	
Mother's age	0.9959	***	0.9949	***	0.9997		0.9997	
	(0.00)		(0.00)		(0.00)		(0.00)	
Child of HH Head	1.6661	***	1.5211	***	1.7301	***	0.9596	
	(0.03)		(0.03)		(0.04)		(0.05)	
Urban residence	0.9985		0.9897		1.1102	****	1.4892	***
	(0.02)		(0.02)		-0.0282		-0.0823	
Observations	123,129		123,123		76,135		29,700	
Pseudo R-squared	0.1374		0.1213		0.0868		0.1571	

Odds ratios reported.