Economic Burden of Malaria on Subsistence Crop Production in Kenya

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Abstract

Background: The global economic, health and social impact of malaria is profound, and Sub-Saharan African countries bear the greatest burden. In Sub-Saharan Africa, the disease accounts for 90% of deaths. In endemic countries, malaria is responsible for a loss of US$ 12 billion in national income due to the impact of morbidity and mortality on labour supply. In Sub-Saharan Africa, malaria affects mostly women and children. Given that women form the majority of households engaged in agriculture, the impact of the disease can be substantial. In Kenya, malaria is the leading cause of morbidity, accounting for 19 per cent of hospital admissions and 50% of outpatient cases in public health institutions. In addition, close to 170 million working days are lost annually in Kenya due to malaria. There is however no evidence of the economic burden of the disease on farm production in Kenya. The objective of this study was to estimate the economic burden of malaria at the household level, and simulate economic effects of malaria.

Methods: The analysis was based on data drawn from Welfare Monitoring Surveys conducted by the Government of Kenya. The data provided information on individual and household socio-economic characteristics, farm level production and community variables such as distance to the nearest health facility, and time taken to collect water and firewood. Two analytic samples were constructed, a full sample comprising households inflicted with malaria and other diseases and a sub-sample of healthy individuals and those having malaria. The analytical samples of crop production were derived from the full probability samples of 59,183 and 47,684 individuals for 1994 and 1997, respectively.

Results: The results based on OLS and 2SLS estimation methods found the coefficient on malaria to be negative and statistically significant at the 1% level. The OLS results showed that a 10% level increase in malaria prevalence would result in a 2.76% reduction in crop output, while a 10% level increase in the prevalence of other diseases reduces crop output by 0.18. Using the 2SLS estimation method, the coefficient on malaria was -4.24 for 1994 and -4.22 for 1997 among households which had suffered from malaria two weeks prior to the survey relative to the crop output in households which had not suffered from malaria. This translates to a loss of 69% and 67% in crop production for 1994 and 1997 sub-samples respectively. This finding suggests that malaria places an economic burden on agricultural production, regardless of whether or not a member of the household actually suffers a malaria episode.

Conclusion: Households are likely to lose a significant proportion of their crops if a member of the household suffers from malaria at certain periods in the agricultural cycle. However, investments in malaria control programmes have large economic returns because they make an immediate contribution to production by increasing the quantity and quality of labour, primarily through reductions in morbidity, debility, and absenteeism from work.

Background

Malaria remains one of the most devastating parasitic diseases in the world and contributes considerably to the poor health situation in Africa [1, 2, 3]]. The global incidence of the disease is estimated at 350 to 500 million clinical cases annually, resulting in 1.5 to 2.7 million deaths each year in sub-Saharan Africa [4]. More than 90 percent of deaths from malaria occur in Africa, where 45 of the 53 countries are endemic for the disease. Malaria endemic countries lose billions of dollars in national income due to the impact of morbidity and mortality from malaria on labour supply [5, 6, 7, 8, 9, 10, 11]. The disease imposes substantive social and economic costs and impedes economic development through several channels, including loss of labour productivity, depletion of human capital, premature deaths, medical costs and reduction in saving and investment [7, 12, 13]. The disease costs Africa more than US$12 billion annually, and it slows economic growth in many African countries by as much as 1.3 percent per year [5].

Although malaria affects all the people, the effect is severe among pregnant women and young children because of their low or non-existent immunity to the disease. Thus, the potential impact of malaria for women engaged in smallholder subsistence agriculture can be substantial. In Africa, women account for about 70 percent agricultural workers and 60 to 80 percent of those producing food crops for household consumption and sale [14]. Given that over 80 percent of the continent's population lives in the rural, the effects of malaria on agriculture, health, and development are widespread.

The disease imposes substantive social and economic costs to poor, rural farmers for preventive measures and treatment. In Malawi, the total annual cost of malaria among the low-income households was estimated at US dollars 24.89, which is equivalent to 32% of household income. Leighton and Foster (1993) found that total household malaria burdens amounted to 9-18% of annual income for small farmers in Kenya, and 7-13% in Nigeria. The total annual value of production loss due to malaria was estimated to be 2-6% and 1-5% of GDP in Kenya and Nigeria respectively [15]. The burden is similar in other countries. Recent estimates of the economic burden of malaria by means of cross-country regression analysis revealed that malaria endemic countries grew on average at 1.3% less per capita, than those without malaria problem. A 10% reduction in malaria appears to boost growth by 0.3% per annum [16]. Thus, eliminating malaria as a constraint could free resources for household productivity and local development.

In Kenya, malaria remains the leading cause of morbidity and accounts for 19 per cent of hospital admissions and between 30-50% of outpatient cases in public health institutions [17]. It is also the leading cause of mortality in children under five years, a significant cause of adult mortality, and the leading cause of workdays lost due to illness [17]. It is responsible for an annual loss of 170 million working days [15], a situation that seriously affects agricultural production and livelihoods of rural farmers since the majority of the days lost due to illness are in agriculture. However, despite its devastating health effects, evidence of the economic burden of the disease on farm production in the country remains largely unknown. Furthermore, since in the absence of a malaria vaccine, prevention and treatment remain the only ways of controlling malaria, an effective control programme requires a clear understanding of the economic burden of the disease to guide resource allocations across the various control activities of the programme. The objective of this study was to estimate the economic burden of malaria at the household level, and simulate economic effects of malaria control investments on farm output in Kenya.

Methods

Conceptual framework

Poor health has been observed to impose sizable economic burden on households [6, 2, 7, 8, 9]. Evidence suggests that illness affects farm production by reducing household's labour supply and the household's ability to effectively utilize resources [18]. The effect is higher among poor households who spend a significant proportion of their income on medical expenditures, and are less able to rely on employed labour, thus reducing farm output significantly.

According to [19], labour is a key input that determines the quantity of output that can be produced with a given technology. Other things being equal, the greater the quantity of labour, the larger the volume of crop output produced. However, poor health or premature mortality due to malaria may have a substantial negative effect on productivity of households if the disease reduces the labour supply [20, 21, 8, 9, 12, 13, 10, 11, 15, 18.]. Malaria morbidity in contrast reduces crop production by increasing absenteeism from farm activities, and by reducing work capacity or effort of household members [23, 24, 9, 8, 22].

According to [25], farm production is related to health status in that morbidity may affect production unless a member of the household adequately compensates for the loss of labour. Malaria risk influences production both through ex-ante crop choice decisions as well as labour productivity. Our hypothesis in this paper is that households living in malaria-endemic regions in the country are more likely to experience significant reductions in crop production that require labour inputs during the planting or harvesting season than the household living in areas with low malaria risk.

Econometric specification

Given that the main focus of this study is to estimate the economic impact of malaria on farm production, we estimate a model of agricultural production. The general functional form of the production function used in estimating the impact of malaria is specified as follows:

$$Q = F(X,M,Z,\varepsilon_1) \qquad [1]$$

Where
Q = Value of agricultural output in Kenya shillings;
X = Vector of quantities of physical inputs such as land holding and fertilisers;
M = Malaria prevalence or malaria episode;
Z = Vector of variables that characterize the individual household such as age, sex, marital status, household size, and occupation;
ε = represents factors that are known to the household but are not measured in the survey and, hence, unobserved by the analyst.

Most existing studies of the economic impact of illness in general, and the impact of illness on agriculture in particular have tended to ignore the effect of government policies on malaria prevention and treatment in mitigating the impact of malaria on agricultural production. Yet, there is evidence that prevention measures aimed at reducing malaria such as early diagnosis and treatment with effective antimalarials, strengthening of local capacity to fight the disease, use of insecticide treated bed nets and selective residual spraying; and prediction and containment of epidemics can reduce the economic impact imposed by malaria on crop production . In this paper, we explore the effect of education and government expenditure on prevention and treatment measures in mitigating the economic burden imposed by malaria on farm production. Education, as a direct tool for transmission of health information, can induce a change in people's behaviour with regard to prevention and hence mitigate malaria impact by enabling individuals and households to use malaria prevention measures [26, 8]. We use a simple production function shown in equation 2.

$$Q = \alpha + X\beta + \theta M + \varepsilon \qquad [2]$$

where

Q is the value of farm production in Kenya shillings, α is the intercept showing the farm output level which is not influenced by malaria and other explanatory variables, β represents the effect of other factors that influence farm production such as household and individual characteristics, and ε is the unobservable random disturbance term. The coefficient of interest θ, measures the effect of malaria on farm output. Assuming the other factors that affect crop production are constant, equation 2 shows the effect of malaria on farm production. Based on the literature, the effect of malaria is negative, implying that farm production is lower if a member of the household suffers malaria. Taking malaria to be a discrete variable that is, taking the value of 1 if a member of household reported malaria two weeks prior to the survey and 0, otherwise, the predicted farm production function is then expressed as:

$$\hat{Q} = \alpha + X\hat{\beta} + \hat{\theta} \qquad [3]$$

Equation [3] shows predicted crop production conditional on the household and individual characteristics and malaria prevalence. If no household member suffers from malaria illness (i.e. M = 0), then we would expect crop production to be higher.

In order to examine whether education and government health and malaria program expenditures mitigate the impact of malaria on crop production, we two interaction terms malaria*education and malaria and expenditure (malaria*expenditure). Including the interactive terms, equation [2] becomes:

$$Q = \alpha + X\beta + \theta \cdot M + \delta G + \varphi(M \cdot G) + \varepsilon \qquad [4]$$

Where, G is government health and malaria program expenditures. Assuming malaria is a dummy variable taking the value of 1, equation [4] is then expressed as:

$$Q = (\alpha + \theta) + X\beta + (\delta + \varphi)G + \varepsilon \qquad [5]$$

If δ > 0, then it implies that government expenditure on malaria control measures and treatment mitigate the negative effect of malaria on crop production. Because it is complementary with other inputs such as feeder roads built to help control malaria, government expenditure might also make schooling better. If on the other hand φ > 0, then government expenditure reduces intensity of malaria infection and also helps cultivation of new land, thus increasing output. The economic burden of malaria was estimated using the following expression:

$$\Psi = [\exp(\hat{\theta}) - 1] \cdot 100 \qquad [6]$$

Where ψ is the economic burden of malaria and represents the percentage decline in Farm production due to malaria. The parameter “theta hat” in the equation is normally negative.

Given that economic theory does not provide much guidance on model specification, the choice of explanatory variables in the current study was guided by the past similar studies. Based on these studies, the apriori expected effects of the explanatory variables assumes the signs indicated in appendix 2.

Data

The analytic samples for the empirical analysis were derived from the full probability samples of 59,183 and 47,684 individuals for 1994 and 1997. Two analytic samples were constructed. A full sample comprising households inflicted with malaria and other diseases and a sub-sample of healthy individuals and those having malaria and for which data on relevant variables used in the estimation was available. In constructing the analytic samples, individual data sets were merged with the corresponding data sets containing household characteristics. Two indicator variables for malaria were constructed. A continuous variable showing the proportion of household members who reported having contracted malaria two weeks preceding the survey and a dummy variable for individuals reporting having contracted malaria two weeks before the survey, taking the value of 1 if a household member reported having contracted malaria and zero otherwise.

Because of endogeneity of malaria, two instruments for malaria were used, time taken to the river during the wet and dry seasons and time taken to reach the source of firewood to instrument malaria. Time taken to the river and the time taken to collect firewood is expected to directly expose household members to the risk of contracting malaria, without affecting the outcome variables, namely, farm output. In addition, two interaction variables, malaria interaction with education, and malaria interaction with government expenditure were constructed to assess their effects in mitigating the economic burden of malaria. The estimation of the economic burden of malaria on crop production was done using ordinary least squares (OLS) and the Two-Stage Least Squares regression methods (2SLS). In estimating the crop production function, we first predicted malaria using all the explanatory variables in equations [1]. The first stage is the reduced form equation for malaria. The predicted value of malaria was then used in the second analysis in place of the actual malaria.

Results

Descriptive statistics

Table 1 presents the frequency and percentage distribution of the dependent and independent variables. Overall, the prevalence rate of malaria was 13.6% for 1994 and 7.8% for 1997. The prevalence rate for other diseases was 14% and 8% for the two years. The mean age of the household head was 45 years and 30 years in 1994 and 1997, respectively while the average household size for 1994 and 1997 was 5.5 and 5.2 persons, respectively. Approximately 42% and 50% of household heads had primary level education in 1994 and 1997, respectively. About 18% of respondents in the 1994 sample had some secondary education while another 37% had no education at all. Only 0.4% of the respondents had tertiary education. Similarly, for the 1997 sample, 10% had secondary education whilst about 0.2% and 0.3% had tertiary and university education, respectively.

Table 1: Frequencies and percentages for explanatory variables

	1994			**1997**		
Variable	Observations	Mean	SD	Observations	Mean	SD
Malaria prevalence	7161	0.136	0.233	6566	0.078	0.157
Prevalence of other diseases	7161	0.141	0.236	6566	0.082	0.275
Age in years	7161	45.3	14.7	6566	30.5	16.6
Household size	7161	5.56	2.91	6566	5.27	2.68
Fertilizer use (1 = use)	7161	0.298	0.457	6566	0.421	0.493
Log crop production	6984	9.25	1.39	6566	7.47	2.40

Education (Years of schooling)	7161	6.49	11.2	6566	4.70	3.87
Pre_primary (=1)	7161	0.004	0.065	6566	0.052	0.222
Primary (=1)	7161	0.420	0.493	6566	0.501	0.500
Secondary (=1)	7161	0.182	0.386	6566	0.100	0.301
Tertiary (=1)	7161	0.018	0.135	6566	0.001	0.042
University (=1)	7161	0.004	0.065	6566	0.002	0.052
No education at all (=1)	7161	0.369	0.482	6566	0.340	0.473
Time taken to water source during wet season (minutes)	7161	24.6	28.2	1815	24.8	14.7
Time taken to water source during dry season (minutes)	7161	43.3	70.3	1815	32.3	18.5
Time taken to collect firewood (Minutes)	7145	62.3	74.5	…	…	…
Average rainfall (mm)	7161	1175	383	6566	0.638	0.480
Agricultural land in acres	7145	5.49	38.7	6566	4.02	11.79
Gender (1=male)	7161	0.727	0.445	6566	0.484	0.499
Experience in crop production (years)	6981	17.6	13.1	6566	28.7	41.4
Area of residence (=1 rural)	7161	0.967	0.177	6566	0.975	0.154
Log expenditure	6980	2.53	0.918	6566	14.82	1.45
Malaria*schooling (primary)	7161	0.054	0.226	6566	0.042	0.073
Malaria*schooling (secondary)	7161	0.023	0.150	6566	0.357	0.986
Malaria*expenditure	7161	44.4	297	6566	1.163	2.323
Central province (=1)	7161	0.173	0.378	6566	0.176	0.381
Coast province (=1)	7161	0.061	0.240	6566	0.087	0.282
Nyanza province (=1)	7161	0.210	0.407	6566	0.198	0.398
Rift valley province (=1)	7161	0.245	0.430	6566	0.259	0.438
Western province (=1)	7161	0.122	0.327	6566	0.108	0.311
Eastern province (=1)	7161	0.167	0.373	6566	0.169	0.375

Regression analysis

Table 2 presents the OLS and 2SLS coefficients, and't' test values. The t-test is used to test the hypothesis (i.e. H0: β = 0) about individual regression slope coefficients. The't' values for individual variables are obtained by dividing their coefficients (e.g. βmalaria) by their standard errors (e.g. SEmalaria). For the 1994 data, the results show that, if other explanatory variables are held constant, a 10% level increase in malaria prevalence would result in a 2.76% reduction in crop output, while a 10% increase in the prevalence of other diseases reduces crop output by 0.18%. Similarly, for the 1997 sample, an increase in the proportion of household members afflicted by malaria by 10% was associated with a decline of 4.3% in crop production. The coefficient on other diseases for both 1994 and 1997 is negative and is statistically significant at the 10% level for the 1994 sub-sample.

Estimates based on the 2SLS method are reported in columns (3) and (4) of Table 2. In column (3), the coefficient on malaria for 1994 is -4.249 in households which had suffered from malaria two weeks prior to the survey relative to the crop output in households which had not suffered from malaria. This translates to a loss of 69%1 in crop production for that year. In column (4), reduction in the log of crop production is 4.22. This is equivalent to a loss of 67% in crop production. These results imply that households were likely to lose a significant proportion of their crops if a productive member of the household suffered from a bout of Malaria. This is largely because household members spent time taking care of the sick relatives and therefore have little time to engage in active farming. Crop production losses can be large if malaria in the household coincides with critical farming activities such as planting, weeding or protecting crops from predators.

The coefficients on secondary education and technical education are positive and statistically significant at the 1% level. The coefficients indicate a positive association between crop production and schooling. This implies that relative to an identical household where the head had primary education, a household where the head had secondary education had higher farm output in 1994 and in 1997. Specifically, the logs of farm outputs were 0.176 and 0.344 higher in 1994 and 1997, respectively. Similarly, relative to a household where the head of household had primary education, a household where the head had university education had 0.22 higher logs of farm outputs in 1994. However, when estimated using IV estimates (column 3), the effect of university education on crop production is lower in both 1994 and 1997 than that associated with secondary education. The most plausible reason for this finding is that households with tertiary or university education are unlikely to pay sufficient attention to subsistence farming, as they prefer non-agricultural jobs to farming.

For comparison purposes, a regression based on a sub-sample of healthy households merged with a sub-sample of households with members suffering from malaria was estimated. In this sample, the labour substitution possibilities exist between healthy and sick family members. The malaria regressor was defined as a dummy variable taking a value of one for all individuals reporting malaria illness. The regression provides additional information on the extent of the economic burden imposed by malaria among households suffering from malaria. The results are reported in Tables 3 and 4 for the 1994 and 1997 sub-samples respectively.

For the 1994 data, the coefficient on malaria dummy (based on the OLS estimation method) is negative and statistically significantly at the 10% level. The coefficient on other diseases is negative as predicted. The negative coefficients imply that households inflicted with malaria and other diseases are less productive compared with healthy households. That is, households afflicted with malaria have lower crop output compared with households not afflicted with malaria. In particular, our estimates show that the log of crop output was lower by 0.075 and 0.053 (for the 1994 and 1997 sub-samples respectively) for households who experienced an episode of malaria compared to the crop output of healthy households. That is, household inflicted with malaria lose about 0.07% of crop output relative to healthy households. The log of crop output obtained using 2SLS method is -2.735 for 1994 and -1.182 for 1997 (Table 3). The results show that the reduction in crop output among households inflicted by malaria was 14.4% and 2.3% for 1994 and 1997 respectively relative to healthy households.

1 According to Halvorsen and Palmquist, (1990), the coefficient of a dummy variable, multiplied by 100, is equal to the percent effect of that variable on the variable being examined. The coefficient of a dummy variable measures the dichotomous effect on the dependent variable. The relative effect on the dependent variable is $\Psi = \exp^{\beta} - 1$, and the percent effect is equal to $100 \cdot \Psi = 100 \cdot (\exp(\beta) - 1)$.

In order to determine whether education and government expenditure mitigate the negative impact of malaria, we added two interaction terms--the interaction between malaria and education and the interaction between malaria and government expenditure on malaria control programmes and treatment. The results are presented in table 4. If education and government health and malaria program expenditures mitigate the negative impact exerted by malaria then we expect the coefficients for the interaction terms to be positive. This is because educated individuals are better able to adopt preventive measures in ways that protect them from diseases compared to the less educated ones. Similarly, evidence from a number of studies has shown that government expenditure in malaria control programmes significantly reduces the malaria intensity and, in turn raises labour productivity (8, 26].

As hypothesised, the coefficients on interaction terms (Government expenditure *malaria and malaria * education) have the expected positive sign. The coefficient on the interaction between malaria and expenditure is positive (0.0002) and statistically significant at the 1% level. Similarly, the coefficient on the interaction between malaria and education is positive but statistically insignificant. Including the two policy variables reduces the negative effect of malaria from -0.325 to -0.2948 or by 9.2%. The interaction term of malaria and education reduces the log of crop output from - 1.173 to -0.884 (equivalent to a loss of 1.4% in crop production). These findings strongly suggest that investment in malaria control activities and in education mitigate the economic impact of malaria. Our results support the argument by [9] and [8] that investment in government expenditure on preventive measures such as early diagnosis and treatment with effective anti-malarials, strengthening of local capacity to fight the disease and use of insecticide treated bed nets is a viable strategy to mitigate malaria burden. Further, the reduction in the prevalence of malaria over time increases productivity levels for crop production. This is consistent with the observed strong and positive correlation between the interaction terms and crop production.

The remaining regressors are rainfall, time taken to the nearest health facility, fertiliser use, soil conservation and regional dummies. The coefficient on rainfall is positive and is statistically different from zero for 1994 and 1997 sub-samples [Table 3]. The coefficient on time taken to a health facility is negatively correlated with crop production regardless of the estimation method. Time taken to the health facility is used as a proxy for the price of malaria treatment. The negative effect of time taken to the dispensary suggests that households with a sick member reduce the amount of time spent on farming to obtain care for the sick member.

The coefficients on the regional dummy variables for 1994 sample have the expected signs and are statistically significant. For example, the coefficients on dummies for Eastern, Western and Nyanza provinces are negative and statistically significant at the 1% level, implying that the Rift Valley province, the omitted province, exhibits higher crop production. The results show that crop production was lower by 3%, 6.6% and 4.9%, respectively in Eastern, Western and in Nyanza provinces relative to Rift Valley (Rift Valley province is the reference region). Although not statistically significant, the negative coefficient on the Central Province dummy further shows that crop production in the Rift Valley is higher relative to crop production in Central Province. We can however speculate the reasons for this. The first one is that Rift Valley is an agricultural area and the environment is ideal for large scale farming. Second, it is possible that the effect of malaria on labour productivity is lower, perhaps, due to low malaria intensity, or due to labour substitution. Similar results are obtained for the 1997 sample, except that the coefficient on the dummy for Nyanza Province turns out to be positive and statically significant at the 1% level.

Discussion

The results have shown that malaria exerts a significant negative impact on crop production. This implies that households inflicted with malaria and other diseases are less productive compared with healthy households. In particular, the estimates have shown that crop output was lower for households who experienced an episode of malaria compared to the crop output of healthy households. The loss in crop production is largely explained by loss of productive time by the sick relative and the time spent by household members taking care of the sick relatives and therefore has little time to engage in active farming. Loss of labour time due to illness implies lower farm output and reduced household capacity to earn income at a time when it needs additional income to pay for medical expenses. Malaria morbidity also reduces output by increasing absenteeism from work, and by reducing work capacity or efficiency of individuals, leading to a decrease in hours worked [10, 7, 8, 23].

The results have shown the role that government health and malaria program expenditures and education can play in mitigating the negative effect of malaria. Based on the results, more educated individuals are better able to adopt preventive measures in ways that protect them from diseases compared to the less educated ones. This finding is consistent with similar studies which show that government expenditure in malaria control programmes significantly reduces the malaria intensity and, in turn raises labour productivity [8, 26].

Conclusion

The evidence arising from this study is that the impact of malaria on crop production was higher among the inflicted households than among the healthy households. Due to reduction in labour productivity, household incurred a loss of almost 70% in crop output in 1994 and 67% in the 1997 sample. The loss in crop output due to malaria was higher than the loss due to other diseases. This shows that households are likely to lose all their crops if a member of the household suffers from malaria at certain periods in the agricultural cycle. Based on the results, there is clear evidence in support of the hypothesis that government investment in malaria control programmes and in schooling mitigates the economic burden of malaria.

Policy implications of this study

In order to increase crop productivity in malaria endemic areas in the country, it will be necessary for the government and other stakeholders to put in place effective malaria control programmes in place. Malaria control can be economically beneficial because these measures make an immediate contribution to output by increasing the quantity and quality of labour, primarily through reductions in morbidity and debility, and secondly through reductions in mortality. The benefit from malaria control should therefore be a motivating factor for the government and development partners to inject additional resources in malaria control.

Since the majority of the Kenyan's population live in the rural areas and work in the agricultural sector and suffer disproportionately from related illness and disease, increased public education awareness about the disease transmission and on prevention measures is necessary to promote agricultural growth, reduce pervasive rural poverty, and improve well-being. Public health interventions which decrease the households' risk of contracting malaria will improve labour productivity and result in higher output levels. Furthermore, improvement in health infrastructure will particularly reduce the susceptibility of low income households to malaria shocks.. With sufficient preventive care and mosquito control, it will be possible not only to reverse the loss of health and productivity but also empower households to purchase adequate preventive measures as well as seek treatment on their own.

Overall, government policies should focus on: (i) improving public education on the importance of seeking prompt treatment and on prevention measures; (ii) increasing budget allocation for public health education campaigns; and (3) improving incomes of people living in malaria prone areas will empower people in high malaria transmission zones to embrace measures aimed at reducing malaria transmission and in doing so reduce the economic burden of malaria and reach a higher standard of living.

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Appendix 1

Table 2: Regression results of the impact of malaria on crop production, 1994. (Dependent variable = log (value of crop output), standard errors are in parentheses).

	OLS Estimates				2 SLS Estimates			
Explanatory variables	(1)		(2)		(3)		(4)	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Malaria Prevalence	-0.276 (0.071)	-3.88***	-0.158 (0.073)	-2.17**	- 4.249 (1.972)	-2.15**	-4.22 (6.505)	-0.65
Prevalence of other Diseases	-0.018 (0 .073)	-0.26	-0. 002 (0.072)	-0.03	-0.848 (0.469)	-1.81*	-0.866 (1.507)	-0.58
Log Age in Years	-0.167 (0.072)	-2.31**	-0.075 (0.069)	-1.09	0.553 (0.213)	2.59**	0.674 (0.291)	2.31**
Age Squared	...	...	…	…	-0.0001 (0.000)	-2.88**	-0.0001 (0.000)	-2.40**
Marital status (1 = male)	-0.056 (0.019)	-2.83**	…	…	-0.006 (0.031)	-0.21	…	…
Sex (1= Male; 0 = Female)	-0.236 (0.046)	-5.09 ***	…	…	-0.062 (0.099)	-0.63	…	…
Log Experience	0.089 (0.022)	4.06***	0.076 (0.021)	3.55***	0.109 (0.042)	2.55**	0.054 (0.037)	1.45
Log Experience Squared	…	…	…	…	-0.000 (0.000)	-1.33	…	…
Fertilizer (=1)	…	…	…	…	0.392 (0.076)	5.11***	0.430 (0.059)	7.28***
Log Rainfall	0.306 (0.033)	9.39***	0.472 (0.035)	13.19 ***	0.365 (0.086)	4.22***	0.385 (0.093)	4.13***
Log land	0.329 (0.019)	17.1***	0.340 (0.019)	17.28***	0.305 (0.022)	13.51***	0.276 (0.074)	3.71***
No Education (=1)	-0.239 (0.044)	-5.49***	-0.333 (0.042)	-7.94***	-0.149 (0.054)	-2.76	-0.231(0.101)	-2.28**
Pre_primary Level (=1)	-0.131 (0.213)	-0.61	-0.059 (0.212)	-0.280	-0.404 (0.301)	-1.34	-0.434 (0.460)	-0.94
Log expenditure	0.010 (0.007)	1.51	0.009 (0.01)	1.43	0.106 (0.045)	2.32***	0.100 (0.140)	0.72
Secondary Level (=1)	0.176 (0.044)	3.96***	0.208 (0.044)	4.71***	0.127 (0.057)	2.21**	0.169 (0.061)	2.76**
Technical Level (=1)	0.344 (0.122)	2.82**	0.381 (0.121)	3.16 ***	0.228 (0.160)	1.42*	0.194 (0.282)	0.69
University Level (=1)	0.223 (0.277)	0.81	0.244 (0.265)	0.920	0.259 (0.356)	0.73	0.361(0.359)	1.01
Log Actual Hours	0.0363 (0.019)	1.95**	0.021 (0.018)	1.170	0.091 (0.031)	2.93***	0.016 (0.039)	0.42

Worked								
Central (=1)	…	…	-0.053 (0.051)	-1.05	…	…	-0.405 (0.461)	-0.88
Eastern (=1)	…	…	-0.306 0(.048)	-6.33***	…	…	-0.197 (0.062)	-3.16***
Western (=1)	…	…	-0.671 (0.056)	-11.79 **	…	…	-0.273 (0.433)	-0.63
Nyanza (=1)	…	…	-0.486 (0.051)	-9.51***	…	…	-0.023 (0.571)	-0.04
Constant	7.49 (0.366)	20.49	5.90 (0.362)	16.29	4.346 (0.882)9	4.92	4.438 (1.09)	4.06
R-Squared	0.100		0.117	…	…	…	…	…
F-Test	F(15, 6593)	46.58	F(17, 6591)	49.87	F(18, 6235) =36	…	F(19, 6396)	…
Sample size	6609	…	6609	…	6254	…	6416	…

Note: ***, ** and * significant at 1%, 5% and 10% level respectively.

Table 3: Regression results of the impact of malaria on crop output, 1997. Dependent variable = log (crop production); standard errors are in the parentheses.

	OLS Estimates				2 SLS Estimates			
Explanatory variables	(1)		(2)		(3)		(4)	
	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Malaria Prevalence	-0.433 (0.186)	-2.33**	-0.432 (0.186)	-2.32***	-0.434 (0.214)	-2.03**	-0.632 (2.45)	-0.26
Prevalence of other Diseases	-0.285 (0.157)	-1.81*	-0.273 (0.158)	-1.73**	-0.392 (0.168)	-2.33**	-0.199 (0.298)	-0.67
Log Age in Years	-0.111(0.051)	-2.18**	-0.165 (0.053)	-3.07***	-0.106 (0.052)	-2.05**	-0.109 (0.214)	-0.51
Age Squared	-0.217 (0.119)	-1.82*	-0.076 (0.120)	-0.64	-0.210 (0.123)	-1.70*	0.181 (0.372)	0.49
Sex (1= Male; 0 = Female)	0.007(0.058)	0.13	0.007 (0.058)	0.13	…	…	…	…
Rainfall	0.251(0.061)	4.09***	0.254 (0.061)	4.13***	0.212 (0.064)	3.27***	-1.43 (2.25)	-0.64
Log land	0.286 (0.031)	9.23***	0.290 (0.031)	9.33***	0.296 (0.032)	9.29***	0.189 (0.090)	2.10**
Log Experience	0.114 (0.019)	5.78***	…	…	…	…	…	…
Pre_primary Level	0.028 (0.139)	0.21	...	...	…	…	…	…
No Education (=1)	-0.010 (0.084)	-0.12	…	…	-0.019 (0.085)	-0.23	…	…

Secondary Level (=1)	0.478 (0.098)	4.86***	…	…	0.474 (0.104)	4.56***	…	…
Tertiary Level (=1)	0.299 (0.444)	0.67	…	…	-0.401 (0.452)	-0.89	…	…
Malaria*education	…	…	…	…	-0.027 (0.021)	-1.31	…	…
Log Education in years	…	…	0.121(0.040)	2.97**	…	…	0.168 (0.082)	2.05**
Log Actual Hours	0.133 (0.018)	7.40***	0.131(0.018)	7.32***	0.140 (0.018)	7.46***	0.098 (0.042)	2.34**
Fertilizer use (=1)	0.433 (0.063)	6.80***	0.436 (0.063)	6.85***	0.434 (0.066)	6.50***	0.332 (0.184)	1.81*
Conservation (=1)	0.197 (0.088)	2.24**	0.196 (0.088)	2.22**	0.228 (0.091)	2.49**	0.628 (0.203)	3.10***
Coast (=1)	0.050 (0.127)	0.40	0.052 (0.131)	0.40	0.031 (0.131)	0.24	-0.388 (0.273)	-1.42
Central (=1)	-0.031(0.094)	-0.33	-0.075 (0.099)	-0.76	-0.079 (0.099)	-0.80	0.057 (0.185)	0.31
Eastern (=1)	-0.784 (0.101)	-7.77***	-0.774 (0.101)	-7.66***	-0.886 (0.103)	-8.61***	-0.474 (0.213)	-2.23**
Nyanza (=1)	0.548 (0.088)	6.21***	0.556 (0.088)	6.29***	0.578 (0.093)	6.17***	0.468 (0.285)	1.64
Western (=1)	-0.166 (0.100)	-1.65	-0.155 (0.100)	-1.54	-0.072 (0.105)	-0.68	0.338 (0.240)	1.41
Constant	6.06 (0.417)	14.53	5.63 (0.441)	12.76	…	…	5.139 (1.35)	3.81
Sample size	6364	…	6364	…	5795	…	…	…
F(21, 6342)	33.67	F(16, 5778)	38.52	…	F(19, 5775) = 31.05	…	…	…
R-squared	0.099	…	0.0970	…	…	…	…	…

Note: ***, ** and * significant at 1%, 5% and 10% level.

Table 4: Impact of Malaria on Crop Output Using a Sample with Malaria Illness Pooled with Healthy Individuals, 1994. Dependent variable = log (crop production); standard errors are in the parentheses.

Explanatory variables	OLS Estimates	t-ratio	2 SLS Estimates	t-ratio
Malaria = 1 if household member had malaria (other diseases omitted)	-0.075 (0.040)	-1.90**	-2.735 (1.064)	-2.57**
Log Age in Years	0.422 (0.203)	2.07**	0.906 (0.350)	2.58**
Log Experience in crop farming	-0.000 (0.000)	-2.74***	-0.000 (0.000)	-2.97***
Marital status (1 = married, 0 otherwise)	0.009 (0.024)	0.38	0.038 (0.035)	1.10
Sex (1= Male; 0 = Female)	-0.165 (0.057)	-2.86***	-0.053 (0.097)	-0.55
Log Rainfall	0.260 (0.037)	7.04***	0.408 (0.094)	4.30***
Log fertilizer	0.466 (0.041)	11.29***	0.319 (0.089)	3.59***
Pre_primary Level (=1)	-0.002 (0.234)	-0.01	0.021 (0.421)	0.05
No education (=1)	-0.034 (0.052)	-0.67	-0.040 (0.073)	-0.55
Secondary Level (=1)	0.156 (0.054)	2.89***	0.168 (0.081)	2.07**
Technical Level (=1)	0.330 (0.153)	2.15**	0.397 (0.224)	1.77*
University Level (=1)	-0.048 (0.279)	-0.17	0.254 (0.491)	0.52
Log agricultural land	0.302 (0.023)	12.80***	0.281 (0.031)	9.08***
Log actual hours spent in farming	0.040 (0.020)	1.98**	0.058 (0.032)	1.76*
Log household size	0.320 (0.034)	9.27***	0.586 (0.107)	5.43***
Constant	5.152 (0.694)	7.42***	3.461 1.305	2.65**
R-Squared	0.133	…	…	…
F-Test	F(15, 4674) = 52.30	….	F(15, 4314) = 23.19	…
Sample size	4690	…	4330	…

Note: ***, ** and * significant at 1%, 5% and 10% level.

Table 5: Impact of Malaria on Crop Output Using a Sample with Malaria Illness Pooled with Healthy Individuals, 1997. Dependent variable = log (crop production); standard errors are in the parentheses.

Explanatory variables	OLS Estimates	t-ratio	2 SLS Estimates	t-ratio
Malaria = 1 if household member had malaria	-0.053 (0.082)	-0.65	-1.182 (1.94)	-0.61
Log Age in Years	-0.030 (0.070)	-0.44	-0.022 (0.074)	-0.30
Log Experience	-0.000 (0.000)	-1.58	-0.000 (0.000)	-1.54
Marital status (1 = married; 0 otherwise)	0.202 (0.113)	1.79*	0.200 (0.112)	1.78*
Sex (1= Male; 0 = Female)	0.010 (0.082)	0.12	0.021 (0.087)	0.24
Log Rainfall	0.205 (0.086)	2.37***	0.170 (0.106)	1.60
Log fertilizer	0.373 (0.091)	4.10***	0.402 (0.106)	3.78***
Pre_primary Level (=1)	0.198 (0.195)	1.02	0.153 (0.200)	0.77
No education (=1)	0.169 (0.117)	1.45	0.138 (0.134)	1.03
Secondary Level (=1)	0.523 (0.142)	3.68***	0.507 (0.149)	3.38
Technical Level (=1)	0.442 (0.638)	0.69	0.825 (1.48)	0.56
University Level (=1)	-0.772 (1.49)	-0.52	-1.02 (1.03)	-0.99
Log agricultural land	0.147 (0.043)	3.38***	0.140 (0.045)	3.08***
Log hours spent in farming	0.162 (0.025)	6.42***	0.155 (0.028)	5.40***
Log household size	0.963 (0.117)	8.20***	1.040 (0.177)	5.87***
Eastern (=1)	-0.980 (0.142)	-6.88***	-0.848 (0.264)	-3.20***
Central (=1)	-0.129 (0.149)	-0.86	-0.126 (0.152)	-0.83
Western (=1)	-0.543 (0.139)	-3.90***	-0.470 (0.196)	-2.40**
Nyanza (=1)	0.492 (0.126)	3.90***	0.616 (0.249)	2.47**
Coast (=1)	0.004 (0.176)	0.03	0.081 (0.214)	0.38
Constant	5.126 (0.307)	16.65	5.63 (0.925)	6.09
R-Squared	12.6%			
F-Test	F(20, 3037) = 21.43		F(20, 3037) = 20.74	
Sample size	3058	3058		

Note: ***, ** and * significant at 1%, 5% and 10% level

Table 6: Impact of education and government investment in malaria control in mitigating the impact of malaria

Explanatory variables	OLS Estimates	t-ratio	2 SLS Estimates	t-ratio
Malaria prevalence	-0.325 (0.079)	-4.11***	-1.173 (0.563)	-2.08**
Prevalence of other diseases	-0.017 (0.069)	-0.25	-0.167 (0.117)	-1.43
Sex (1= Male; 0 = Female)	-0.376 (0.037)	-0.04	-0.328 (0.049)	-6.60***
Log Age in Years	-0.338 (0.063)	-5.35***	-0.288 (0.071)	-4.03***
Log experience	0.088 (0.020)	4.32***	0.086 (0.020)	4.20***
Log Rainfall	0.291 (0.033)	8.92***	0.315 (0.037)	8.44***
Pre-primary level (=1)	-0.084 (0. 244)	-0.34	-0.100 (0.246)	-0.41
Secondary level (=1)	0.202 (0.046)	4.35***	0.190 (0.047)	4.03***
Technical level (=1)	0.458 (0.118)	3.88***	0.470 (0.119)	3.93***
University level (=1)	0.243 (0.241)	1.01	0.291(0.244)	1.19
Log land holding	0.333 (0.017)	19.05***	0.330 (0.017)	18.59***
Log actual hours worked	0.035 (0.018)	1.89*	0.035 (0.018)	1.93*
Log household expenditure	…	…	0.013 (0.009)	1.47
Malaria*primary education	0.039 (0.078)	0.50	0.316 (0.203)	1.55
Malaria * secondary education	0.030 (0.118)	0.26	0.289 (0.212)	1.36
Malaria* expenditure	0.0002 (0.000)	3.83***	0.0002 (0.000)	3.71***
Constant	8.19 (.346)	23.70	7.86 (0.415)	18.95
R-Squared = 0.0938; F(15, 6968) = 48.09 Sample size = 6984	…	…	F(16, 6967) = 43.61	…

Note: ***, ** and * significant at 1%, 5% and 10% level.

Appendix 2

Table 7: Definitions and Measurement of Variables

Variables	**Variable code**	**Variable description**	**Expected signs of effects of variables on**		
			Crop production (Kshs)	**Household income**	**Wage earnings**
Malaria	Malaria-prevalence	Proportion of household members reporting having malaria two weeks prior to the study (a continuous variable) and a dummy variable =1 for malaria presence; 0 otherwise)	Negative	Negative	Negative
Other diseases	Prevalence of other_diseases	Proportion of household members having contracted other diseases two weeks prior to the survey (a continuous variable) and a dummy variable taking the value of 1 if a member reported having contracted malaria; 0 otherwise	Negative	Negative	Negative
Age	hh_age	Age of household head/respondent's age in years	Uncertain	Uncertain	Uncertain
Age squared	hh_Agesq	Household head's/Respondent's age squared	Positive	Negative	Negative
Gender	hh_gender	Gender = 1 if respondent is male; 0 =	Uncertain	Uncertain	Uncertain

		female			
Education	hh_educ	Respondent's education in years of schooling (a continuous variable)	Uncertain	Positive	Positive
Pre_primary school(=1)	hh_pre-primary_educ	=1 if household head completed pre-primary school; 0 otherwise	Uncertain	Negative	Negative
primary school (=1)	hh_prim_edu	=1 if household head completed primary school; 0 otherwise	Positive	Uncertain	Uncertain
Secondary (=1)	hhedu_secondary	=1 if household head completed form 4; 0 otherwise	Uncertain	Positive	Positive
Tertiary (=1)	hheduc_tertiary	= 1 if household head attained post secondary education; 0 otherwise	Uncertain	Positive	Positive
University (=1)	hheduc_university	= 1 if household head completed a degree programme; 0 otherwise	Uncertain	Positive	Positive
Marital status	Marital_stat	Marital status =1 if married; 0 otherwise	Uncertain	uncertain	Uncertain
Single	marital_single	Never married (reference group)	Uncertain	Uncertain	Uncertain
Other marital status	Other_marital	=1 if individual is divorced, separated, widowed, deserted; 0 otherwise	Uncertain	Uncertain	Uncertain
Household size	hh_size	Total number of adults in a household	Positive	Positive	Positive
Urban	urbrur	Rural or urban residence taking the value of 1 if urban residence and 0 otherwise		Positive	Positive

Hours worked	work_hours	Total number of hours devoted to agricultural production, working in off-farm activities and in formal employment	Positive	Positive	uncertain
Region	Province	Dummy variables defined as (province_2 through 6) leaving province 1 (Rift Valley as the reference category for crop production function) and Nairobi for household income and earnings	Positive	Positive	Positive
Occupation	g_employ	1 = if head of the household is engaged in gainful employment; 0 otherwise	Positive	Positive	Positive
Rainfall	Adequate_rain	1 = if respondents reported experiencing adequate rainfall; 0 otherwise	Positive	Positive	Uncertain
conservation	conserve	Land conservation = a dummy variable equal to 1 if the family conserves soil erosion; otherwise 0	Positive		
Crop land	hh_land holdings	Crop land in acres	Positive	Positive	Positive