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THE ECONOMIC BURDEN OF MALARIA IN KENYA: A HOUSEHOLD-LEVEL INVESTIGATION

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THE ECONOMIC BURDEN OF MALARIA IN KENYA:

A HOUSEHOLD-LEVEL INVESTIGATION

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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This thesis has been submitted for examination with our approval as university supervisors

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ABSTRACT

The economic impact of malaria on households and individuals is increasingly becoming a subject of considerable interest to researchers and policy makers. Available evidence indicates that malaria endemic countries stand to lose billions of dollars in national income to malaria morbidity and mortality. 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. Despite the devastating effects of malaria, there exists little empirical evidence on the economic burden of the disease. This thesis sought to estimate the economic burden of malaria at the household level, and simulate economic effects of malaria control investments on farm output and household incomes.

The data used for the study was obtained from the welfare monitoring surveys conducted by the Government of Kenya, Ministry of Planning and National Development. Structural models of crop production, household income and wages were estimated to measure the economic burden of malaria, controlling for other covariates in these models. In all the models, malaria is endogenous but valid instruments are used to vary it exogenously.

The estimation results show that malaria imposes large economic burdens on households in Kenya. In some seasons households lost up to 70% of their crop output and almost 93 % of their income to malaria in the early 1990s. Moreover, the results show that the economic burden due to malaria is substantially greater than the burden imposed by other diseases.

An important finding of this thesis is that government expenditures on malaria control and schooling has a significant mitigating effect on malaria burden. Thus, malaria control activities can significantly contribute to poverty reduction in malarious environments in the country. Indeed, investments in malaria control programmes have large economic returns. The explanation for these returns is that malaria control makes an immediate contribution to output or income by increasing the quantity and quality of labour, primarily through reductions in morbidity, debility, and absenteeism from work.

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CHAPTER ONE: BACKGROUND AND CONTEXT

1.1 Introduction

Malaria remains one of the most devastating parasitic diseases in the world. It contributes considerably to the poor health situation in Africa. 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 and parts of Asia (WHO, 1997, 1999; 2000). About 90% of these deaths occur in young children below the age of five years, who have not yet acquired clinical immunity, and pregnant women, whose immunity to malaria is temporarily impaired. It accounts for an estimated 25% of all childhood mortality below the age of five years, excluding neonatal mortality (WHO, 1997). In Sub-Saharan Africa (SSA) malaria is responsible for between 30 to 50 % of outpatient visits and between 10 and 15 % of hospital admissions (WHO, 1999). In addition, the disease exerts enormous pressure on scarce health resources in SSA countries. In general, it is estimated that malaria accounts for an average of 3% of the total global disease burden. More evidence points to significantly increasing malaria morbidity and mortality in SSA due to emergence of resistance by *Plasmodium Falciparum* to existing first line drugs (Arrow et al., 2004).

According to WHO and the World Bank, malaria is responsible for an estimated annual loss of 45 million disability-adjusted life years (DALYs)[1] worldwide. This was higher than the loss of 39 million DALYs reported in 1998 and more than 36 million DALYs in 1999 (WHO, 1998, 1999, 2002; World Bank, 1993). In SSA, more than 10% of all disability adjusted life years were lost to malaria in 2000 (WHO, 2002). It has furthermore been estimated that among the ten leading causes of loss in DALYs in the world in 2000, malaria is ranked eighth with a share of 2.8% of the global disease burden (WHO, 2002).

In Sub-Saharan Africa however, malaria is ranked first, accounting for 10.6% of the disease burden (WHO, 2002). In addition to the disease burden, it is also estimated that the total cost of malaria to Africa increased from US dollars 1.8 in 1995 to US dollars 2 billion in 1997

[1] The Disability Adjusted Life Year lost or DALY lost is a health gap measure that extends the concept of potential years of life lost due to premature death to include equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability. One DALY lost can be thought of as one lost year of 'healthy' life. DALYs lost for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality (YLL) in the population or loss of healthy life from premature mortality (WHO, 2002, Hyder and Morrow, 2000).

(WHO, 1997). Recent estimates have placed the economic losses due to malaria in Sub-Saharan Africa to over US dollars 12 billion annually (Gallup and Sachs, 1998; WHO, 2000). Most importantly, malaria exerts a devastating effect on the development potential of SSA countries and mostly affects the disadvantaged and economically susceptible households, who in many Sub-Saharan African countries constitute the bulk of subsistence farmers. Available evidence further indicates that malaria imposes high and regressive cost burden on households that have a sick family member, with poor households spending a higher proportion of their income on health care than the better off households (Russel, 2004; Goodman et al., 2000). In addition to expenditure on insecticides, drugs, and equipment, large numbers of malaria patients make health personnel get stretched beyond capacity, thus affecting the standard of care they give to patients. From the foregoing, it is evident that malaria is a serious problem affecting many sectors of a country's economy.

Although the global impact of malaria on health, productivity, and general household welfare is immense, the effects of the disease vary depending on its severity and by geographical region. The World Health Report on the burden of malaria shows that out of the total 56 million deaths reported in 2002, Africa accounted for about 86% of the malaria deaths, followed by Southeast Asia (8.5%), Eastern Mediterranean (4.9%) and Western Pacific (0.9%). The report also indicates that out of the total world deaths in 2002, malaria accounted for 9% in Sub-Saharan Africa, followed by Eastern Mediterranean (1.3%), South East Asia (0.07%) and Americas (0.02%). Thus, while malaria mortality and morbidity has declined in most developed countries, the situation in Sub-Saharan Africa appears not to have experienced a corresponding decline in mortality and morbidity rates.

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. It is the main cause of anaemia among pregnant women and can lead to miscarriages, stillbirths, underweight babies and maternal mortality. It has also been shown that frequent malaria can lead to disabling neurological sequelae. Further, the disease is the major cause of school absenteeism among school going children and has been shown to slow intellectual development of children in malaria endemic areas (Lucas, 2005). The WHO estimates that about 2% of children who suffer from cerebral malaria experience brain damage including epilepsy (WHO, 2003).

The disease adversely affects the labour supply of the household and its ability to rely on off-farm labour income as insurance against income shocks. The adverse impact of malaria on household production and gross domestic product has been shown to be substantial (Lucas, 2005; Laxminarayan, 2004; Laxminarayan and Klaus, 2003; Goodman et al., 2000; McCarthy et al., 2000; Audibert, 1986; Sachs and Malaney, 2002). What these studies have found is astonishingly consistent – malaria imposes substantive social and economic costs and impedes economic development through several channels, including but undoubtedly not limited to, loss of labour productivity, depletion of human capital, premature deaths, medical costs and reduction in saving and investment. Some researchers have placed the economic burden on households due to malaria prevention measures to between US dollars 0.23 and US dollars 15 each month, and to between US dollars 1.79 and US dollars 25 due to treatment measures. 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. Shepard et al., (1991) estimated the aggregate cost of malaria to be US dollars 3.15 per capita (equivalent to 0.6% GDP). Other studies support the view that a larger proportion of the health sector budgets are spent on malaria control and treatment. For example, Evans et al., (1997), Goodman et al., (2000), Kirigia et al., (1998), WHO, (2002) show that malaria is responsible for 40% of the public health expenditure, 30-50% of hospital admissions and up to 50% of outpatient visits in countries with high malaria transmission.

The negative effect on economic growth, demographic change, acquisition of human capital, and subsequent health has been well documented (Sachs and Malaney, 2002). At the macro level, regression analyses conclude that malaria exerts negative effect on economic growth by reducing productivity and efficiency of the labour force (Gallup and Sachs, 2001). The regressions show a strong and negative association between *Falciparum* malaria and GDP growth. An important finding of these studies is that elimination of malaria is associated with significant increase in GDP growth rates. The basic economic theory postulates that the quantity of a given output that is produced is a function of several factors, including capital stock, quantity and quality of the labour force available. Given that labour is the input most affected by malaria, it could be argued that malaria reduces subsistence agricultural output, household income and by extension the total national income. 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 (Gallup and Sachs, 2001).

A close examination of the incidence of poverty underscores the strong mutual relationship between poverty and malaria. Gallup and Sachs (2001) and others argue that the world's malaria-endemic countries are also the poorest. With a per capita income ranging from US dollars 100 to US dollars 800, Africa remains the poorest continent in the world and has suffered considerably from the disease (Mitra and Tren, 2002). Lower incomes imply less expenditure for prevention and treatment so that in areas of high transmission malaria has a strong grip on the affected areas. In turn, by hampering economic growth and development, the basic improvements in land use and personal preventive measures that were enjoyed by countries that eliminated malaria are not achieved and the cycle of malaria and poverty is maintained (Mitra and Tren, 2002). Apart from its effect on economic growth, malaria exerts negative effects on the growth of tourism, industrial investment and trade, particularly in malaria endemic areas. Trade restrictions due to malaria limit development of markets that form the building blocks of economic growth. Malaria also negatively impacts on the accumulation of human and physical capital through its effects on school attendance and performance (Lucas, 2005; Malaney et al., 2004; Goodman et al., 2000; Holding and Snow, 2001).

However, there are large variations in malaria prevalence and the economic burden of the disease in Sub-Saharan Africa for several reasons. First, there is great variation in the vector transmission dynamics that favour or limit malaria infections and the associated mortality and morbidity risks from the disease. Predominant among the sources of this variation are climatic and environmental factors, particularly those that affect habitat and breeding sites of the anopheline vectors such as temperature, adequate rainfall, and humidity, presence of water, vegetation cover and man to vector contact (Snow et al., 1999; Molyneux, 1988). The second set of factors contributing to variability in malaria burden is differences in socioeconomic development across countries. Some of the socioeconomic factors in this regard include differences in poverty rates, access to health care and health education, public expenditures on malaria prevention and treatment (Breman et al., 2001; WHO, 2004).

1.2 The Research Problem

The economic impact of malaria on countries, households and individuals is increasingly becoming a subject of considerable interest. Emerging evidence from macroeconomic studies indicates that malaria endemic countries stand to lose billions of dollars in national income due to the impacts of morbidity and mortality from the disease on labour supply. In Kenya, malaria is 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. 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 (Republic of Kenya, 2004). Recent estimates show that 170 million working days are lost annually in Kenya due to malaria (Republic of Kenya 2001), a situation that seriously affects agricultural production and livelihoods of rural farmers since the majority of these days are lost in agriculture. However, despite its devastating health effects, empirical evidence of the economic impact of the disease on farm production, household income and wage earnings 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. This study fills the knowledge gap that exists concerning the economic burden of malaria at the household and individual levels in Kenya.

1.3 Objectives of the Study

The broad objective of this thesis is to estimate the economic burden of malaria at the household level, and simulate economic effects of malaria control investments on farm output and household incomes. The specific objectives of the study are to:

1. Estimate the economic burden of malaria at the household and individual levels,
2. Simulate economic effects of malaria control in Kenya,
3. Suggest policy recommendations for reducing the economic burden of malaria in the country.

1.4 The Economic Burden of Malaria Defined

The World Health Organisation (WHO, 1948) defines health as complete physical, social, economic, mental and social wellbeing of an individual, and not merely the absence of disease or infirmity. This definition puts the impacts of malaria in society into perspective by suggesting three dimensions of malaria burden: the health, economic and social burdens.

The health burden of malaria is the ill-health and premature mortality associated with malaria. The social burden of malaria includes loss in social capital resulting from restrictions in movement and networking of people due to fear of contracting malaria. The economic burden is the total loss in output or income that is associated with malaria morbidity and mortality (WHO/AFRO, 2001). The economic burden of malaria can also be defined in terms of costs incurred by individuals or households to seek treatment and in terms of expenditure on the prevention and control of malaria (see for example Ettling and Shepard, 1991, 1994; Attanayake et al., 2000; Cropper et al., 1999; Leighton et al., 1991 and Hamoudi and Sachs, 1999). It has been shown that malaria attacks result in morbidity, disability and often in mortality. The negative effects of these conditions constitute the economic burden of malaria measured in monetary terms.

1.5 Significance of the Study

In fighting malaria, provision of sufficient drugs to treat clinical episodes of malaria remains a key challenge for Kenya. However, the recent change in the treatment policy from sulfadoxine-pyrimethamine (SP) to artemesinin-based combination therapy (ACT), presently, Coartem (artemether-lumefantrine) as a first line drug, has fuelled debate about the affordability and sustainability of ACT and other control measures in the country (Republic of Kenya, 2006). The World Health Organisation (WHO) and health policy makers have repeatedly stated that the main challenge in the fight against malaria is inadequate resources (WHO, 2002 and 2003). One approach proposed by the Roll Back Malaria initiate is to mobilise sustainable financing for anti-malarial interventions in Africa. In Kenya, mobilisation of additional resources in the fight against malaria remains the centrepiece of this initiative, but the country's efforts in this direction have been severely constrained by lack of knowledge about the magnitude of economic burden of the disease. As a result, returns to investment in malaria control activities are not readily available to policy makers. The present study rectifies this situation.

In addition, the study contributes to the existing literature both theoretically and methodologically. First, we use crop production functions, household welfare equations and wage functions to measure the economic burden of malaria. These equations are estimated with instrumental variable methods to ensure that the measured effect of malaria is unbiased and consistent. Because malaria is endogenous, the usual estimation method, the OLS, understates the economic effect of malaria (see Rosenzweig and Wolpin, 2000)

Further, this study uses a unique data set compared with data used in the existing literature on economic burden of malaria. The data set used includes two important policy variables: public health expenditure on malaria prevention and treatment, and general education attainment of household members. We show that public expenditure on malaria control programmes and schooling can mitigate the economic burden of malaria. Previous researchers have often ignored this line of investigation, yet, according to recent evidence (Laxminarayan, 2005) investment in malaria control programmes and treatment can be a powerful strategy of reducing both the malaria burden and poverty and hence living standards of affected people.

1.6 Organisation of the Thesis

This thesis is organized into 6 chapters. The first chapter presents the background to the study and formulates the research problem and outlines the policy relevance of the study. Chapter 2 looks at the geography and malaria prevalence in Kenya. The chapter also provides a review of malaria treatment and control strategies in Kenya. Chapter 3 presents a review of literature relevant to this study. It starts with a review of malaria effects on household income, productivity, ending with the literature on the macroeconomic burden of malaria. Chapter 4 focuses on the study methodology and on empirical models for measuring the malaria impacts. The chapter also describes the data sets, particularly their sources and quality, and provides definitions of variables of interest. Chapter 5 presents the empirical results, and discusses them in relation to the existing literature. The simulation results are also discussed in this chapter. The summary and conclusions of the study are in chapter 6.

CHAPTER TWO: MALARIA IN KENYA

2.1 Geography and Malaria Prevalence

As noted in the chapter 1, malaria is the leading cause of morbidity and mortality in Kenya; however, the endemicity or distribution of malaria is not uniform and varies from region to region, mainly due to geographical differences in altitude, rainfall and humidity. These geographical factors influence the transmission patterns as they determine the vector densities. The higher the ambient temperature, the shorter the sporogonic cycle of the parasite in the mosquito, hence the shorter the duration of the life cycle of the parasite (Republic of Kenya, 2006).

Figure 1 shows that most areas of the country are prone to malaria. As shown in figure 1, the country can be divided into four malaria eco-zones. These eco-zones are described as stable[2] malaria zone (holoendemic and hyperendemic), seasonal malaria zone (mesoendemic), epidemic prone areas, unstable[3] malaria zone (hypo-endemic) and malaria free zone with large spatial and temporal differences in transmission dynamics. Stable malaria is transmitted throughout the year and is common in areas situated at altitudes not exceeding 300m above sea level (Republic of Kenya, 2006). The level of endemicity in these areas is high since favourable environment exists throughout the year for the disease transmission. These areas include the Lake Region and coastal areas. Areas like Taita Taveta, Lamu in the coastal region and Siaya, Kakamega, Bungoma and Busia malaria intensity is very high (hype-endemic). The predominant species of the malaria causing parasite in the stable areas is *Plasmodium falciparum*, which is quite fatal (Republic of Kenya 1997, 2003). Severe infections are common in children under five years and pregnant women. Due to continuous exposure to the parasite, the majority of children above five years and adults in the stable areas develop partial immunity and become resistant to severe malaria infection. However, regardless of the age group, malaria presents the major cause of morbidity in the stable areas.

[2] Malaria is said to be stable if it is transmitted throughout the year, albeit with the potential of wide seasonal variations in transmission intensity and disease incidence. The transmission can last up to 6 months depending on the prevailing climatic conditions. Annual transmission is particularly important in the case of malaria caused by *Plasmodium falciparum* because infected household members tend to become non-infectious within two months after infection (Kiszewski et al., 2004, Goodman et al., 2000).

[3] Areas described as unstable experience sporadic malaria transmission and frequently appear in epidemic form in areas previously free of infection. In such areas, mortality is not limited to children under five years but the whole population is at risk of infection because of lower immunity.

Seasonal malaria zone (Mesoendemic malaria transmission) occurs in many other parts of the country but manifestations appear seasonally. Several districts in North eastern areas experience malaria where communities live near water. Due to limited rainfall the transmission of parasites lasts only a few months resulting in low infection prevalence rates in children and adults. Unstable malaria transmission is common at altitudes ranging from 300m-1700m and in semi-arid areas it appears in epidemic forms. In these areas malaria transmission is characterised by intermitted transmission which may be annual, biannual or variably epidemic. The breaks in transmission lead to the death of the parasites in infected individuals and breaks the cycle of infection. However, due to lack of continuous exposure to infection, communities living in unstable regions do not develop immunity and any malaria outbreak results in severe illness and death. Areas with seasonal malaria include parts of Eastern province (Machakos, Embu and Kitui) and Rift Valley (Marigat and Ngurumani) (Republic of Kenya, 2006). It has however been observed that this situation is changing since favourable micro-climate exists in other parts of the country as a result of population movements and small scale irrigation projects.

In areas situated in altitude ranging from 1,700m-2,500m above sea level including semi-arid areas, malaria appears in epidemic forms. According to the 1992 national plan of action for malaria control, the districts that are located in the Kenya highlands are prone to malaria epidemics. These include Kisii, Nyamira, Nandi, Kericho, Bomet, Transmara, Kakamega, West Pokot, Uasin Gishu, Trans Nzoia and Gucha, Turkana and Narok.

In 1997, approximately 46% of the total population was classified as being at risk of malaria epidemics. In 1995 and 1996, malaria accounted for 42% and 32% of all hospital admissions and deaths in Nyamira district. Malaria has also been a major health problem in Uasin Gishu district, and was responsible for 27% of all admissions and 9.4% of the deaths reported in district hospitals in the district between 1953 and 1957 (Some, 1994). The district further experienced epidemics in 1991, 1995, and 1997 and in 1998. Malaria epidemics may be caused by climate anomalies (e.g. excessive or prolonged rainfall) or unusual increase in temperatures mainly in arid and semiarid areas. The transmission of the disease could also be seasonal, caused by changes in meteorological conditions such as El Nino weather conditions (Lindsay and Martens, 2001).

Figure 1: Endemicity of Malaria in Kenya

Estimates of population at risk in Kenya indicate that in 1997, 30% of the total population in Kenya lived in unstable transmission areas while 38%, 14% and 18% resided in areas of moderate stable transmission, high stable transmission (mainly the lake region and coastal areas) and low stable transmission (e.g. Kitui, Isiolo, Mandera, Meru, Nyeri, Machakos and Turkana among others) respectively.

All four species of malaria parasites infecting man are found in Kenya. The most common species is *Plasmodium falciparum*, which accounts for 80% of all malaria infections and is associated with significant morbidity and mortality.. Other malaria species found are *Plasmodium malariae* and *Plasmodium ovale*, which account for only 10% and 8 % of the reported cases, respectively, while P. vivax is rarely seen. The climatic and environmental factors favour the existence of *falciparum* species resulting in high vectorial capacity for malaria transmission. Vectorial capacity is a measure of the efficiency with which mosquitoes carry malaria from one person to another, that is, an estimate of the number of secondary cases of malaria generated by one primary case. Table 2 shows the distribution of total population exposed to malaria risk in selected districts.

Table 2.1: Population Distribution by Malaria Endemicity in Selected Districts, 2000

District	Unstable Transmission	Low Transmission	Moderate Transmission	High Transmission	Total
Baringo	315,844	-	1,511,742	-	1,827,586
Kericho	241,165	-	418,433	-	659,598
Nakuru	1,193,730	59,539	-	-	1,253,269
Uasin Gishu	540,867	69,725	9,765	-	620,357
Bungoma	103,987	87,245	452,539	295,240	939,011
Garisa	80,413	50,803	-	-	131,216
Homa Bay			791882	67,865	859,747
Kisii	226,480	-	675,777	-	902,257
Kisumu	-	-	293,828	663,484	957,312
Embu	150,043	333,654		-	483,697
Kitui	68,199	611,901	136,924	-	817,024
Meru	310,386	794,455	-	-	1,104,841
Muranga	404,388	670,059	-	-	1,074,447
Nyeri	688639	50814	-	-	739,453
Kwale	-	-	436,065	75,151	511,216
Kilifi	-	-	866525	-	866525
Tana River	25,016	106,070	48,478	-	179,564

Source: Republic of Kenya, 1998

Malaria as a disease is closely bound to geographical conditions which favour the survival of the anopheles mosquito and the life cycle of the parasite. These conditions are predominantly determined by climatic factors, by vegetation coverage and by the vector's access to water surfaces for breeding requirements (Ghebreyesus, 1996). Human population movements from malaria endemic zones also contribute to malaria transmission. A possible source of variation that is not determined by natural factors such as climate and environmental factors may be differences in socio-economic development, which has played a major role in the control and eradication of malaria in some countries (Mitra and Tren, 2002; Goodman et al., 2000). Existing evidence shows that socio-economic development could reduce malaria transmission in several ways. For example, increases in household income of women and poverty reducing measures have the potential to reduce exposure to malaria and improve health seeking behaviour and quality of treatment (Packard, 1984). However, socio-economic development could equally increase malaria transmission due to movement of people with little or no immunity into areas of high malaria transmission.

2.2 Malaria Treatment and Control Strategies

Kenya's malaria control policy aims at reducing the incidence of malaria by 50% through provision of early diagnosis and prompt treatment; early detection and prevention of epidemics; use of effective and sustainable preventive measures, including vector control, strengthening capacity in research in order to promote regular assessment of malaria situation and encourage improvements in the control of malaria; and development of human resource capacity at all levels for effective treatment and control of malaria. The main area of focus is case management, which involves case detection, diagnosis and malaria preventive measures (such as vector control and parasite control). The vector control programme involves identification of high-risk areas and spraying structures with residual insecticides, while parasite control focuses on treatment of people that have contracted the parasite in order to disrupt the parasite's life cycle and reduce the rate of transmission (Republic of Kenya, 2006).

2.2.1 Malaria Treatment

The importance of providing prompt and effective treatment cannot be overemphasized. The main focus of the government here is to provide information on which drugs are effective and clear communication of national drug policy to all who treat patients, ensuring adequate supplies of anti-malarial drugs, support drugs and diagnostic materials where patients can have access to drugs, adequate and well-trained and motivated health care providers, well managed health services with responsive information systems and public awareness of the symptoms of malaria and appropriate ways to find treatment.

Two types of malaria cases are treated in Kenya, complicated (or severe) malaria and uncomplicated (or mild) malaria (Republic of Kenya 1997, 2003 and 2006). The main symptoms of complicated malaria as convulsions, severe anaemia, renal failure, sepsis, pneumonia, adult respiratory distress, circulatory shock and cerebral malaria while those of uncomplicated malaria are flu, high fevers, sweats, body pains and headaches (Republic of Kenya, 2003, 2006). Uncomplicated malaria cases are usually treated with drugs but complicated malaria requires more intensive treatment and usually hospitalization. Until recently, the first line treatment regime for uncomplicated malaria was a single dose of sulfadoxone-pyrimethamine (500mg-25mg tablets) and sulfalene-pyrimethamine (500mg-25mg tablets while Amodiaquine or oral quinine continue to be used as a second line treatment regime in SP resistant areas. Due to the drug resistance, the recommended first line treatment for uncomplicated malaria is artemether-lumefantrine (Republic of Kenya, 2006).

In an attempt to provide good quality treatment with minimum duplication and wastage of very scarce resources, the government of Kenya has adopted the Integrated Management of Childhood Illness (IMCI) approach. This is a holistic approach to childhood illness, which developed from the recognition that every year 12 million children die before their fifth birthday, many in their first year and 7 out of 10 of these deaths are due to one or more of just 5 conditions: malaria, diarrhoea, pneumonia, measles and malnutrition (Republic of Kenya, 2006).

However, because of the emergence of drug resistance the government has changed the treatment policy for malaria from single therapies to artemisinin-based combination therapy (ACT). This change occurred in September 2006 when the Ministry of Health launched ACTs as the first line drug for malaria treatment. ACT is a more effective drugfor countering the spread and intensity of *Plasmodium falciparum* resistance to chloroquine, sulfadoxine/pyrimethamine, and other antimalarial drugs (Arrow et al., 2004). Proponents of ACT argue that early use of the drug delays development of resistance to the traditional drugs and is effective in reducingmortality and morbidity associated with use of ineffective drugs

(Breman et al., 2004). A major obstacle however, to using ACT is its cost, priced at US dollars 1.20-2.50 per adult treatment compared with US dollars 0.10-0.20 per adult treatment for Chloroquine and Sulfa-component and pyrimetha-mine (SP). If we take into account other direct costs such as consultations, and laboratory investigations, then the cost of the drug increases by approximately 20% (Breman et al., 2004). This is definitely beyond the reach of many people especially those living in the rural areas where majority of them live below the poverty line (see Fosu and Mwabu, 2007). This has serious implications for the treatment of the disease given that malaria attacks are associated with poor economic and environmental conditions (Goodman et al., 2000). Furthermore, resistance to treatment is likely to continue particularly in rural areas because individuals who contract malaria do not seek early treatment at the health facilities until the symptoms are at an advanced stage. The situation is even worse in poor rural areas where access to treatment is limited by distance to health facilities or cost of treatment.

2.2.2 Intermittent preventive treatment in pregnancy

As noted previously, pregnant women are at high risk of malaria infection due to reduced immune system. Malaria in pregnancy contributes to maternal and neonatal mortality, infant anaemia, maternal anaemia and low birth weight babies. Because of the serious consequences of malaria in pregnancy, protecting pregnant women is a top priority of the Ministry of health. The prevention measures recommended for pregnant women at risk of contracting malaria include: IPT especially in areas of high malaria transmission (see figure 1) and IPT using Sulphadoxine 500mg Pyrimethamine 25 mg given as a dose of three tablets. Other treatment measures include use of Insecticide Treated Nets (ITNs) especially in high transmission areas. All pregnant women and children under five years of age are supposed to sleep under an ITN.

2.3 Malaria Prevention

2.3.1 Malaria Vector Control

Malaria Vector Management and Control, builds into the overall decision-making process for the management of vector populations, in order to reduce or interrupt transmission of malaria as a vector-borne disease. This entails selection of methods based on knowledge of local vector biology, disease transmission and morbidity; utilization of a range of interventions, often in combination; collaboration within the health sector and private and public sectors that impact on vector breeding; involvement of local communities and other stakeholders and rational use of insecticides. This fits very well into an Integrated Vector Management (IVM) approach which takes into account the available health infrastructure and resources and integrates all available and effective measures. In addition, the approach also promotes an integrated approach to the control of other mosquito borne disease.

Vector control is aimed at reducing levels of mortality and morbidity by reducing transmission of the disease. This strategy involves application of targeted site-specific activities that are cost-effective. Some of the vector control strategies being deployed include indoor Residual Spraying (IRS) with insecticides, personal protection measures, larval control, and environmental Management. Indoor spraying is one of the strategies that have been relied on as a vector control strategy in the country. Indoor residual spraying is used mainly in epidemic-prone areas especially in the highlands. Past experience shows that if it is properly implemented, it can be effective; however, it requires very targeting specific areas and a clear understanding of where it is most effective.

Personal protection measures are based on insecticide-impregnated materials such as Impregnated Treated Nets (ITNs) mainly. It has been demonstrated that if they are properly applied they can provide a 30 to 60 % reduction in malaria morbidity, and can be useful in terms of preventing drug resistance (Republic of Kenya, 2006).Some studies have shown that regular use of ITNs reduce clinical malaria episodes by 48% and can avert up to 6 deaths for every 1000 children protected every year regardless of the intensity of transmission (Lengeler, 1998). The main challenge with this strategy is that the coverage remains very low, with only 4 % of households owning at least one mosquito net (KDHS, 2003). As a result, various approaches have been promoted by the division of malaria control programme to increase ITN coverage including public sector distribution, social marketing by non-governmental organisations, and public-private partnerships with sale through commercial outlets. The scaling up the distribution of nets has also been hampered by lack of adequate financial and operational resources. Large-scale distribution of nets requires high financial and human resource inputs, which may not possibly be maintained given the financial constraints facing the ministry of health. Furthermore, access to ITNs by the poorest segment of the population presents a major challenge mainly because most of the poor people at risk of malaria live in rural areas with limited or no health facilities.

Because of the nature of the vectors, which breed mainly in a small amount of water on the surface of the ground, larvae control is effective only under suitable mapping and characterization of breeding sites, and works mainly in urban and peri-urban areas. Larval control can be done through chemical or biological and can be controlled through environmental management, large space coverage, and community participation. Environmental control is used to prevent breeding, nesting, and feeding of vectors by source reduction and through better housing, windows, doors and screening. Environmental control is suitable mainly in urban and peri-urban areas, and requires community participation and inter-sectoral collaboration.

2.3.2 Current Malaria Control Strategy

To address the burden of malaria in Kenya, the Ministry of Health has prioritized malaria control through the National Health Sector Strategic Plan (NHSSPII) and mandated the Division of Malaria Control (DOMC) to coordinate the implementation of the National Malaria Strategy. In collaboration with partners, the government also developed a 10-year Kenyan National Malaria Strategy (KNMS) 2001-2010 to provide strategic guidelines in the fight against the disease. The KNMS adopted the Abuja targets which were set by the Roll Back Malaria (RBM) movement in Abuja in 2000 as benchmarks for measuring progress towards reducing malaria morbidity and mortality in the country. Thus, the Kenya National Malaria Strategy 2001 – 2010 provides the framework for the prevention, control and treatment of malaria in the country. It outlines the four strategic interventions discussed earlier- case management which focuses on formulation and implementation of malaria treatment policy issues. It is intended to ensure that all people have access to prompt and effective treatment, to significantly reduce illness and death from malaria. The second intervention focuses on Management of malaria and Anaemia in Pregnancy (MIP). It mainly focuses on the provision of malaria prevention measures and treatment of pregnant women including provision of Insecticide Treated Bednets and Intermittent Preventive Treatment (IPT). The vector control is intended to guarantee use of insecticide treated nets by at risk communities so as to significantly reduce rates of the disease and other methods through Integrated Vector Management. Finally, epidemic Preparedness and Response (EPR) is aimed at improving epidemic preparedness and response by establishment of malaria early warning systems and carrying out preventive measures such as the Indoor Residue Spraying (IRS) campaigns.

These efforts are, however, making limited impact on the disease control, since the malaria situation is actually worsening in many parts of the country. There is therefore, a possibility that, even with the additional resources, malaria treatment and control measures may not be receiving adequate attention. This could be due to lack of awareness by the policy makers and households about the economic burden of the disease. In view of this, it is imperative that the economic burden of malaria be better understood. In the current situation, it is difficult for policy makers and planners to think about reducing the malaria burden until the magnitude of the disease is known.

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

In recent times, there has been an increasing interest among health policy makers in the links between malaria and its effect on households and on economic growth. Many of the empirical studies have focused on the macroeconomic impact of the disease. There is however, very little exploration in contemporary literature of the impact of malaria on agricultural production and on household well-being. This chapter reviews some evidence of economic consequences of malaria on households. Section 3.2 reviews evidence on the effect of malaria on household expenditure while sections 3.3 and 3.4 provide reviews of studies on the effects of malaria on productivity and on cognitive development, respectively. A review of evidence on the macroeconomic burden of malaria is presented in section 3.5.

3.2 The Cost of Illness Approach to the Measurement of Burden of Malaria

The literature in this areas is based on the cost of illness methodology that separates malaria cost into direct costs of medical care and supplies (including costs of treatment, transport, special foods etc) and the indirect costs associated with wages lost by the infected person and any other family members who abandon their work to take care of the sick family member (Malaney, 2003). At the household level, direct costs represent the resources that could have been used for other types of consumption or investment had malaria not occurred. Indirect costs of malaria are measured as an estimate of time lost multiplied by a wage rate.

Several studies have applied the cost of illness (COI) approach to estimate the cost burden of malaria. The main studies of this type are by Ettling et al., (1994), Sauerborn et al., (1991), Shepard et al., (1991), Mills (1993), Asenso-Okyere and Dyzator, (1997), Goodman et al., (2000) and Attanayake et al., (2000). Ettling et al., (1994) estimated household expenditure on malaria treatment to be between US dollars 0.41 and US dollars 3.88 per person per month, which is equivalent to US dollars 1.79 and US dollars 25 per household per month. These expenditures tend to be highly skewed. For example, in Malawi, expenditure on malaria prevention and treatment was found to be highly regressive, accounting for a larger proportion of income among the poor households. Poor households in endemic areas spent about 19 to

28% of their cash income treating episodes of malaria as opposed to only 2% among the high income households. Although the poor in general spend less on treatment than other income groups this pattern of spending makes up a higher proportion of monthly or annual income for poor people than for those on higher incomes. Worrall et al., (2002) points out that such high cost burdens for the poor are likely to deplete household assets or trigger coping strategies, which further deepen the economic burden on the poor households. This view is shared by Hampel and Najera, (1996) who note that the cost of prevention, treatment, and loss of productivity resulting from malaria-related morbidity and mortality accounts for a larger proportion of the annual income of poor agricultural households.

In Ghana, Asenso-Okyere and Dyzator, (1997) estimated the average expenditure at US dollars 8.7 per malaria episode. In Ethiopia, Cropper, (1999) showed that households spent US dollars 0.8 and US dollars 1.6 per malaria episode, which was equivalent to a loss of 12-26 days of work, accounting for up to 5-8% of household income. In Nigeria, Obima et al., (2004) showed that households spent on average US dollars 1.84 per month on malaria treatment while expenditure on other illnesses amounted to US dollars 2.60 per month. The cost of days lost from malaria illness was higher at US dollars 1.28 per month compared with that of other illnesses, which was US dollars 1.08. The combined financial cost of treating malaria and that of other diseases accounted for 7.03% of the monthly average household income, with the treatment of malaria illness accounting for 2.91% of the household income. Overall, cost of malaria treatment and prevention accounted for 45.9% of the total household health care spending or US dollars 3.11 per month while other illness episodes including HIV/AIDS contributed 54.1% with a mean of US dollars 3.7 per episode.

Similar studies undertaken in Sri Lanka, Zimbabwe, and Zambia provide further evidence of the cost burden of malaria. These studies show that on average, households spent close to 25% of their income on malaria prevention and control. In Sri Lanka, for example, Jowett et al., (2002) found that on average households lost approximately 1.8 working days due to malaria illness, which is equivalent to US dollars 15.5 per malaria episode per household. If we consider other malaria-related expenditures apart from medical expenditure, then the economic burden would perhaps be much higher than is reported by most studies. Given that an episode of malaria lasts for about seven days, it means that each malaria affected household will have to spend an additional proportion of their income on food, which adds a considerable burden on the household, particularly if more than one member of the family is sick.

Another work relevant to our study is that by Ruiz and Roeger (n.d) who carried out an in-depth analysis of the socio-economic impact of malaria in three communities of Colombia and Ecuador. In Colombia, the average cost per case of malaria stood at US dollars 17.30. Indirect costs accounting for the largest component of the costs (US dollars 15.80) with the direct costs accounting for only US dollars 1.50 of the total computed cost. The loss was equivalent to a 5.6 days work. In Ecuador, the average cost per case of malaria was estimated at US dollars 10.40 with indirect costs estimated at US dollars 5.90 and direct costs US dollars 4.50. The loss was equivalent to 21% of monthly wage earnings. The authors concluded that the major economic effect of malaria was in the reduction of household labour (indirect costs).

Few studies have employed the willingness to pay approach in estimating the economic losses associated with malaria morbidity (see for example Masiye and Rehnberg, (2005), Mcarthy, (2000) and Whittngton et al., (2003). Masiye and Rehnberg, (2005) estimated the economic benefits that can be derived from an improved treatment programme. The economic benefit of an improved malaria treatment programme was estimated at US dollars 77 million per annum, representing a 1.8% of the country's GDP. The authors concluded that treatment of malaria generates enormous economic benefits to society.

Whittington et al., (2003) uses the willingness to pay approach to evaluate adults' perceived magnitude of economic benefits of avoiding malaria. The study estimated the probability of an individual's willingness to pay for a hypothetical vaccine for a specified set of price and wealth levels. They estimated a multivariate regression function using a probit model based on a random utility framework, which assumes that respondents' aim at maximising their utility when they make decisions whether to pay for a vaccine at a specified price in order to avoid malaria. The average willingness to pay to avoid an illness was estimated at US dollars 14. This implies that the economic benefits to families and individuals from malaria control activities are large. The marginal effects of wealth on willingness to pay for a vaccine were large and significant at low price levels but negative for medium and high prices. There are two explanations for this finding. One explanation for the finding is that malaria vaccine is a normal good so that increased income increases its demand and therefore the willingness to pay for it. The other explanation, which is also in line with economic theory, is that, increased wealth makes the individual price-sensitive since he has other ways of protecting himself from malaria, rather than through the vaccine.

3.3 The Production Function Approach to Burden Identification

Most of the studies that have examined the impacts of malaria on productivity have applied production models of various types (Audibert, 1986, Wang'ombe and Mwabu, 1993, Laxminarayan, 2004, Laxminarayan and Moeltner, 2003). The main work under this category is by Audibert, (1986) who estimated the relationship between health status and agricultural non-wage peasant production in Cameroon. Output of rice per acre was modelled as a function of a range of explanatory variables, including prevalence of malaria and schistosomiasis among household members. Other key explanatory variables included family size, number of years of experience in specific crop farming, size of the working population (measured by the total number of people effectively working in the farm and number of adults working in the farms), and a seasonal dummy variable to capture the effects of climatic changes on rice growing. Other covariates included the surface area of cultivated land, fertility of cultivated soil, the number of millet fields and the duration of transplanting for the rice farmers.

Contrary to expectations, the coefficient on malaria (measured by the levels of parasitaemia) was not statistically significant in the rice output equation but the schistosomiasis prevalence was found to have statistically significant effect. It is possible that the use of malaria prevalence during the dry season without also considering the effect of the disease during the rain season when the prevalence would have been higher may have been responsible for the unexpected results. Secondly, and most importantly, malaria is potentially endogenous to farm output and the author's failure to address the endogeneity problem could also have contributed to the unexpected results.

In an attempt to address past estimation failures, Audibert et al., (1991) applied a stochastic frontier production model to assess the effect of malaria on farm efficiency. Technical efficiency (defined as the maximum output achieved from available inputs) was modelled as a function of malaria and other covariates. Prevalence of malaria among adults with a parasitemia density greater than or equal to 500 parasites per micro litre of blood was used as a proxy for malaria. Similar to previous estimation results, the coefficient on prevalence of parasitaemia did not have a statistically significant effect on technical efficiency. However, when parasitaemia with a density greater than 500 was included in the model, the coefficient was found to be statistically significant.

Leighton and Foster (1993) provide further evidence on the impact of malaria on annual crop production due to malaria morbidity. The authors examined the short-run economic impact of malaria in Kenya and Nigeria, based on field data. Specifically, the study focused on the annual malaria-related production loss at the national, sectoral, and household levels, as well as for urban and rural populations and for men and women. They also investigated the effect of malaria on labour productivity for the individuals who resumed work during a malaria episode. High variations in productivity loss were noted between rural and urban areas, between social economic groups and across sectors. The burden of health expenditures was unevenly distributed among rural and urban populations, with households at lower socioeconomic levels spending greater shares of their income than better-off households. The findings further revealed that the loss in income was higher among women than men. The loss in the agricultural sector were 58% compared to 7% in the industrial sector in Kenya while in Nigeria the losses in agricultural and industrial sectors were 50% and 10% respectively.

Few studies have examined the effects of malaria on agricultural land use patterns (see for example Wang'ombe and Mwabu, 1993; Laxminarayan and Moeltner, (2003). Wang'ombe and Mwabu, (1993) examined the effect of malaria on agricultural land use patterns and household income in irrigation and non-irrigation areas in Kenya. The study used two production functions to measure the effect of malaria on cassava production and total household income. In the first equation they examined the effect of malaria on cassava production while controlling for household size and other household characteristics over a period of three months. In the second specification, they examined the impact of family size, malaria and the level of household education on annual total household income. They too, like Audibert et al., (1986), found that malaria did not have a statistically significant effect on cassava production nor on the acreage cultivated. There are two possible explanations for the findings. First, intra-household labour substitution including household hiring of labour to substitute the sick family member may have attenuated the effects of malaria episode on income or cassava production at the time of the illness. Second, no effort was made to control for endogeneity of malaria variable in the production equations estimated.

Laxminarayan and Moeltner, (2003) estimated the impact of malaria risk on agricultural production and crop choice. They specified a reduced form equation of crop supply function. All individual crops were grouped into three categories: rice, food and industrial crops. The explanatory variables included prices for each category of food, agricultural land for annual crops, labour endowment in male equivalent, %age of crop land under irrigation, age and years of schooling of household head, province specific malaria risk, agricultural wages, price of fertilisers, distance to the nearest hospital and pharmacy and indicator terms for regions. The dependent variable in the year specific models was the amount of crops harvested. The main findings of the study were that the risk of malaria had a significant negative effect on production of many agricultural crops such as rice, corn and vegetables. Specifically, a 1% increase in the four-week malaria risk resulted in a 0.34% reduction in rice output, and a 0.25% increase in food supply. Malaria did not however, have a significant effect on the production of annual industrial crops. Based on the findings, the authors concluded that the risk of malaria places an enormous economic burden on agricultural production, regardless of whether or not a number of the household actively suffers a malaria episode. The second conclusion was that farmers who anticipate malaria attack may adapt coping strategies e.g. choice of crop, selecting less risk crops to minimise risk associated with illness.

Pandey (2001) and Liu Qunhua et al., (2004) concur with the findings by Laxminarayan and Moeltner. Both studies found that the decline in malaria incidence not only improved the health status of the population but also the productivity of farmers. Pandey (2001) for example, found that crop output for households with malaria was lower, regardless of whether or not a household member suffered an episode of malaria. Pandey's study is useful from the policy point of view because it shows the mechanism through which malaria affects farm output. One important mechanism is through the reduction in labour supply of households or lower productivity of workers and increased expenditure on medical care. Increased expenditure on malaria treatment and prevention implies that less expenditure on farm inputs such as fertilizers, which may affect farm output. The effect was however, found to be minimal among high-income households because they can better afford anti-malaria measures and treatment when necessary. A similar study by Cole and Noemay (2005) supports earlier findings that poor health (due to disease illness) has a strong negative impact on total factor productivity.

Households living in malaria-endemic areas are less likely to have access to economic opportunities than those living in malaria free regions, as malaria endemic areas tend to benefit less from investments. However, certain characteristics of a region, such as administrative capacity, economic potential or political importance may determine the extent of malaria burden and the living standards of the households. For example Utzinger et al., (2001) found that increased government expenditure in malaria control and prevention reduced workers' absenteeism in copper mines, resulting in increased production.

Laxminarayan (2004) arrived at similar conclusions as Utzinger and others. Using data from Viet Nam, he showed that reduction in the incidence of malaria due to increased government investment in malaria control and treatment significantly improved income for all households living in malaria endemic areas. To test this hypothesis, he estimated the impact of changes in malaria incidence on changes in household living standards over a six year period. The results showed that a 10% decrease in malaria cases resulted to a decrease of 0.63% in health care expenditures. This was equivalent to US dollars 0.16 benefit to each household for every 10% reduction in malaria. Simulation results further showed that if malaria cases were reduced by 60% nationwide, the reductions would translate to an annual economic benefit of approximately US dollars 14 million (or a 1.8% increase in annual household consumption).

3. 4 The Effect of Malaria on Cognitive Development

It is well established that malaria can impair cognitive development, performance and behaviour, and thus reduce learning ability at school and productivity at work (Lucas, 2005). Several studies have found that malaria in pregnancy is associated with anaemia, epileptic convulsions and growth retardation during the first three years of life. Shiff et al., (1996) for example found that children unprotected by impregnated bed-nets grew less in a 5-month period and were twice as likely to be anaemic compared to protected children. As previously indicated, malaria remains the single most important cause of seizures in early childhood in SSA. Epileptic seizures are associated with learning disabilities in children, resulting in poor cognitive performance and reduced school attendance.

Lucas (2005) points out that malaria has the greatest influence on education outcomes during the first years of life. Using malaria eradication campaigns in the malaria periphery as quasi-experiments he demonstrated the effect of malaria on lifetime human capital accumulation in three countries: Paraguay, Sri Lanka and Trinidad. Education (measured as years of completed schooling, ability to read a newspaper or reading a newspaper with difficulty) was specified as a function of malaria (proxied by pre-eradication and eradication period), place of residence indicators (city, town, and country-side) and location. Estimates obtained using Tobit and probit models in the three countries showed a negative and significant effect of the malaria rate on educational achievement. Extending the analysis to 13 African countries with the highest malaria endemicity, the predicted gains in years of completed education ranged between 0.11 years in Zimbabwe and 0.56 years in Uganda. The gains in education correspond to an increase in the per capita GDP of US dollars 16 (1.2%) and US dollars 77 (7.5%) in Zimbabwe and Uganda, respectively. Overall, the results showed that a reduction of malaria incidence rate by 10% would result to an increase in the years of completed education of 0.074 and 0.119 years and an increase in the probability of being literate of 0.7% and 1.7%.

3.5 Macroeconomic Burden of Malaria

There is a substantial body of literature on the effect of malaria at the macroeconomic level (see for example Gallup and Sachs 1999, 2000, 2001, Sachs and Malaney, 2002, McCarthy et al., 1999). These studies combine cross-country regressions with malaria index within a country to estimate the economic burden of malaria. Most of the studies find a negative correlation between the index of *falciparum* malaria and GDP per capita globally. The estimates for the effect on growth range from 0.54% to 1.3% per annum. According to the regression analyses conducted by Gallup and Sachs, GDP growth increased significantly after the eradication of malaria, even after discounting for factors such as low initial income, geographical disadvantages and poor human development index. Although the estimates are able to capture the total effect of malaria, the correlations are weak to establish a direct link between tropical conditions and GDP growth.

Few studies have shown that reduction in malaria is associated with an increase in growth rates (see for example Mitra and Tren, 2002, Malaney et al., 2004).Mitra and Tren (2002) for example, conclude that a 10% reduction in malaria would increase economic growth by 0.3 %, even after accounting for differences in income, geographical disadvantages, and poor human development index. Similarly, a 1% increase in malaria was matched by a decrease in GDP growth. Further evidence indicates that the world's malaria-endemic countries are also the poorest. Mitra and Tren (2002) analysis of public health spending of malaria-endemic in low income countries revealed that African countries with a per capita income ranging from US dollars 100 to US dollars 800 spent US dollars 5 to US dollars 30 per capita on malaria against a world average of US dollars 583 in 2001. They concluded that since poor countries spend less on public health than high income countries, they are understandably more disease-prone. Lower incomes mean less money for prevention and treatment. The consequence of lower expenditure is that in areas of stable or unstable malaria, malaria gains a strong presence and in turn impedes economic growth and development.

Comparison of the economic burden obtained using macroeconomic approaches and cost of illness approach show a wide variation. For instance, whereas evidence from macroeconomic studies indicates that the burden of malaria is enormous in malaria endemic regions, particularly in Sub-Saharan Africa, evidence from microeconomic studies provide conflicting results. For instance, while some microeconomic studies find a strong negative association of malaria with crop production, others find a much smaller impact, generally less than one % of annual per capita (see MacCarthy et al., 1999; Goodman et al., 2000; Mwabu et al., 2001; Laxminarayan, 2004; Malaney, 2000; WHO, 1999). It is also evident from the previous literature that estimation of economic burden of malaria varies greatly with the methodology and the available data.

3.6 Overview of Literature

Evidence from the literature shows that four analytical approaches have been employed in estimating the economic burden of malaria on households: the production function method, the willingness to pay approach and the wage rate method, which relates wage earnings to malaria (see for example, Ettling et al., 1993, Ettling and Shepard, 1991, Mitra and Tren, 2002, Leighton and Foster, 1993), or more generally, the cost of illness approach (see Fosu and Mwabu, 2007).

The evidence from the reviewed literature shows that the economic effects of malaria on households differ widely (see for example, Goodman et al., 2000, Hamplel and Najera 1996, Malaney 2003 and Attanayake et al., 2000). Partly, the difference in cost estimates could be explained by the variations in methodology, differences in patterns of malaria endemicity, cost components considered in various studies and the differences associated with particular species of malaria parasite. However, regardless of the method used in estimating the burden of malaria, all the studies generally demonstrate that the burden of malaria falls heavily on the poor because the direct and indirect costs of a single malaria episode often accounts for a significant portion of an individual's income (see Olagoke, 2007).

The literature has also shown that health has a sizable effect on functioning levels of individuals and that better health is likely to result in higher output and income levels (see for example, Barlow, 1967). Yet, among household level studies, there is not much existing evidence on the impact of malaria on crop production, household income and wage earnings. In this thesis we use household level data to examine whether crop production, household income and earnings are influenced by malaria among households. Our study also contributes to the economic literature by addressing the endogeneity problem of malaria. In the literature, all the microeconomic studies have tended to treat malaria as exogenous with respect to crop production or household income. This is however, not the case because malaria is a potentially endogenous variable and is simultaneously determined with crop production. For instance, errors in the survey measurement of malaria lead to measurement bias in the estimation by ordinary least squares (OLS) of malaria's effect on crop production or total household income. Our empirical strategy to correct the possible endogeneity bias which we follow is to specify a set of instrumental variables (IVs) for malaria. These variables affect malaria transmission without directly affecting crop production, household income and wage earnings.

The policy environment that may exacerbate or mitigate the malaria burden has not been given attention in previous research, yet, this is critical in guiding current and future policies and intervention intended to reduce the economic loss due to malaria. For example, based on the literature, it is apparent that increased government expenditure on malaria control and schooling would reduce the effects of malaria on agricultural output, household income and on wage earnings. This notwithstanding, there is not much evidence of the contribution of these policy variables in mitigating the negative impact of malaria on output, household income and wage earnings. To investigate this relationship, we include interaction terms between government expenditure and malaria and schooling and malaria in the equations used to identify malaria burden in order to show that schooling and investment in malaria control can mitigate the negative effect of malaria. Furthermore, this study adds new findings to the existing literature on the economic burden of the disease because it controls for effects of malaria endogeneity through the use of IV in order to show more explicitly the effect of malaria.

CHAPTER FOUR: METHODOLOGY

4.1 Introduction

The aim of this chapter is to give an exposition of the various approaches to the estimation of malaria burden using a household production model and its variants. Section 4.2 examines the theory and assumptions related to household models. Section 4.3 presents the econometric models used in estimating the economic burden of malaria in households. Section 4.4 discusses estimation issues, paying particular attention to implications of the endogeneity of malaria to the outcome variables. The final section, section 4.5, is a summary of the chapter.

4.2 A Model of Household Production and Consumption

4.2.1 The Impact of Malaria on Crop Production

Poor health has been observed to impose sizable economic burden on households. Additionally, households are constrained by other factors in farm production decisions. Evidence suggests that illness affects farm yields by reducing household's labour supply (Pandey, 2001). Although poor health affects productivity of farm inputs, it may not have direct productivity effect; rather, the disease may affect the household ability to effectively utilize resources (Singh et al., 1986). 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.

In chapter one, the economic burden of malaria was defined as the total loss or reduction in farm output, household income or wage earnings due to malaria morbidity and mortality. In the theory of production functions, labour is a key input determining 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 (Varian, 2003, Mwabu et al., 2001; McCarthy, 1999). Poor health or premature mortality due to malaria, however, may have a substantial negative effect on productivity of households if the disease reduces the labour supply. Malaria morbidity in contrast reduces crop output by increasing absenteeism from work, and by reducing work capacity or effort of household members. Singh et al., (1986) for example points out that ill health directly affect the quality of labour supplied by the household. They further point out that changes in the health of the household members affect income by changing the household's available time, managerial abilities or productivity of work time.

Available evidence show that a single malaria attack, depending on severity, leads to a loss of four or more working days, followed by additional days with reduced work capacity (Leighton and Foster, 1993; Picard and Mills, 1992; Hempel and Najera, (1998). Lost 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 in contrast reduces output by increasing absenteeism from work, and by reducing work capacity or efficiency of individuals, leading to a decrease in hours worked. According to Audibert, (1981), Wang'ombe and Mwabu (1993); Strauss and Thomas (1998); Mwabu et al., (2002); Ramanan and Klaus, (2003); Laxminarayan (2004); Bartel and Taubman, (1979), Thomas and Strauss, (1997) and Lucas (2005), malaria morbidity also affects intellectual development (cognitive skill, years of schooling and performance of children) considered important determinants of future variations in productivity. Based on this, it can be argued that malaria attacks are a major cause of loss in agricultural output, household income and earnings mainly due to withdrawal of labour from active participation in agricultural activities and from the labour market.

In studies by Becker and Grossman, investment in human capital aimed at increasing its capacity e.g. education and health, are assumed to contribute to the productivity of workers and to lead to increased crop production. From economic theory (see Varian, 1993), a household is assumed to maximise the expected utility function having as the argument morbidity status (e.g. malaria), leisure time, and consumption of non-health related goods, all of which are subject to the constraints of consumable income, time, health and farm production functions. 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. A change in health may also affect the productivity of farm inputs or the ability to use resources (see for example Audibert and Etard, 2003).

We assume that regional environmental conditions and existing infrastructure at time that allows a household living in region j to potentially produce up to S_j different crops.

Further assuming that the household faces a time constraint, implying that it cannot allocate more time to leisure, on crop production, or farm employment than the available time to the household, then the total time for the household can be given as:

$$T = l_s + l_o + n \qquad (4.2)$$

where T is the total stock of household time and is composed of time for crop production (l_s), time for off-farm employment (l_o) and time for leisure (n). In addition, the household faces a production constraint or production technology which describes the relationship between inputs and crop output (see Singh, Squire and Strauss (1986). This relationship can be expressed as:

$$Q = Q\ (L, M) \qquad (4.3)$$

where the variables are as defined before. Equation (4.3) excludes other variables such as household and individual characteristics, fertiliser and community variables e.g. distance to the nearest market or a health facility which are important determinants of crop production. It is also assumed that family labour and hired labour are perfect substitutes and can be added directly (see Singh et al., 1986).

Assuming that there is a known risk of contracting a malaria episode within a specific time interval, say a 4-week period, then conditional on preventative measures taken by a household to reduce malaria attack, the probability of experiencing an episode, and the length of illness and associated losses in productivity for a given member of the household is largely a function of genetic endowment, general health status, and quality of medical treatment (Laxminarayan and Moeltner (2003). Given that a household has no control over the risk of contracting a disease, we treat the probability of malaria infection as exogenous, and assume the duration of illness and productivity loss to be a function of health expenditures per episode, h. This in turn, depends exogenously on prices of medical consultation and drugs p_h. As noted in chapter 3, an episode of malaria within a household implies loss in productivity for the household member for the duration of the illness. Assuming that each member of the household works 300 days per year, the total annual endowment in the absence of malaria episodes can be computed by multiplying the number of days per year times the number of working members of the household. However, if we assume that the quantity of labour available for crop production depends on the state of nature which is described by Ω, i.e. disease incidence, then the expected annual labour available under a 4weekly probability of contracting malaria, the expected available annual labour under malaria risk is given by:

$$L_e = a(\Omega - \gamma * \alpha_{v,r} * d_{v,r}(p) * \psi_{v,r}(p)) \tag{4.4}$$

where L_e is the expected annual labour in the presence of malaria , Ω is the number of days per year that a member of households can work, γ is the total number of malaria episodes per household member per year[4], $\alpha_{v,r}$ is the probability of a disease occurrence at the household level, r is the area of residence, $d_{v,r}$ is the expected duration of illness, $\psi_{v,r}$ is the productivity loss associated with member of household.

Similarly, the expected annual health expenditure associated with malaria can be expressed as:

$$AE = \gamma \sum \alpha_{v,r} \bullet h_{v,r}(d_{v,r}, p_h, Y) \tag{4.5}$$

where AE is the expected annual expenditure on malaria treatment and prevention, γ is the number of malaria episodes per household member per year assuming that each member experiences an episode of malaria after every 4 weeks ($\gamma = 52/4$), $\alpha_{v,r}$ is the probability of a disease occurrence at the household level, r is the area of residence, $d_{v,r}$ is the expected duration of illness, p_h refers to prices of medical consultation and drugs and Y is the household income. It can therefore be seen that the presence of malaria attack affects the household's optimization strategy given in equation (4.1) primarily in two ways. First it reduces the expected amount of available annual labor, and second, it imposes additional expected health costs on the household budget.

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[4] The Welfare Monitoring Survey module on health collected information on individuals who suffered malaria illness two weeks prior to the survey. Depending on the residence of the individual, and assuming that a household suffers an episode of malaria within a two week period, the total number of episodes in a year will be 26, i.e. 52/2 = 26.

of inputs, taking into account the influence of prices and illness on technology chosen. The equation satisfies the properties of a standard neoclassical production function. Household profits would however, be independent of the household head's health status if market substitutes are easily available for labour input, measured in time. Given however, the imperfect nature of the market for labour, malaria will affect crop output and farm productivity. That is, the separability between crop production and malaria will be non-existence. Malaria affects the household's optimisation problem primarily in two ways: First, it reduces the expected amount of available labour; that is, it directly affects the quality of labour supplied by the household. Thus, the effective labour L_e units supplied by the household are a function of malaria and time worked; that is $L_e = \varphi(l_s, M)$. Second, it imposes additional expected costs on the family budget, thus reducing the amount of resources that can be spent to improve productivity.

4.2.2 Household Welfare

Since Becker (1965) developed the unitary approach to decision making within a household, a number of alternative frameworks for analyzing household decision-making have been put forward. Becker's model assumes that decisions within the household are made jointly, that is, the head of household maximizes a single set of objectives for all members and that the single utility function is consistent with that of the head of the household, who makes decisions with due regard to the common good of the family.

4.2.3 The Unitary and Collective Household Models

In the unitary model, household members are assumed to share the same preferences and maximize a single utility function, implying that income is pooled and expenditures are independent of which individuals in the family receive income. This model assumes that all household members have identical preferences and outcomes represent consensus or that within the household there is a single decision maker, who makes choices for the entire household (Becker, 1974, 1981). In this model, household members derive utility from the consumption of a vector of individual commodities x (which includes goods and leisure), and which are influenced by a vector of household characteristics, z. The preference maximization problem can be written as:

The preference maximization problem can be written as:

$$Max\ U = U(x, z) \quad (4.8)$$

$$s.t.$$

$$Y = y_j + y_o + y_\lambda$$

The total household income (Y) in equation (4.8) is composed of joint income y_j and individual income, y_o and y_λ. Given that individual preferences are identical and income is pooled, the solution to the maximization problem leads to a series of demand functions for x, which are functions of prices p, total household income y and household characteristics z.

$$x_i = x_i(p, y, z) \quad (4.9)$$

For a given set of prices and pooled income, resources are allocated to household members according to their ability to translate those resources into goods from which the household derives utility.

4.2.4 The Collective Model

Another model that has been employed is the collective model which accords different decision-makers different preferences. The model also assumes that there is no unique household welfare index to be interpreted as a utility function, thereby allowing the index to be dependent on prices and incomes as well as preferences. Each household member's utility is dependent on their own and as well as the other members' consumption of a vector of goods X, which includes leisure and home produced goods.

Assuming that a household is made up of two individuals, o and λ, the household welfare is given by:

$$\text{Max } U = [U_o(x,z), U_\lambda(x,z)] \quad (4.10)$$

s.t.

$$Y = y_j + y_o + y_\lambda$$

where u is utility function. The household maximizes welfare given a budget constraint, which assumes that income is composed of joint income y_j, and individual incomes. Finding solutions to the maximisation problem gives demand functions which are a function of the vector of prices P, individual and joint incomes y_j, y_o, y_λ and household characteristics Z. Thus, the consumer's utility maximisation problem leads to a system of demand functions as follows:

$$X_i^* = x_i(p, y_j, y_o, y_\lambda, z) \quad (4.11)$$

The demand function (4.11) does not impose restrictions on the effects of individual incomes. This is in contrast to the unitary model, where the coefficients on y_o and y_λ should be zero, since a member who earns extra money should have no effect on demand and allocation on expenditures when preferences are similar. This is so because in a unitary model, household consumption is efficient irrespective of the household member who controls resource allocation.

Based on duality theorem, we can express consumer decisions in terms of expenditure or cost functions, which specify the money needed by a utility maximising household to attain a given level of utility. The determinants of household income include household labour characteristics, land and asset endowments and community level factors. A larger degree of illness in the household will however, have a negative effect on household welfare. In addition, time constraints will also reduce household income.

Based on (4.11) we can derive the total household income. We assume that the household income is a function of a vector z_i of household characteristics and malaria prevalence (M) however, is associated with a loss of earnings capacity mainly due to reduction in labour supply or reduced labour productivity. Earlier works in this area include Bartel and Taubman (1979) who find that the presence of various diseases decreases labour supply and hence wage earnings. A similar study by Berkowitz et al., (1983) examined the impact of health on wages, labour supply and annual earnings. They found a negative correlation between poor health indicators and wages. Using single equation fixed effects and random effects instrumental variable estimators, Conntoyannis and Rice, (2001) found a significant impact of psychological well-being on the hourly wage for men and on self assessed health on women's wage. They expressed wage as a function of self assessed health indicators, marital status, work experience, age, occupational class and education among other variables.. The idea of health having an effect on wages or earnings is theoretically grounded in the concept of individual health as a component of human capital.

Thus, by expanding the standard Mincerian wage function with variables related to personal characteristics (X), health indicator (M) and community characteristics (Z) the wage earnings function can be expressed as:

$$\ln(W_i) = \alpha + \Sigma\beta_k X_{ik} + \delta M + \psi Z_i + \varepsilon \tag{4.14}$$

Where $\ln W_i$ is the log of monthly wage for individual i, X is a vector of personal characteristics such as education dummies[5], age and its square, work experience, sex, and marital status; M represents malaria prevalence rate, Z is a vector of community variables such as residence location, access to local community infrastructures such as distance to the market and health facility. In addition to malaria, an additional health indicator variable, the prevalence of other diseases showing the number of household members afflicted by other diseases can also be included in the specification. The coefficients α, β_k, δ, and ψ are the parameters to be estimated and, ε is the disturbance term. The observed concave profile for lifetime earnings is captured by the experience and quadratic experience variables, measured by years of work, or approximated by age, with positive and negative values of the coefficients, respectively. The parameter of interest is the coefficient on M, which shows the

[5] Education dummies represent the different education levels. In our study, we constructed five dummy variables, none, pre-primary, primary, secondary, tertiary and university education. Pre-primary for example, takes the value of 1 for household heads who only attained pre-primary education. The reference group in our estimation is primary education.

effects of malaria on wage earnings. Based on evidence from empirical literature, we expect a negative coefficient on M. The rest of the coefficients represent the effects of the independent variables on monthly wage earnings. The error term (ε) captures the combined effects of other factors that influence the individual's wage and is ~ NID $(0, \varepsilon)$ (i.e. the residuals are independently and normally distributed with mean zero and a common variance).

4.3 Econometric Models

The economic burden of malaria is analysed using three stochastic relationships, namely, farm production function, to measure the impact of malaria on crop production; the household income function, to examine the impact of malaria on total household income; and wage function, to estimate the effect of malaria on labour earnings. We follow Audibert, (1986); Wang'ombe and Mwabu (1993); Strauss and Thomas (1998); Mwabu (2007); Laxminarayan and Klaus (2003); Laxminarayan, (2004) and Pandey, (2001) in specifying equations for measuring effects of malaria on farm outputs, household income and wages. The general form estimating models can be stated as follows:

$$Q = F(X, M, Z, \varepsilon_1) \tag{4.15}$$

$$Y = G(S, M, Z, \varepsilon_2) \tag{4.16}$$

$$W = H(K, M, Z, \varepsilon_3) \tag{4.17}$$

Where

Q = value of agricultural output in Kenya shillings;

X = a vector of quantities of physical inputs such as land holding and fertilisers;

M = malaria prevalence or malaria episode;

Z = a vector of variables that characterize the individual household such as age, sex, location and occupation;

Y = total household income;

S = a vector of community level variables such as availability of a health facility, environmental conditions and fiscal resources available to communities;

W = monthly wage earnings;

K = a vector of human capital variables in a wage function (such as education, experience and experience squared);

ε = represents factors that are known to the household but are not measured in the survey and, hence, unobserved by the analyst.

4.4 Mitigating the Effects of Malaria

One of the key contributions of this thesis is to assess whether government policies such expenditure on malaria prevention and treatment and investments in education can mitigate the economic burden of malaria on households. As noted earlier, education is one of the strongest predictors of good health, and a few studies have examined its role in reducing disease burden (see for example Mwabu 2002; Appleton, 2000; Phillips, 1994 and McCarthy et al., 1999). These authors argue that education can reduce the effect of a disease and hence increase worker productivity and labour supply. Thus, 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. That is, the more educated the individuals are, the greater the likelihood of them using malaria prevention measures and hence, the more likely they are to reduce the burden of malaria.

Furthermore, evidence also indicates that virtually all countries that managed to eradicate malaria had invested substantial amounts of money in malaria control and treatment (Mitra and Tren, 2002) and in public education. Empirical evidence demonstrates that reductions in malaria incidence through government-financed malaria control programmes can contribute to higher household income for all households living in endemic areas. In Vietnam, increase in government investment in malaria treatment and control was associated with significant reduction in malaria incidence and subsequent rise in standards of living (Laxminarayan, 2004).

The common approach to measuring the effect of a policy variable on the dependent variable is through the use of interaction terms. In this thesis, we examine the hypothesis that government policies related to education and spending on malaria prevention and treatment can mitigate the impact of malaria by using a simple production function shown in equation (4.17).

can mitigate the impact of malaria by using a simple production function shown in equation (4.17).

Consider the following specific functional form of equation (4.15).

$$Q = \alpha + X\beta + \theta M + \varepsilon \qquad (4.18)$$

where

Q is the farm output 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, then equation (4.18) shows the relationship between malaria and crop production. Based on evidence from the literature, the effect of malaria is negative, implying that farm production is lower if a member of the household suffers malaria. Assuming that malaria is 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 can be written as:

$$\hat{Q} = \alpha + X\hat{\beta} + \hat{\theta} \qquad (4.19)$$

The equation shows predicted crop production conditional on the household and individual characteristics and malaria prevalence. Given that the coefficient for malaria is negative, the predicted Q is hypothesised to be lower. If however, no household member suffers from malaria illness (i.e. M = 0), then we would expect output to be higher. Several researchers have however shown that, through the coping process within the family labour pool and the extra intra-family substitution of time, a decrease in production caused by loss of productivity due to poor health can be avoided.

Including the interaction terms, equation (4.18) can then be re-written as follows (see Mwabu, 2007):

$$Q = \alpha + X\beta + \theta \cdot M + \delta G + \varphi(M \cdot G) + \varepsilon \qquad (4.20a)$$

Where, G is government expenditure on malaria control activities. If malaria dummy is set equal to one, then equation (4.20a) would read:

$$Q = (\alpha + \theta) + X\beta + (\delta + \varphi)G + \varepsilon \qquad (4.20b)$$

If $\delta > 0$, then it implies that government expenditure on malaria control 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 in malaria control might also make schooling better. If on the other hand $\varphi > 0$, then government expenditure reduces intensity of malaria infection and also helps cultivation of new land, thus increasing output. As indicated earlier, malaria reduces effort and labour supply but this negative effect is overcome by the positive effect of the malaria control programme.

Thus, inclusion of policy variables in equation (4.20b) reduces, at least in theory, the effect of malaria on crop output. From the human capital literature, improvement in education have been seen as essential for reducing the burden of malaria since in part; the failure to adapt preventive and control measures by the people are the outcome of low levels of literacy that impede access to information relating to malaria control and treatment. Raising educational attainment is therefore an important element in any successful strategy for responding effectively to the malaria burden.

The economic burden of malaria can be calculated using the following expression:

$$\Psi = [\exp(\hat{\theta}) - 1] \cdot 100 \qquad (4.21)$$

In this equation, the economic burden of malaria is represented by ψ which is the percentage decline in crop output, household income or wage earnings associated with malaria. The parameter "theta hat" in equation (4.21) is necessarily negative.

4.5 Estimation Issues

4.5.1 Endogeneity of Malaria

In estimating crop production, household welfare and wage earnings, certain econometric specifications need to be taken into account. Since malaria illness is self reported in the welfare monitoring survey data used in this thesis, some households might tend to under-report illness while others might over-report illness. If this is the case, then it will be hard to separate the effect of malaria illness on crop production, household welfare and wage earnings from the effect of the reporting error.

Second, it is possible that we may encounter the problem of simultaneity which is due to the possibility of reverse causality between crop production, household income or wage earnings and malaria. This relationship implies that an increase in malaria episode in a household might reduce worker productivity and hence crop output. On the other hand, an increase in farm output might improve the household income status, which in turn would improve the household's ability to seek prompt treatment or adopt control and preventive measures against malaria. The causation might also run from changes in household income influencing the likelihood of malaria illness. This is a common problem faced by researchers using health reported data.

4.5.2 Using Instrumental Variables to Deal With Endogeneity

The econometrics literature suggests useful methods for tackling the endogeneity problem. Among the common approaches to this problem, is the use of instrumental variable two stage least square (2SLS) method. The 2SLS estimation procedure is used to address the problems relating to measurement error bias, simultaneity and omitted variables. This method requires identification of an observable variable or instrument that is correlated with the endogenous variable but uncorrelated with the error term (see for example, Wooldridge, (2002); Behrman and Deolalikar (1988); Griliches and Mairess, (1998); and Ackerberg and Caves, (2003). The challenge however, is to identify an observable variable, z_i, that satisfies two conditions. First, the selected variable is uncorrelated with the error term. This means that the $\text{cov}(z_i, \varepsilon) = 0$, that is, z_i, is exogenous in estimation equation.

The second requirement involves the relationship between the identified instrument, z_i, and malaria. This means that the identified variable should have an impact on malaria; i.e., z must be relevant. This requires regressing malaria prevalence against all the exogenous variables, including the instrument (Wooldridge, 2002; Greene, 2000). In the first regression, the variables should return significant coefficients when the choice variable (malaria) is regressed on the identifying variable in the company of all other variables (Ackerberg and Caves, 2003; Baum and Schaffer, 2003).

To deal with the endogeneity of malaria, we used data from the 1994 and 1997 surveys which provide information on time taken to the river during the wet and dry seasons as well as time taken to reach the source of firewood to instrument malaria. Distance to health facilities was also used to instrument malaria. Theoretically, 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, household income and wages. That is, we expect the proportion of household members inflicted with malaria to increase with distance to the river or to the source of domestic energy. Hence, we estimate the regression equations (4.15), (4.16) and (4.17) using our estimate of malaria to control for the endogeneity problem.

For instance, equation (4.17) is estimated as follows:

$$\ln (w_i) = \alpha + \sum \beta_k S_{ik} + \delta M^* + \psi Z_i + \varepsilon^* \qquad (4.22)$$

where M^* is the predicted value of malaria and ε^* is an error term that is uncorrelated with M^*. To obtain M^* and ε^*, equation (4.23), which is the first stage regression, is estimated.

$$M = \beta_0 + \beta_1 X + \beta_2 S + \beta_3 F + \beta_4 V + \mu \qquad (4.23)$$

Where; X, S and F are as defined in equations (4.15), (4.16), and (4.17), and V is a vector of identifying instruments for malaria. The term μ is assumed to be well behaved (i.e. independently and identically distributed, i.i.d.) with mean zero and constant variance.

The malaria instruments V are valid if they are strongly correlated with malaria and uncorrelated with the error term in equation (4.22). That is, after controlling for malaria, the effect of the V vector of instruments on outcome variables should be close to zero. The limitations of instrumental variables approach to the estimation of causal effects are in Bound et al., (1995). Strauss and Thomas, (2007) discuss advantages of experimental methods in dealing with endogeneity problem, as well as highlighting disadvantages of these new approaches.

4.6 Hypotheses to be tested

This study tests two hypotheses. The first hypothesis is that "Malaria has no effect on farm output, household income and earnings". This hypothesis is tested by estimating three production functions, farm output, household income and wage production functions. It is expected that an increase in the prevalence of malaria leads to a substantial reduction in crop output, household income and earnings. The second hypothesis is that the economic burden of malaria does not differ by the education level of household members and with government expenditure on malaria control programme. This hypothesis is tested by examining the effects that the interactions of government expenditure and malaria and schooling and malaria have on crop production, household income and wage earnings. This hypothesis is important because it suggests that investment in malaria control interventions and schooling might be important policies for mitigating malaria effects.

4.7 Definition and Measurement of Variables

In this sub-section, we provide a definition of variables used in estimation of the various equations. The dependent variables are the value of farm output produced by households, household income and wage earnings. Both the dependent and independent sets of variables were constructed from the 1994 and 1997 welfare monitoring survey data.

4.7.1 Dependent variables

CROPPROD (farm output) is defined as the total value of crop production in Kenya Shillings. The total crop value was computed from individual data set and comprises of total value of crop sales, total value of crops consumed and total value of stocks, all expressed in Kenya shillings. We aggregated the value of different crops reported in the welfare monitoring survey to construct the value of farm output. This was then merged with household data to obtain the value of crop output at the household level.

The household income variable, INCOME, measures the natural log of total household income in Kenya shillings for 1994 and 1997. The household income data includes several sources of income including annual wages, salaries, profits and income from the sale of crops and other assets such as livestock.

Wage earnings were constructed as mean of off-farm income reported for different sources except farm income. The wages were estimated from a sample of household members between 15 years and 65 years. For purposes of econometric analysis, we include wages of those who are working in non-agricultural related activities and in the other sectors of the economy as reported in the WMS II and WMS III.

4.7.2 Explanatory variables

The key explanatory variable of focus in this study is malaria prevalence. The health status of the household members was indicated by the occurrence of self-reported malaria illness two weeks prior to the surveys. We constructed two indicators of malaria prevalence, a continuous variable and a dummy variable. The continuous variable, which measures the proportion of household members reporting an episode of malaria two weeks prior to the survey was computed by dividing the number of cases reported in a household by the total number of household members. We also derived a dummy variable for malaria taking the value of 1 if the household reported having a member inflicted with malaria two weeks prior to the survey and 0 otherwise. We further constructed a continuous variable and a dummy variable for other diseases. We expect the malaria effect in all the specifications to be negative, implying that as the prevalence of malaria rises, less output is produced.

We approximated the human capital of the household head by level of education and experience. We constructed six dummy variables for education levels namely; none, pre-primary education, primary education, secondary education, technical education and university education. Evidence from the literature indicates that education has a positive effect on crop production, household welfare and on wage earnings. However, the effect of levels of education on crop production is mixed and unpredictable a priori. Some studies find primary and secondary education levels to be positively associated with crop production; however, the effects of other education levels on crop production, household income and on wage earnings are undetermined. Based on previous studies, the effect of schooling on household income and individual wage earnings is hypothesized to be positive.

The age of the head of household could have a positive or a negative effect upon the farm output, household income and wage earnings. Psacharopoulos, (1994) observes that wage earnings and income increase with age and work experience up to around 30 years of experience. In our empirical model, we use age squared of the household head to capture experience in wage employment. Previous studies have shown that income and therefore welfare may fall at older ages with the retirement and declining productivity. A negative relationship is therefore hypothesised between welfare, wage earnings and the square of age. Also, based on past studies, the coefficient on experience is hypothesized to be positive in all specifications. This demonstrates that there is a correlation between the length of years spent at a certain employment opportunity, and the increase in skill acquisition. Furthermore, crop production, wage earnings or household income rise with an increase in the acquisition of skills. The decline in wage earnings close to retirement can be explained by either a decrease in hours worked, or by less overtime.

With respect to crop production, the effect of age and its square is hypothesised to be positive because households with many years of experience in a certain crop are expected to have a higher farm output. We hypothesise the coefficient on experience to be positive, while that on experience squared is negative.

Household size is used in this dissertation as a measure for family labour. We included household size in our estimation for two reasons. First, household size can influence household's labour endowment just like malaria illness. Second, household size might be endogenenous to malaria in which case we need to instrument for the household size. There could be certain characteristics of the household that could be affecting crop production or household income which might be correlated with malaria as well as household size. Where applicable, we used actual hours spent in crop production to proxy household size. Household size is expected to have a positive effect on crop production since a household with many members has a pool of workers to even substitute for the sick household member, thus minimising the effect of malaria on crop production. With respect to income, the larger the family size and the greater the number of household members working, the greater the likelihood that the household will have high income relative to smaller households.

Based on previous studies, the effect of gender on crop production, household income and wage earnings remains unclear. A dummy variable taking the value of 1 for male headed households and 0 otherwise was used. The size of land holding, measured in acres, is one of the factors that have been hypothesized as a determinant of crop production. Most studies find a positive and statistically significant relationship between farm size and crop production. This is plausible because the greater the size of the land devoted to crop farming, the greater is the opportunity to apply new technologies e.g. fertilisers, and hence farmers could be expected to be more efficient. Its effect on household income and wage earnings is however, uncertain.

Fertilizer is one of the land augmenting inputs that is likely to enhance crop production. It is widely acknowledged that the use of fertilizers leads to higher yields. A number of studies have found positive and significant statistical relationships between fertilizer use and farm yields. Studies undertaken in Kenya have, however, shown that the use of fertilizer is still very low especially among subsistence farmers. Two indicator variables were generated, a dummy variable indicating whether a household applied fertilizers, and a continuous variable showing the quantity of fertilizers used. A positive association between crop production and fertilizer is hypothesized.

Occupation (gainful employment) is hypothesised to have a positive effect on crop production, household welfare and on wage earnings. We expect that people who have had malaria before should be more inclined to use preventive and control measures, because they know from experience the consequences of an episode of malaria. Distance to the nearest health facility captures the fact that people close to a public health facility have access to treatment and/or are less exposed to malaria infection. We hypothesise a negative correlation between distance to a public health facility and crop production to be negative. However, its effect on household welfare and on wage earnings is unclear.

A number of interaction terms were included in our specifications for crop production, household income and wage earnings. These include age and education (age*education) which indicates that as the age and education of workers increase, the income or wage level is likely to fall. The possible reason for this is that as employees become older, though their level of education is higher, their age remove them out of wage employment. This is supported by the fact that most of the workers with high education are young while most of the older ones have low education. Another interaction term, gender and education (Gender*education) suggests that no matter the level of education, incomes or wages tend to fall as gender dominance of workers changes from male to female. A negative correlation between the interaction term and household welfare or wage earnings is hypothesised. Gender*age shows that irrespective of the gender of workers, as the age of workers increases income or wages offered will also increase. Other potential explanatory variables used in the estimation models were soil conservation technologies (a dummy variable) and distance to the nearest school or market.

Differences in earnings, household welfare and in crop production between provinces are controlled for by introducing regional dummy variables. The regional dummies capture any differences in crop production due to shocks at the regional level and any other variation in characteristics across regions which can potentially influence malaria prevalence.

Few studies have shown that investment in malaria control interventions and schooling (see Laxminarayan, 2004; and Mitra and Tren, 2002) has a considerable effect in mitigating the economic burden of malaria. To capture the effect of the two policy variables, we constructed two interaction variables, malaria interaction with education, and malaria interaction with government expenditure on malaria control programmes. We hypothesise a positive association between crop production, household income and wage earnings and the interaction variables. This is plausible because if the policy variables attenuate the disease burden (which exerts a negative effect), then the coefficients of the interaction variables should be positive. The explanatory variables and the sign of their expected impact are presented in Table 4.1.

Table 4.1: 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 = female	Uncertain	Uncertain	Uncertain

Table 4.1 continued					
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)	Positive	Positive	Positive

		leaving province 1 (Rift Valley as the reference category for crop production function) and Nairobi for household income and earnings			
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
Time	Time_health	Time taken to the nearest health facility during rain and dry season (a proxy for health infrastructure which potentially may reduce household risk of contracting malaria). On the other hand long distance to the health facility for treatment may have the opposite effect	Negative	Negative	Negative
Interaction term	Pubexp_Malaria	An interaction term = public expenditure * malaria prevalence	Positive	Positive	Positive
Interaction term	Malaria and education	An interaction term = malaria * education level	Positive	Positive	Positive
Fertiliser use	Fert_use	Proportion of households using modern farming technologies such as use of fertilisers (a continuous variable) and a dummy variable taking the value of 1 if	Positive		

		household reported using fertiliser; 0 otherwise			
Interaction term	Age_education	An interaction term = age*education	Positive	Positive	Positive
interaction term	Gender_edu	An interaction term = gender *education in years	Uncertain	Negative	Negative
Age*education		An interaction term = age* education	Uncertain	Negative	negative

4.8 Data Sources and Analytic Samples

This sub-section presents a description of the data sources and analytical samples used to perform various estimations. The data used in this survey are drawn from welfare monitoring surveys conducted by the Government of Kenya (Central Bureau of Statistics, Ministry of Finance and Planning). The surveys were aimed at enabling the government to assess the welfare of the people. The 1994 data was administered from June to July in all the districts and covered 10,857 households consisting of 59,183 individuals. The 1997 covered 10,873 households, comprising 47,684 individuals drawn from 1,107 clusters of the National Sample Survey and Evaluation Programme (NASSEP III)[6].

The WMS data provided information on individual and household socio-economic characteristics such as gender of household head, marital status, age, health, fertility rates, and household size, education level of household head, occupation of household members, job experience, child nutrition and social amenities. More importantly, both surveys collected measurement of subsistence and cash income, farm level production, value of inputs, farm output, variety of crops, household assets, demographic information about members of the household, household consumption and expenditures, and community variables such as access to market, distance to the nearest health facility, school, river, post office or telephone and time taken to collect water and firewood. Further, the surveys collected information on community variables such as urban/rural residence, provinces, and access to a health facility. Besides, the WMS contain information on incidence of malaria and other diseases (self-reported) by category of illness, two weeks prior to the surveys.

The data from the WMS was augmented with information on government expenditure on malaria prevention and treatment which were merged with the individual household survey data. The division for malaria control in the Ministry of Health and budget estimates contained in printed budget estimates provided the expenditure by government, bilateral and multilateral organizations. Because the information on expenditure on malaria treatment and control is not sufficient in explaining how much each household is entitled for, we assumed

6 It is imperative to note that although the data used in this study was collected in 1994 and 1997, the information is still relevant for our analysis and for policy direction because the structures that are under investigation remain almost the same.

that each household within a district received an equal share of government allocation within a district.

In order to estimate the economic impact of malaria at the household level, it was important to construct analytical samples for crop production, income and wage earnings. The samples were derived from the full probability samples of 59,183 and 47,684 individuals for 1994 and 1997, respectively. The first step in constructing the analytic samples involved merging individual data sets with the corresponding data sets containing household socio-economic characteristics. This involved matching individual characteristics with relevant characteristics of their own households. Individual characteristics which had no corresponding household characteristics were dropped from the merged data. The next step involved placing restrictions on the merged data to obtain the final analytic samples. Three analytic samples were constructed: a full sample comprising households inflicted with malaria and other diseases, a sub-sample of healthy individuals and those having malaria and for which data on relevant variables used in the estimation was available, and finally a sub-sample consisting of healthy individuals and those inflicted by other diseases. The sub-samples containing a dummy variable for malaria and other diseases was obtained from the larger sample by considering only the households inflicted by either malaria orother diseases.

Finally, we constructed two indicator variables for malaria: 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 two weeks prior to the survey. The dummy variable measure indicates a malaria episode at the individual level, whilst the continuous variable is an indicator variable showing the prevalence of malaria at the household level. A dummy variable and a continuous variable for other diseases were also constructed similarly.

CHAPTER FIVE: EMPIRICAL RESULTS

5.1 Introduction

In this chapter, we report the empirical results for crop, welfare and wage earnings models. The empirical results are presented separately for 1994 and 1997. In addition, several remarks regarding the empirical results are in order. First, the results presented below are obtained using two sub-samples for each of the household functions. In the first sub-sample we analyse the effect of the proportion of household members afflicted by malaria and other diseases on crop production, wages and household incomes. Next, we estimate the same functions using a sub-sample consisting of healthy individuals and individuals afflicted by malaria. The idea of having different sub-samples is to determine whether the magnitude of the disease differs significantly among malaria-afflicted households compared with populations affected by other diseases. In the three sets of descriptive statistics presented below, the statistic for a given variable, (e.g. age) might differ across analytic samples for the same year (e.g. 1994) because of differences in the number of observations in the various sub-samples.

5.2 Summary Statistics

5.2.1 Variables Included in the Crop Production Model

The summary statistics of the variables considered in this study are reported in Tables 5.1, 5.2 and 5.3. From Table 5.1, we observe that 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 1994 and 1997, respectively. The mean age of the household head was 45 years and 30 years in 1994 and 1997, respectively while the average household size in the sample for 1994 and 1997 was 5.5 and 5.2 persons, respectively.. Only 29.8% and 42.1% of the households in the 1994 and 1997 samples indicated having used fertiliser. The average number of years of schooling of household head was 6.4 years for the 1994 sample and 4.7 years for the 1997 sample. With regard to levels of education, 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. The data also shows that 34% had no education at all for 1997 sample.

Table 5.1 further shows that only 3.3% and 2.5% of the households in the 1994 and 1997 samples respectively were resident in the urban areas and that the mean log of crop output was 9.25 and 7.47 for 1994 and 1997, respectively. For the 1994 analytical sample, on average, households took about 23 minutes to reach to the water source during the rain season and about 47 minutes during the dry season. Similarly, it took about 24 minutes to reach the water source during the rain season and 34 minutes during the dry season in the 1997 sample. It is apparent from this table that the time taken to the water point during the dry season in the 1994 was significantly lower than that of 1997. The difference could be due to differences in the intensity of rainfall between the two periods. For example, the 1994 period was characterised by prolonged drought while in 1997 the country experienced the El Nino rains.

Table 5.1: Variables Included in the Crop Production Model

	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

5.2.2 Variables Included in the Household Income Model

The most noteworthy observation in this table is the decline in the prevalence of malaria and that of other diseases from approximately 14% in 1994 to about 9% in 1997. This however could be a reflection of the change in the sampling frame. Malaria prevalence can be interpreted as the risk of experiencing an episode of malaria during a two-week period for any member of household living in a given area. Overall, the mean annual income of the 1994 analytic sample was log 9.91 with a standard deviation of 1.52 while the mean annual income for 1997 was log 7.24 with a standard deviation of 2.10. The mean age of the head of the household was 44 years in the 1994 and 45 years in 1997.

The average number of years of schooling of household head was 6 in both the 1994 and 1997 analytic samples. The mean household size was 5.4 and 4.9 persons in 1994 and 1997, respectively. The decline in the mean size of household members was mainly because of declining fertility rate. On average, the household took 24 and 48 minutes walking to the water source during the wet and dry season, respectively, and 58 minutes walking to the source of firewood. The average time to collect water and firewood was much lower in 1997, averaging 14 minutes and 21 minutes during the wet and dry seasons, respectively.

Other characteristics that might affect household income include size of land, participation in gainful employment, and the amount of rainfall in an area. Table 5.2 indicates that on average, the majority of households had 5 and 1.1 acres of crop land in 1994 and 1997, respectively. A comparison of the WMS II and WMS III shows that agricultural land holding sizes substantially reduced in the period between the two surveys. A plausible explanation for the difference in land holding sizes is because the 1994 data includes all the land used for crop farming and livestock rearing activities, whereas the 1997 sample contained land strictly used for crop farming activities (Republic of Kenya, 1996 and 1997).

Table 5.2: Variables Included in the Household Income Model

Variable	1994			1997		
	Observations	Mean	SD	Observations	Mean	SD
Malaria prevalence	8144	0.146	0.234	8414	0.092	0.197
Prevalence of other diseases	8144	0.138	0.232	8414	0.080	0.181
Age in years	8144	44.46	14.63	8414	45.60	14.9
Yeas of Schooling	8144	6.536	11.42	8414	6.230	4.54
Sex (1= Male; 0 = Female)	…	…	…	8414	0.711	.453
Married	8144	0.321	0.467	8414	0.777	0.415
Single	…	…	…	8414	0.580	0.493
Other marital status	…	…	…	8414	0.086	0.281
Pre_primary level (=1)	8144	0.028	0.167	8414	…	…
Primary level (=1)	8144	0.428	0.494	8414	0.481	0.499
Secondary level (=1)	8144	0.109	0.312	8414	0.131	0.337
Tertiary level (=1)	8144	0.008	0.092	8414	0.013	0.113
University level (=1)	8144	0.002	0.053	8414	…	…
No education (=1)	8144	0.412	0.492	8414	0.337	0.472
Household Size	8144	5.47	2.90	8414	4.980	2.74
Log Household Income	8087	9.91	1.52	8414	7.240	2.10
Time taken to river during wet season (Minutes)	8117	24.3	30.96	8409	14.30	14.5
Time taken to river during dry season (Minutes)	8117	48.4	190	8409	21.90	19.1
Time taken to source of firewood (Minutes)	8117	58.7	74.2	…	…	…
Distance to a health facility (Minutes)	…	…	…	…	5.809	1.70
Experience in years	7933	16.8	12.8	…	…	…
Residence (1=rural; 0 = Urban)	8144	0.915	0.278	8414	0.887	0.315
Gainful Employment	…	…	…	8414	0.743	0.436
Agricultural land in acres	8117	4.98	36.38	…	1.160	7.45
Rainfall (mm)	7161	1175	383	8414	0.686	0.796
Nairobi province (=1)	8144	0.009	0.099	8414	0.023	0.151
Central Province (=1)	8144	0.176	0.381	8414	0.161	0.367
Coast province (=1)	8144	0.073	0.261	8414	0.094	0.291
Eastern Province (=1)	8144	0.158	0.365	8414	0.156	0.363
Nyanza Province (=1)	8144	0.200	0.400	8414	0.193	0.394
Rift valley province (=1)	8144	0.245	0.430	8414	0.272	0.445
Western Province (=1)	8144	0.110	0.313	8414	0.098	0.297

5.2.3 Variables Included in the Earnings Model

Table 5.3 presents the sample means of the variables used in the wage equation. The Table reveals a significant variation in the total wage earnings in the two years, which was Log 10.4 and Log 7.07 in 1994 and 1997, with a standard deviation of Log 1.11 and Log 1.76 for 1994 and 1997, respectively. Like in the previous tables, on average malaria prevalence among households who reported having a malaria episode two weeks prior to the survey was higher in 1994 (13.8%) than for the 1997 (8.8%). The prevalence of other diseases in 1994 and 1997 sub-sample, on average, stood at 12.2% and 8.84%, respectively. Turning to the household size, we find the average household size was about 5.6 for the 1994 sample with a standard deviation of 2.7, whilst the household size for 1997 was 6.9 persons per household with a standard deviation of 2.6. The increase in the mean of household size is in contrast to the evidence from the Kenya Demographic and Health Surveys (KDHS) of 1993 and 1998 which indicates that fertility in Kenya during this period continued to decline. The higher fertility rate for the 1997 could be due to the sample used rather than the national total fertility rate.

The mean age in this sub-sample was 39 and 28 years in 1994 and 1997, with a standard deviation of 10.6 years and 14 years respectively. In 1994, the average number of years of schooling of a household head was 6.4 years and approximately 6.1 years in 1997, with a standard deviation of about 15 years and 4 years, respectively. As can be seen in Table 5.3, there are pronounced differences in the two sub-samples between individuals with secondary, tertiary and university education. About 43% of the individuals had primary education in the 1994 sub-sample. This figure rose to 54% in 1997. In 1994 sub-sample, almost 26% of the household heads had secondary education, 2.5% tertiary education, and 1.2% university education. The respective figures for the 1997 sub-sample were 10%, 0.35% and 0.37%, respectively. The data further indicates that about 25% of the household heads in 1994 and 5% in 1997 did not have any formal education. A striking feature of the data in the two years is that less than 5% of the respondents had attained tertiary or university education.

In the 1994 wage earnings sample, households took about 23 minutes on average to reach the water source during the rain season and about 47 minutes during the dry season. In 1997, the time varied from 24 minutes during the rain season to 34 minutes during the dry season. Approximately 18% of the respondents in the 1994 sample had residence in the urban areas. The means for land and experience variables were 3.5 acres and 13.3 years, respectively in 1994.

Table 5.3: Variables Included in the Earnings Models

		1994			1997	
Variables	**Observations**	**Mean**	**SD**	**Observations**	**Mean**	**SD**
Malaria prevalence	3115	0.138	0.22	4750	0.088	0.154
Prevalence of other diseases	3115	0.121	0.195	4750	0.088	0.162
Household Size	3115	5.580	2.74	4750	6.940	2.680
Log mean wage (in Kshs per year)	3115	10.4	1.11	4750	7.07	1.76
Age in Years	3115	39.6	10.6	4750	28	14
Sex (1= Male; 0 = Female)	3115	0.783	0.41	4750	0.490	0.499
Time taken to river during wet season (Minutes)	3102	23.20	31.3	4750	24.2	14.4
Time taken to river during dry season (Minutes)	3102	46.9	177	4750	34	20.0
Time t taken o source of firewood (Minutes)	3102	49.8	69.3	4750	...	...
Education in years	3115	6.44	12.7	4750	5.09	4.35
Pre-primary Level	3115	0.004	0.066	4750	...	...
Primary Level (=1)	3115	0.429	0.495	4750	0.591	0.49
Secondary Level (=1)	3115	0.264	0.441	4750	0.110	0.313
Tertiary Level (=1)	3115	0.025	0.158	4750	0.003	0.059
University Level (=1)	3115	0.012	0.106	4750	0.003	0.061
No Education (=1)	3115	0.246	0.431	4750	0.298	0.457
Agricultural land in acres	3102	3.50	7.64		...	...
Experience in years	3042	13.3	9.76		...	...
Residence (1=rural; 0 = Urban)	3115	0.823	0.381	4750	0.953	0.211

5.3 Estimation Results

5.3.1 Introduction

This section reports estimated effects of malaria on crop output, household income and earnings. The results are presented in Tables 5.4-5.6 for the 1994 sample and tables 5.7 and 5.8 for the 1997 sample. Column (1) of Table 5.4 reports OLS estimates with malaria measured as a continuous variable. Column (2) reports the OLS estimates with five additional explanatory variables distinguishing among five regions in Kenya. The regional dummies are included to account for unobserved regional specific variables. Because malaria is endogenous to crop output, we estimate our model using the 2SLS method. Column (3) and column (4) therefore reports crop production equation using two stage least squares (2SLS). In addition to the covariates included in column (3), column (4) adds regional dummies with Rift Valley as the reference province. Malaria was instrumented with time taken to the river during the wet and dry seasons and time taken by the household to collect firewood.

5.3.2 Impact of Malaria on Crop Production

For the 1994 data, the results show that the coefficient on malaria is negative and statistically significant at the 1% level. 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% level increase in the prevalence of other diseases reduces crop output by 0.18%. Similarly, for the 1997 sample, the results show that an increase in the proportion of household members afflicted by malaria by 10% was associated with a decline of 4.3% in crop output. The coefficient on other diseases for both 1994 and 1997 is negative as predicted and is statistically significant at the 10% level for the 1994 sub-sample. It can also been seen from table 5.4 that an increase in the proportion of household members inflicted with malaria and other diseases on crop production persists irrespective of the type of estimation method used.

Estimates based on the 2SLS method are reported in columns (3) and (4) whilst the first stage least squares estimates for 1994 and 1997 sub-samples are presented in Table A1 and A2 in the appendix. In estimating the crop production function, we first predicted malaria using all the explanatory variables in equations (4.15), (4.16) and (4.17). 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. As noted, the instruments for malaria must be correlated with malaria, and uncorrelated with the error term. A statistic commonly used, as recommended by Bound et al., (1995), is the R^2 of the first stage regression. According to Hahn and Hausman, (2002b), if the explanatory power in the first stage regression is zero, the model is in effect unidentified with respect to the endogenous variable. An alternative measure is the F-test of the joint significance of the Z_1 instruments in the first stage regression. According to Staiger and Stock, for a single endogenous regressor, an F-statistic of 10 and above is recommended. Staiger and Stock further points out that an F-test could be relevant provided that the instruments are supported by economic theory. The calculated value for the F-test was 3.42, which is below 10. Although this shows that the strength of the instruments in explaining the variations in the malaria prevalence is low, basic economic theory shows that the selected instruments are obviously correlated with malaria.

Looking at column (3) in Table 5.4, 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%[7] in crop production for that year. In column (4) which includes regional dummy variables, reduction in the log of crop production is 4.22. This is equivalent to a loss of 67% in crop production. The results imply that households inflicted by malaria lost a significant proportion of their crop production due to malaria related illnesses. The results provide evidence on the impact of morbidity due to malaria on efficiency and production. The empirical evidence presented in Table 5.4 clearly shows that malaria illness experienced by a member of a household does significantly reduce 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 (see Olagoke, 2007). Crop production losses can be large, as indicated in table 5.4 if malaria in the household coincides with critical farming activities such as planting, weeding or

7 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 $100\cdot\Psi=100\cdot(\exp(\beta)-1)$.

protecting crops from predators. Looking at the OLS estimates (model 2) for 1994, one can see that the negative effect of malaria on crop production is almost two times the effect of other diseases and 5 times smaller than the effect obtained using 2SLS. That is, the IV estimate of the effect of malaria is much higher than the corresponding OLS estimate (see Table 5.4).

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. 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 effects of secondary education on logs of crop output increased to 0.127 and 0.474 in both 1994 and 1997, respectively. The effect of university education on crop production is lower in both 1994 and 1997 than that associated with secondary education. The results further shows that relative to a household where the head of household had no education at all, a household head with primary level of education (1-8 years of schooling) had 0.239 higher logs of crop output. The coefficient on pre-primary education is negative as predicted but not statistically significant showing that relative to a household head with primary education, the log of farm output for that household was 0.13 lower.

Although the coefficient on tertiary education is positive in 1994 sample, it is not statistically significant. Similar findings are reported for the 1997 sample, except that the coefficient on tertiary/university schooling is negative. 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. Our results are similar to previous studies which find that primary and secondary education levels are important determinants of crop production relative to tertiary education. Appleton (2000) for example, found that households with 4 years of schooling were more productive in agriculture than those with tertiary education level. The study findings further showed that four years of farmer education were associated with a 10% rise in agricultural production. Earlier studies by Appleton and Balihuta, (1996) and Weir, (1999) found non-monotonic effects of education with more than 7 years of schooling being associated with lower productivity. They showed that farmers with secondary education tended to reallocate labour from the farm to non-farm self-employment and wage employment.

The coefficient on land is positive and statistically significant at 1% level for both 1994 and 1997 samples. This is a strong result, since the model specification holds land area cultivated constant, implying that production rises with land holding. In particular, a 1% increase in land holding increases crop output by 0.32% and 0.29%, respectively for 1994 and 1997 (OLS estimates). Its effect continues to be positive and statistically significant at the 1% level even when estimated using 2SLS method. The coefficient on age is negative and statistically significant at the 5% level for 1994 and 1997 data. The negative effect continues irrespective of the estimation method, but it is not statistically significant when estimated using the 2SLS method.

The household potential experience in crop farming represented by age squared (for 1994) is mixed. For the 1994 data, the coefficient on experience of the head of household in crop farming is positive as predicted, and is statistically significant at the 1% level (OLS estimates). The coefficient remains positive and statistically significant when estimated using the 2SLS. In Table 5.5, which presents estimation results for the 1997 sample, the coefficient on age squared (a proxy for experience) obtained by OLS and 2SLS methods is negative and statistically significant at the 5% and 1% levels. The effect of marital status is mixed; it is negative and statistically significant at the 1% level when estimated using the OLS technique, but is not statistically significant when estimated using the 2SLS method. The negative coefficient indicates that crop production was higher among women than men. This is not surprising given that most of the subsistence farming in rural areas is done mainly by women. The results clearly show that women contribute more to crop production than men.

As predicted, the number of hours spent in farming has a positive association with crop production. For the 1997 sample, the coefficient is large and statistically significant at the 1% level irrespective of the estimation method. It may thus, be argued that households who spent significant amount of their time on the farm are more likely to be more knowledgeable about farming technologies; hence the discernible effect of actual hours spent farming. On the other hand it may be argued that by spending more time on crop farming, households gather specific crop production skills that enable them to realise high crop yields.

The remaining regressors are rainfall, time taken to the nearest health facility, fertiliser use, soil conservation and regional dummies. In columns 1-4 in table (5.4), the coefficient on rainfall is positive as predicted, and is statistically different from zero for 1994 and 1997 sub-samples. For the 1997 sub-sample, the coefficient on time taken to a health facility is negatively correlated with crop production regardless of the estimation method. We use time taken to the health facility as a proxy for the price of malaria treatment. This variable was also used as an instrument for malaria. 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. For the 1997 sub-sample the coefficient on soil conservation is statistically significant at the 5% level and has the expected positive signs. Finally, the coefficient on fertiliser is positive and statistically significant at the 1% level.

In the 1994 sample, the coefficients on the regional dummy variables 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.

Table 5.4: Estimates 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 Worked	0.0363 (0.019)	1.95**	0.021 (0.018)	1.170	0.091 (0.031)	2.93***	0.016 (0.039)	0.42
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 5.5: 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.

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 5.6 and 5.7 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 as would be expected. 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 5.6) showing that malaria imposes large economic burden on households. In particular, 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. The main observation that emerges from this analysis is that malaria imposes a significant negative effect on crop production relative to other diseases..

Several studies have shown that coping strategies such as intra-family substitution of time determines the extent of the disease burden. The results are however mixed. For example, Pitt and Rosenzweig (1986) found no effect on farm profits, although the quantity of labour available decreased when the spouse becomes ill. In Columbia, Bonilla and Rodriguez, (1993) observed that non-wage earner family members rather than hired workers compensated for the reduction in labour resulting from ill health, as such illness in the family did not have effect on farm profits. Conly (1975) found that malaria did not reduce farm production largely because household members increased family working time so as to cope with the reduction of labour productivity. Studying the impact of Schostosomiasis on rice output and farm inputs, Audibert and Etard, (2003) noted that a reduction of family labour intensity was not followed by a reduction in rice production. They concluded that the reduction in efficiency due to illness of family workers was compensated for by family members who worked more hours. They also found that an improvement in health was associated with an increase of 69 man-days for family workers.

The results pertaining to personal characteristics of the head of the household such as the head of the household's age, experience and education are encouraging in that the signs of the regression coefficients are, in both estimation methods, as predicted. We first look at the head of household age variable. The OLS results presented in column (2) of Table 5.6 suggests that crop production is positively related to age of household head. The coefficient on age is positive and statistically significant at the 5% level. From the economic literature, the coefficient on age and its square are used to proxy for potential experience and actual experience in certain crop production. We next look at the effects of household experience of the household on crop production. Although the coefficient on experience in crop production is statistically significant at the 1% level, the sign is negative. This is not consistent with the findings from previous studies which show that households with experience in certain crop farming produce more farm output relative to those with less experience. One factor that could potentially contribute to the observed sign reversal include differences in crop quality of farm inputs at the household level.

Turning to the education variable, we find that the coefficients on education dummies are quite consistent across specifications and are statistically significant. As indicated in Table 5.6, we find that the coefficients on secondary and technical education levels are both positive and statistically significant at the 1% level and 5% level respectively. These estimates show that relative to a household where the head has primary education, a household where the head of household has secondary and tertiary education experienced a higher crop output. The negative coefficient on household with no formal education, though not statistically significant suggests that household head with at least primary education had higher crop output compared to the household head with no formal education. The coefficients on university education for the 1994 and 1997 samples are negative but not statistically significant. Although we cannot, as noted, sign a priori university education effects on crop production, it is not surprising that the effect of university education on crop production is negative. It is likely that few people with university education will be engaged in subsistence farming activities. This is consistent with labour market conditions where those with tertiary education and above work in non-agricultural settings.

Other important predictors of crop production shown in Table 5.6 and Table 5.7 include rainfall, fertiliser, and agricultural land and hours spent in crop production. As columns (1-4) show, the OLS and 2SLS coefficients on rainfall and fertiliser are positive and statistically different from zero, as predicted.. The coefficient on actual hours spent in crop production is, in all the estimation methods, statistically significant at 1% level. The coefficient on the size of household size is also statistically significant at the 1% level.

Table 5.6: 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 5.7: 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

To complete the analysis, a regression for a sub-sample was run with malaria and other diseases estimated as dummy variables. That is, the value 1 for malaria and 0 for other diseases and value of 1 for other diseases and 0 for malaria. In both cases, the comparison group is the healthy households. This is intended to compare the effect of malaria and other diseases on crop production. The results are reported in Table A3 in the appendix. Using the 2SLS estimates, we find that crop output is lower by 3.5% for households inflicted with malaria compared to healthy households. Similarly, crop output among households affected by other diseases is lower by 0.1%. As indicated earlier, malaria and other diseases have a negative effect on crop production, which accords with the sign expected. The important conclusion that emerges from this analysis is that households afflicted with malaria experience lower crop outputs than other diseases. Moreover, the burden exerted by malaria is larger than that inflicted by other diseases.

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 5.7. If education and government expenditure mitigate the negative impact exerted by malaria then we expect the coefficients for the interaction terms to be positive. A possible explanation for this finding is that 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 (Laxminarayan and Klaus, 2004, and Mitra and Tren, 2002).

Further, studies by Becker and Grossman shows that investment in human capital aimed at increasing its capacity e.g. education and health, contribute to the productivity of labour and hence lead to increased crop production. Previous studies focusing on investment in health have sought to assess the productive benefits of this form of human capital. Although most of these studies failed to show any economic effect, our findings revealed that investment in education and in malaria control programmes can generate substantial benefits to the individuals, households and to the country.

As hypothesised, the coefficients on interaction terms i.e. government expenditure and malaria and malaria and 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. Considering the effect of malaria and the interaction terms, one can see that the interaction terms will reduce the negative effect of malaria as shown below:

Crop production = 8.19- 0.325 malaria -0.017 other diseases - 0.336 sex - 0.338 age + 0.088 expenditure + 0.291rainfall -0.084 pre-primary + 0.202 secondary + 0.458 technical + 0.243 university + 0.333 land + 0.035 hours worked + 0.039 malaria pre-primary + 0.030 malaria*secondary + 0.0002 malaria * expenditure.

We can therefore see that the inclusion of interaction terms reduces the negative effect of malaria from -0.325 to -0.2948 or by 9.2%. As shown in Table 5.8, the loss in crop production is higher when estimated with the 2SLS method. In column (4) of Table 5.8 the log of crop output is -1.173 indicating a reduction of 2.23% in crop production. The effect on crop production can be explained by the increase in risk of contracting malaria for available labour supply and associated concerns for timing of agricultural activities that accompanies an increase in malaria prevalence.

If we include the interaction term of malaria with expenditure in the estimation equation the log of crop production decreases marginally to -1.1728 from the previous log of – 1.173. 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 Ramanan and Klaus, (2004) and Mitra and Tren, (2002) 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.

Table 5.8: Comparison of the impact of Malaria and other diseases on Crop Production, (1994); Dependent variable = log (crop output) (Standard errors of the estimated coefficients are shown in the parentheses)

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.

The important conclusions that can be drawn from the analysis in this section are that malaria prevalence, prevalence of other diseases, education, age, land holding and experience have significant effects on crop production. The results have also shown that the economic effect of the disease is higher among households afflicted by malaria relative to households afflicted with other diseases.

5.3.3 Impact of Malaria on Household Income

The key results reported in Table 5.9 and 5.10 are the effect of malaria on household income. The first stage estimation results are shown in Tables A4-A5 in the appendix. The OLS estimates show that the coefficient on malaria column (1) and column (2) has the expected sign. For the 1997 data, the coefficient remains negative and is statistically significant at the 5% level when estimated by OLS method. This finding implies that an increase of 10% in the proportion of household members affected by malaria reduced income by2.1% and 6% for 1994 and 1997, respectively. The negative relationship between household income and malaria is consistent with the hypothesis that malaria exerts a negative impact on household income by incapacitating available labour.

When we estimate the model by 2SLS method, the coefficient is negative and statistically significant at the 10% level for both 1994 and 1997 sub-samples. The results suggest that malaria incidence reduces the logs of household income by 4.54 and 4.55 for the 1994 and 1997 respectively. The estimates of -4.54 and -4.55 indicate that the loss in income among households afflicted by malaria is 92.6% and 93.6% for 1994 and 1997 sub-samples respectively, which are consistent with crop losses because these are agricultural households who derive their income mainly from farming. Our results support earlier estimates obtained using cost of illness approach that the economic burden of malaria on households is immense and that there is a high probability that households incur huge loses due to malaria illness (see for example Laxminarayan, 2004, Laxminarayan and Moeltner, 2003).

For both 1994 and 1997 estimates, the coefficient on age and age squared are statistically significant at the 1% level. Both the OLS and 2SLS estimates show that household income initially increases with age but declines eventually at older ages as hypothesized; the association is statistically significant in both 1994 and 1997 sub-samples. Economic theory predicts that as individuals advance in age, their inherited health stock depreciates at an increasing rate and is likely to depend on past savings. Turning to other covariates, the linear and quadratic terms of the household experience (proxied by age squared) and experience measured in the number of years in a certain job are statistically significant at the 1% level, with positive and negative signs for 1994 as expected. This means that income rises with work experience at a decreasing rate until it finally decreases with age. The coefficient on age squared is quite large, and is highly statistically significant at the 1% level. The effect on age variable in the income equation suggests age-related decrease in work-time. This can either be driven by a positive choice for more leisure at older ages, or a negative effect on work-time through generally poorer health, or both. This is consistent with Grossman's argument that because health stock depreciation rate rises with age, it is unlikely that old people will earn higher incomes than the young people.

The coefficient on place of residence (rural =1) is positive as predicted and is highly statistically significant at the 1% level. The magnitude of the coefficient shows that households residing in urban areas earn higher incomes (2.7% higher) compared to those residing in rural areas. The coefficient on marital status (1= married) (column 3) is positive for the 1994 sample but not statistically significant. Although it is expected that a married person might get spousal support, this is not borne out by our estimates. For the 1997 results, the effects of marital status on household income are similar to the 1994 results. As expected, secondary education, tertiary education and university education levels (reference group is primary education) have a positive effect as predicted and are statistically significant at the 1% level.

The coefficient on occupation of the head of household is positive and statistically significant at the 1% level. As hypothesised, the coefficient for interaction of education and malaria (OLS estimates) is positive and statistically significant at the 1% level in the 1994 sub-sample. The interaction dummy remains significant at the 1% level even when interacted with primary education. These findings provide evidence that education can mitigate the negative effects of malaria on household income.

Table 5.9: Impact of Malaria on Household Income, (1994). (Dependent variable = log (household income, Kshs) (Standard errors of the estimated coefficients are shown in the parentheses).

	OLS Estimates				**2SLS Estimates**	
	(1)		(2)		(3)	
Explanatory variables	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**	**2 SLS Estimates**	**t-ratio**
Malaria prevalence	-0.215 (0.073)	-2.93***	-0.484 (0.094)	-5.12***	-4.54 (2.864)	-1.59
Prevalence of other diseases	-0.116 (0.076)	-1.51	0.120 (0.077)	-1.56	-0.865 (0.500)	-1.73*
Log Age in Years	0.997 (0.176)	5.65***	1.01(0.177)	5.73***	0.132 (0.079)	1.68*
Age of head of household squared	-0.0002 (0.000)	-7.67***	-0.0002 (0.000)	-7.53***	…	…
Pre-primary level (=1)	0.234 (0.269)	0.87	0.254 (0.271)	0.94	…	…
Secondary level (=1)	0.376 (0.046)	8.06***	0.390 (0.054)	7.17***	0.255 (0.059)	4.28***
Technical level (=1)	0.667 (0.128)	5.20***	0.723 (0.131)	5.51***	0.128 (0.383)	0.33
University level (=1)	0.947 (0.282)	3.35***	0.984 (0.278)	3.53***	0.974 (0.334)	2.92***
Residence (1=rural; 0 = Urban)	1.32 (0.118)	11.23***	…	…	1.629(0.222)	7.31***
Log actual hours worked	0.023 (0.019)	1.19	0.022 (0.019)	1.11	0.054 (0.023)	2.33**
Log Experience	0.066 (0.023)	2.85***	0.074 (0.023)	3.16***	…	…
Occupation of household head	0.082 (0.009)	9.03***	0.089 (0.009)	9.78***	…	…
Malaria*education	…	…	0.474 (0.189)	2.51**	3.59 (2.86)	1.26
Malaria*primary education level	…	…	0.589 (0.145)	4.04***	…	…
Marital status	…	…	…	…	0.004 (0.075)	0.05
No education	…	…	…	…	0.017 (0.329)	-0.05
Constant	5.97 (0.583)	10.23	5.86 (0.586)	9.99	…	…
R-Squared = 0.0650 F-Test F(12, 7075)=46.00 Sample size = 7088	…	…	Sample size = 7088 F(13, 7074) = 32.37 R-squared = 0.0567		Number of obs = 7104 F(12, 7091) = 27.69	

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

Table 5.10 Estimates of the Impact of Malaria on Household Income, (1997)
(Dependent variable = Log (Total household income), standard errors of estimated coefficients are shown in parentheses

Explanatory variables	**OLS Estimates**	**t-ratio**	**2 SLS Estimates**	**t-ratio**
Malaria prevalence	-0.413 (0.163)	-2.53**	-4.55 (2.48)	-1.83*
Prevalence of other diseases	-0.145 (0.129)	-1.13	-0.656 (0.277)	-2.37**
Sex (1= Male; 0 = Female)	-0.320 (0.061)	-5.19***	-0.000 (0.000)	-3.58***
Married	-0.023 (0.079)	-0.29	0.241(0.086)	2.78***
Single	0.044 (0.055)	0.81	0.105 (0.059)	1.77*
Other marital status	-0.115 (0.113)	-1.02	0.049 (0.146)	0.34
Log Age in Years	0.654 (0.207)	3.15***	0.690 (0.317)	2.17**
Age of head of household squared	-0.0002 (0.000)	-5.69***	-0.000 (0.000)	-3.58***
Log household size	0.193 (0.041)	4.65***	…	…
No education (=1)	-0.106 (0.052)	-2.03**	-0.083 (0.057)	-1.44
Secondary level (=1)	0.694 (0.072)	9.51***	0.441 (0.077)	5.73***
Tertiary level (=1)	1.28 (0.214)	6.00***	0.271 (0.340)	0.79
Residence (1=rural; 0 = Urban)	…	…	1.32 (0.113)	11.64***
Log public expenditure	0.035 (0.014)	2.44**	0.025 (0.019)	1.30
Malaria*tertiary education	-1.15 (0.493)	-2.34**	4.43 (2.59)	1.71
Malaria*education	0.092 (0.021)	4.32***	…	…
Malaria*public expenditure	1.79 (4.64)	3.86***	…	…
Constant	4.91 (0.703)	6.98	3.73 (1.26)	2.96

Number of observations = 8414 F(17, 8396) = 29.95, R-squared = 0.0539	…	…	Number of observations = 8414 F(14, 8399) = 42.42	…

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

Table 5.11: Impact of Malaria on Household Income Using a Sample with Malaria Illness Pooled with Healthy Individuals

Dependent variable = log (log household income); standard errors are in the parentheses. Malaria = 1 if a household member had malaria and 0 if other diseases.

	1994		1997			
Independent variables	**2SLS**		**2SLS**		**2SLS with interaction terms**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Malaria = 1 if household member had malaria and 0= if other diseases	-2.298 (1.030)	-2.23	-3.017(1.156)	-2.61**	-3.459 (1.26)	-2.73***
Log Age in Years	0.784 (0.364)	2.15**	1.183 (0.373)	3.17***	1.232 (0.391)	3.14***
Age of head of household squared	-0.0002 (0.000)	-3.02***	-0.000 (0.000)	-4.49***	-0.000 (0.000)	-4.32***
Sex (1= Male; 0 = Female)	-0.254 (0.096)	-2.64**	-0.162 (0.142)	-1.14	-0.146 (0.147)	-0.99
Log Household Size	0.608 (0.1007)	6.03***	0.585 (0.106)	5.49***	0.728 (0.144)	5.06***
No Education (=1)	…	…	-0.069 (0.089)	-0.78	-0.891(0.404)	-2.20**
Primary (=1)	0.231(0.070)	3.27***	…	…	0.834 (0.401)	2.08**
Secondary(=1)	0.519 (0.092)	5.61***	0.593 (0.138)	4.30***	-1.178 (0.546)	-2.15**
Tertiary (=1)	0.691 (0.222)	3.11***	0.764 (0.381)	2.00**	…	…
University level (=1)	1.123 (0.486)	2.31**	…	…	…	…
Residence (1= rural; 0 = Urban)	1.299 (0.324)	4.00***	1.36 (0.146)	9.33***	1.362 (0.148)	9.16***
Land holding in acres	0.210 (0.0305)	6.89***	…	…	…	…
Malaria* education	…	…	…	…	4.524 (1.622)	2.79***
Log public expenditure	…	…	…	…	0.044 (0.025)	1.72*
Single (=1)	…	…	0.0749 (0.089)	0.84	0.065 (0.092)	0.71
Married (=1)	0.104 (0.034)	3.02***	0.115 (0.146)	0.79	0.084 (0.147)	0.57
Constant	7.430 (0.980)	7.58***	3.020 (1.245)	2.43**	2.235 (1.332)	1.68
Sample size = 4397					Sample size = 4010	

Note: ***, ** and * significant at 1%, 5% and 10% level. In parentheses are the standard errors.

The results in Table 5.11 are obtained from a sub-sample of household members afflicted with malaria. That is, healthy households were excluded from the sample to generate analytical sub-sample comprising households with malaria and other diseases. As clearly evident from the table, the loss in household income due to malaria (based on OLS estimation method) is greater relative to the losses from other diseases. The 1997 results are similar to those of 1994 except that the losses are greater relative to the losses of the other diseases. As in the previous estimates, the coefficient on malaria obtained using the 2SLS method is negative and statistically significant at the 1% level. The results indicate that losses from malaria are greater than losses from other diseases. In particular, both the 1994 and 1997 results indicate that income among households inflicted with malaria was lower by 8.95% and 19.42% respectively relative to other diseases. The results clearly indicate that malaria impairs work ability among affected members of the household more relative to other diseases. Given that poor health lowers the productivity of workers, the results clearly show that sick people have lower incomes relative to healthy people. In particular, a household's income is lower if a member of the household experiences an episode of malaria than in the event of other diseases. Turning to the coefficient on the interaction of malaria with schooling, we see that the coefficient is positive and statistically significant at the 1% level. The positive coefficient shows that schooling mitigates the impact of malaria. Specifically, the coefficient of 4.524 implies that schooling reduces the negative effect of malaria on household income by approximately 91%. This is the benefit that will accrue to the households if malaria were to be eradicated.

5.3.4 Impact of Malaria on Earnings

In this section, we follow the human capital theory of wage determination, and adopt the basic Mincerian (1974) wage equation to measure malaria burden. That is, the natural log of wage is a function of malaria and individual skills measured as the level of education and age. Other socioeconomic covariates considered in the wage equation include the years of current job experience, square of experience, marital status and gender. Ordinary least squares (OLS) estimates of the wage earnings and the 2SLS estimates are presented in Table 5.12. The OLS estimates are presented in column (1) and (2), and the IV estimates are presented in column (3 and 4). The first stage regression estimates are presented in Tables A5 and A6 in the appendix. The first stage is the reduced form equation for malaria on the full set of instruments Z. According to Baum and Schaffer, (2003) the validity of the instruments relate to the explanatory power of the excluded instruments in these regressions. As noted previously, a statistic commonly used is the R^2 or the F-test for the joint significance of the instruments. According to Staiger and Stock (1997) an F-test above 10 recommended. The estimated F-test of the instruments of malaria in the earnings function is 2.54. Although the joint test of the instruments is below 10, economic theory predicts a close association between malaria and time taken to the river during the wet and dry seasons and time taken to collect firewood.

The coefficient on malaria is negative as hypothesized and statistically significant at the 1% level. The results indicate that a 10% increase in the proportion of individuals affected by Malaria was associated with a reduction of 3.3% of wage earnings. Similarly, the coefficient on other diseases is negative and statistically significant at the 5% level. The results further indicate that other diseases reduce earnings by approximately 2.2%.

Based on the 2SLS estimates, one can see that the coefficient on malaria is negative as hypothesized and statistically significant. The results indicate that an increase in malaria prevalence reduces the log of wage earnings by 3.81. The coefficient of 3.81 implies that individuals afflicted by malaria have 44% lower earnings. Similarly, the coefficient for other diseases is also negative and statistically significant at the 5% level. It is evident from these results that the effect of malaria on earnings is larger than that of other diseases.

Turning to other covariates, we note that the coefficients on age and its square have the expected signs and are statistically significant at the 1% level. The results show that wage earnings increases with age, but declines at older ages as predicted. From economic theory we know that as individuals advance in age, their inherited health stock depreciates at an increasing rate or they reach retirement age and are therefore likely to depend on past savings. The low earnings associated with age squared also suggests that as people advance in age, the quantity of time devoted to working is reduced. As noted, this can either be driven by a positive choice for more leisure at higher ages, or a negative effect on work-time through generally poorer health, or both. These results concur with previous studies which find a concave relationship between earnings and age. For example Contoyannis and Rice (2001) found a concave relationship between years of experience in one's current job and wages. Schultz and Tansel, (1997) found that work days missed because of sickness reduced wages and annual earnings both in Cote d'voire and Ghana. Similar studies using nutritional health indicators (protein intakes, BMI or calorie), report a negative relationship between health and labour supply, health and wages, or health and labour productivity (see for example Adebayo and Aromolaran, 2004).

The effects of completing schooling are consistently higher for secondary, tertiary and university level of education. The coefficients are positive and statistically significant at the 1% level implying that educated people are earning more wages than un-educated people. Taking primary education as the reference group, the effects of completing secondary, tertiary and university education levels are higher relative to primary education. This implies that completion of secondary, tertiary and university levels is associated with 1.9%, 3.9% and 4.4% increase in earnings. The results show that people with university education have comparatively high mean wage earnings than those with secondary or tertiary education. The earnings for all those individuals who received no formal education are lower by about 8.7%. A slightly different picture can be observed for individuals with primary and pre-primary education. Their mean wage earning is more or less the same and it seems there is no difference in wages as depicted by the positive coefficient on pre-primary level. Specifically, the results imply that the effects of completing primary education are lower by about 2.7%. Based on the human capital theory, we know that educated people have higher productivities so that they deserve higher wages. The results suggest that higher levels of education may in fact increase one's productivity and earnings.

The coefficient on gender (estimated by 2SLS) is positive and statistically significant at the 1% level of significance. The coefficient is 0.706 implying that females in the sample earned 7% lower wages than their male counterparts. Some possible explanation for this could be that fewer women are involved in off-farm activities and therefore their wage earning opportunities are fewer relative to those of men. The coefficient on household size is positive and statistically significant at the 5% level. The coefficient on residence variable is negative and statistically significant, implying that individuals living in urban areas earn higher wages relative to those based in the rural areas. Specifically, the results indicate that urban residents earn more than 70% higher wages relative to those working in rural areas. Results obtained by the 2SLS method indicate that the coefficient on urban residence is pretty big, and this shows the gap in wage earnings between rural and urban areas is quite large.

The coefficient on actual hours worked is positive and statistically significant at the 1% level irrespective of the estimation method. The results indicate that individual wage income is positively correlated with the number of hours an individual spents on a certain job. The coefficient on the interaction term between age and schooling (age*schooling) and between age and sex (age*sex) are statistically significant at the 1% level.

Table 5.12: Effects of Malaria on Earnings (1994) (Dependent variable = log Wages) (Standard errors of estimated coefficients are shown in parentheses)

	OLS		2SLS	
Independent Variable	Coefficient	t-ratio	Coefficient	t-ratio
Constant	7.704 (0.818)	9.42***	8.99 (0.527)	17.05
Malaria prevalence	-0.336 (0.080)	-4.19***	-3.81 (1.99)	-1.92*
Prevalence of other diseases	-0.225 (0.085)	-2.63***	-0.800 (0.346)	-2.31**
Sex (1= Male; 0 = Female)	…	…	0.706 (0.208)	3.39***
Logarithm of age of household head	0.718 (0.263)	2.73***	0.051 (0.016)	3.20***
Log of age squared	-0.0005 (0.000)	-5.16***	-0.0005 (0.000)	-2.72***
Area of residence (urban =1; rural =0)	-0.735 (0.047)	-5.63***	-0.728 (0.059)	-12.25***
Logarithm of household size	0.073 (0.034)	2.17***	…	…
Primary level (=1)	0.277 (0.306)	0.91	0.344 (0.059)	5.80***
Secondary level (=1)	0.196 (0.063)	3.10***	0.614 (0.074)	8.30***
Tertiary level (=1)	0.397 (0.139)	2.85***	0.985 (0.127)	7.71***
University level (=1)	0.447 (0.244)	1.83*	…	…
No education (=1)	-0.867 (0.165)	-5.25***	…	…
Log working days	0.164 (0.022)	7.54***	0.163 (0.025)	6.49***
Log house hold size	0.073 (0.034)	2.17**	…	…
Log age*schooling	0.002 (0.001)	3.77***	…	…
Log years of schooling*sex	-0.024 (0.015)	-1.59	…	…
Log age*sex	0.010 (0.002)	4.46***	-0.011 (0.005)	-2.06**
Sample size = 3115 F(11, 3103) = 52.41 R-Squared = 0.235	…	…	…	…

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

Table 5.13 shows the estimated results of the impact of malaria on earnings using malaria as a dummy variable. The coefficient on malaria (malaria =1) in model (1) had the expected negative sign but not statistically significant. The estimates show that a %age increase in malaria morbidity rate reduces earnings by 0.042%. This implies that earnings of individuals afflicted with malaria have lower earnings relative to the earnings of healthy individuals. The coefficient on malaria obtained using IV regression method is negative and statistically significant at the 10% level as well. The 2SLS results in model (2) indicate that malaria reduces the log of earnings by 3.04 implying that individuals afflicted by malaria have 19.9% lower earnings relative to healthy individuals. Similar to earlier findings, the magnitude of the disease impact on earnings is higher in the IV regression model compared to OLS regression results.

The stock of human capital, proxied by education levels is positive in models (1) and (2) and statistically significant at the 1% level and 5% level except for the pre-primary education which is not statistically significant in all the models. These results indicate that an individual who attains secondary education level has a 0.46% higher earning relative to an individual who has primary education. Both the coefficients on tertiary and university education are positive implying that, individuals with tertiary and university education levels have 0.9% and 0.7% respectively higher earnings relative to individuals with primary education level (OLS estimates). The impact of tertiary and university education levels is slightly higher when estimated using the 2SLS method. The results show that earnings are higher by about 0.8% and 1.8% respectively for individuals with tertiary and university education level relative to those with primary education. The results imply that individuals who attain higher education are better compensated compared to the individuals who attain lower education levels.

The coefficients on age and experience are positive and negative and statistically significant at 5% level of significance. The coefficient on household size has the predicted sign and is statistically significant at the 5% level when estimated using the 2SLS method. The coefficient on gender is positive and statistically significant at the 1% level of significance and 5% level in model 1 and 2 respectively. The coefficient is 0.304 implying that female earn lower than their male counterparts. Specifically, female workers earn 0.35% lower relative to males. Some possible explanation for this could be that fewer women are involved in off farm activities and therefore their wage earning opportunities are fewer relative to that of men. The coefficient on area of residence (rurban) is positive in both estimation methods and is statistically significant at the 1% levels. The results indicate that those individuals living in urban areas have higher earnings relative to the individuals living in rural areas. This finding however need to be interpreted with caution because there are people in urban areas (especially those living in slum areas) who earn lower incomes compared to those living in rural areas. However, as noted earlier, individuals living in urban areas have more job opportunities compared to those living in the rural areas and this partly explains the differentials in earnings. Finally, the coefficient on the actual hours worked is positive in both estimation methods but it is only statistically significant at the 1% level in the OLS method. What this results imply is that most of the individuals included in the sample are likely to be working on non-permanent basis and their earnings are dependent on the actual number of hours worked.

Table 5.13: Impact of Malaria on Earnings Using a Sample with Malaria Illness Pooled with Health Individuals (199). Dependent variable: Monthly mean wage earnings (Standard errors of estimated coefficients are shown in parentheses).

Independent variable	OLS		2SLS	
	(1)		(2)	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	6.77 (1.021)	6.63	6.325 (1.790)	3.53***
Malaria = 1 if household member had malaria; 0 if other diseases	-0.042 (0.046)	-0.910	-3.046 (1.691)	-1.80*
Gender (=1 male; 0 otherwise)	0.304 (0.063)	4.83***	0.240 (0.120)	2.00**
Marital status (1 = married)	0.024 (0.026)	0.930	0.073 (0.057)	1.29
Log Age of household head	0.892 (0.329)	2.71**	1.728 (0.731)	2.36**
Log Age squared	-0.003 (0.000)	-3.19***	-0.000 (0.000)	-2.62**
Log Experience	0.000 (0.015)	0.001	-0.013 (0.028)	-0.47
Urban or rural area (Rural =1)	-0.776 (0.061)	-12.67***	-0.805 (0.112)	-7.15***
Logarithm of household size	0.154 (0.043)	3.57***	0.220 (0.089)	2.47**
Pre_primary (=1)	0.001 (0.314)	0.01	0.324 (0.613)	0.53
Secondary level (=1)	0.384 (0.052)	7.28***	0.257 (0.121)	2.12**
Tertiary level (=1)	0.690 (0.128)	5.39***	0.563 (0.269)	2.09**
University level (=1)	0.558 (0.237)	2.36**	1.026 (0.442)	2.32**
No education (=1)	-0.396 (0.062)	-6.34***	-0.467 (0.113)	-4.13***
Log working days	0.167 (0.032)	5.18***	0.089 (0.073)	1.23
Observations	2051			
F(14, 2036)	14.04			

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

Table 5.14 compares the effect of malaria and other diseases on earnings relative to the healthy group. The coefficients on malaria dummy and on the other diseases show the extent to which earnings are lower among individuals afflicted by malaria or other diseases relative to earnings of healthy individuals. The coefficient on malaria dummy is negative and statistically significant at the 1% level regardless of the estimation method. The coefficient on other diseases is negative as well and is statistically significant at the 10% (OLS) and 1% (2SLS) respectively. The results in table 5.14 reveal substantial differences in the magnitude of the disease burden on earnings. The table shows that earnings of individuals afflicted with malaria are lower by 16% compared to earnings of healthy individuals, while the loss in earnings due to other diseases is lower by 0.6%% relative to that of healthy individuals. There are two implications in these results. First, it is evident that earnings are lower among individuals afflicted with malaria relative to other diseases. Second, the loss in earnings is much higher among individuals afflicted with malaria compared to the loss of earnings due to other diseases. The results confirm previous studies which indicate that malaria imposes a large burden on individuals and households compared to other diseases.

Table 5.14: Comparison of the Impact of Malaria and other Diseases on Earnings (1994). Dependent variable: Monthly mean wage earnings (Standard errors of estimated coefficients are shown in parentheses)

	OLS		2SLS	
Independent Variable	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Constant	7.165 (0.795)	9.01	8.479 (1.379)	6.15
Malaria = 1 if household member had malaria and 0 if other diseases	-0.165 (0.049)	-3.35***	-2.84 (1.331)	2.14**
Other diseases = 1 if malaria and 0 if other diseases	-0.089 (0.053)	-1.69*	-0.504 (0.246)	2.05**
Gender (1 = Male)	0.318 (0.044)	7.25***	...	...
Log of age of household head	0.833 (0.255)	3.27***	0.572 (0.416)	1.38
Log of years of age squared	-0.0003 (0.000)	-3.55***	-0.0002 (0.000)	1.81*
Urban or rural area (Rural =1)	-0.745 (0.047)	-15.95***	-0.454 (0.166)	-2.73***
Logarithm of household size	0.083 (0.033)	2.52**	...	...
Pre_primary (=1)	...	...	0.082 (0.415)	0.20
Secondary level (=1)	0.332 (0.041)	8.01***	0.170 (0.104)	1.63
Tertiary level (=1)	...	...	0.503 (0.260)	1.93*
Tertiary (=1)	0.704 (0.096)	7.29***	...	...
University level (=1)	...	...	-0.046 (0.461)	-0.10
None_pre_primary (=1)	-0.349 (0.052)	-6.72***	...	...
No education (=1)	...	...	-0.707 (0.242)	2.92***
Log working days	0.165 (0.022)	7.59***	0.151 (0.033)	4.51***
Log house hold size	...	...	-0.049 (0.116)	0.43
Age*education	...	...	0.001 (0.001)	1.41
Log age*sex	...	...	0.004 (0.002)	1.95*
Observations	2206	...	...	...

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

5.3.5 Policy Simulations

Based on the analytical framework and results from the previous chapter, we provide a set of policy simulations to illustrate the potential impact that the interaction between government expenditure on malaria and between malaria and education have in mitigating the economic burden of malaria. We recognize that some policy interventions, such as investment in malaria prevention and in education can potentially reduce the economic burden imposed by malaria. The analysis is divided into two parts, and is motivated by two questions frequently discussed in the literature on the role of education and government expenditure in mitigating the economic burden of malaria. First, what is the role of government expenditure in reducing the economic burden of malaria? Second, can education play a significant role in reducing the economic burden of malaria?

Two types of interventions are simulated, one influencing malaria prevalence and the other influencing education in general. First, we estimate the impact of malaria on crop production, household income and on wage earnings and use the results to predict the mean outcome—this is the baseline. We then change the policy variables to reflect the simulation and use the estimated coefficients to predict the new mean outcome. We report the %age change in the mean outcome over the baseline. The policy simulations consider the impact of reducing malaria prevalence on crop production and household income or increasing government expenditure on malaria control programmes. Results of these simulations are presented in Table 5.15.

The first thing to note from Table 5.15 is that the elasticities on malaria and other diseases are negative as hypothesised. The estimated elasticity on malaria was -0.0049 in 1994 and -0.004 in 1997. This implies that an increase in the prevalence of malaria by 1% would reduce crop production by 0.5% in 1994 and 0.47% in 1997. The elasticity on other diseases was -.04 and -0.47 for 1994 and 1997 samples, respectively. The elasticities with respect to the interaction terms are positive as predicted and are consistent with economic theory.

Table 5.15: Crop Production Elasticities

Policies	Elasticities	
	1994	**1997**
Malaria prevalence	-0.0049	-0.004
Prevalence of other diseases	-0.0004	-0.004
Government expenditure*malaria (Interaction term)	0.0010	0.0004
Malaria * schooling (Interaction term)	0.0002	0.0041

The simulation results provide plausible results: For the crop production function model, a 10% decrease in malaria prevalence would be associated with a 5% increase in crop production in 1994 and 4.7% in 1997. If, malaria were to be reduced by 50% as per the Millennium Development Goals, the country would have gained by approximately 25% and 23.5% for 1994 and 1997 respectively. The increase in crop production would in turn enable the households to adopt malaria prevention measures, thus reducing malaria prevalence further. Simulation results by Laxminarayan, (2004) showed that a 10% decrease in malaria at the provincial level in Vietnam was associated with a 0.63% decrease in health expenditures. This was equivalent to US dollars 0.16 benefit to each household for every 10% reduction in malaria at the provincial level. Mitra and Tren, (2002), Fosu and Mwabu, (2007) and Gallup and Sachs, (2001) points out that because of the close relationship between malaria and poverty levels an effective malaria control programme would not only improve the living standards of households, but will also help in reducing poverty levels.

Next we examine the effect of government expenditure on malaria control programmes and the level of education on crop production, using parameters estimated in our regression analysis. For policy related to government investment in malaria control activities, the elasticity of 0.0010064 and 0.00041 for the 1994 and 1997 samples respectively, showing that a 1% increase in public expenditure increases crop output by 0.1% and 0.04% in the 1994 and 1997 sub-samples. Note that the impact of the interaction term is larger in the crop production. This is attributable not only to the size of the coefficient on the interaction term, but also to the fact that more households would benefit from increased government expenditure in malaria control policy. The elasticity of crop production with respect to other diseases is estimated at -0.04 for the 1994 sample and -0.47

for the 1997 sample. This shows that a %age decrease in the prevalence of other diseases would have reduced crop production by 0.04% and 0.47% in 1994 and 1997 respectively. If other diseases were reduced by 10%, the gain in crop production would have increased by 0.4% in the 1994 sample and 4.7% in the 1997 sample.

With respect to the interaction term between malaria and education, we simulate the impact on household crop production if all household heads received the basic level of education. Overall, the elasticity of the interaction term is positive implying that increasing literacy of head of households would increase crop production by 0.02% in the 1994 sample and 0.42% in the 1997 sample. These gains can be translated into %age increase in the crop production by comparing what crop output would have been in the absence of malaria with crop output in the presence of malaria.

Basic economic theory suggests that household income would decrease if the prevalence of malaria increased (the estimated elasticity for malaria is -0.00318 while that of interaction terms between education and malaria and between malaria and government expenditure are 0.00026 and 0.00051 for the 1994 sample). The results indicate that if malaria were to decrease by 10%, this would have increased household income by 0.4% and 9% in 1994 and 1997, respectively. Similarly, if government expenditure were increased by 10%, then household income for the 1994 and 1997 period would have increased by 0.3% in 1994 and 1.9% in 1997.

on cassava production and on total household income. Their results showed a positive association between malaria and cassava production. The results by Wang'ombe and Mwabu, (1993) were plausible given that growing of cassava; a subsistence crop is not labour intensive. Pitt and Rosenzweig, (1986) found no statistically significant effects of family illness on profit but did find an effect on male labour supply. The most plausible explanation for this could be due to presence of an active labour market, through which family labour can be replaced at constant wages and not necessarily absence of productivity. A number of studies show that family members sacrifice their other activities including leisure in order to compensate for the decreased productivity of a sick family member (see for example Pitt and Rosenzweig, 1986; Olagoke, 2007 and Audibert and Etard, (1998).

Of the education variables, secondary education and technical education have been shown to increase crop production. The results obtained using OLS method showed that the logs of values of farm outputs were 0.176 and 0.344 higher in 1994 and 1997, respectively. The effect of secondary education on logs of crop output however increased by 0.127 and 0.474 in both 1994 and 1997, respectively when estimated using the 2SLS method. One striking observation from our results is that the effect of university education on crop output was lower for both 1994 and 1997. Similar results were reported by Appleton (2000) who found that households with 4 years of schooling were more productive in agriculture than those with tertiary education level.

Both age and age squared variables have significant coefficients, whilst also corresponding to a priori expectations on crop output. The coefficient on experience of the head of household in crop farming was contrary to a priori expectations. For the 1994 and 1997 sub-sample, the coefficient on age squared (a proxy for experience) turned out to be negative and statistically significant at the 5% and 1% level. The stock of human capital, as measured by secondary level of education for the 1994 and 1997 data show an additional level of education for the head of household has an increasing effect which is more than in other levels of education. This is an important finding, because it shows the importance of education in enhancing ones knowledge in farming techniques.

The coefficient on gender variable was negative indicating higher output for women, regardless of the estimation method, although not statistically significant when estimated by the OLS method. The results clearly point out that women contribute more to increasing crop production than men. In addition, the results showed that land is a critical variable and this is indeed the case, especially in 1994 and in 1997. The coefficient on hours spent in farming was positive regardless of the estimation method. This finding indicates that households who spent significant amount of their time in farming are likely to acquire specific farming skills that enable them to improve their crop production.

Our regression results have also shown that rainfall and time taken to a health facility were all significant explanations of crop production. The coefficient on rainfall and time taken to the nearest health facility seems to be consistent with Laxminarayan and Moeltner's (2001) notion that, the implicit cost of treatment as measured by distance to the nearest health facility exerts a negative effect on production. This finding suggests that the risk of malaria places an economic burden on crop production, regardless of whether or not a member of the household actually suffers a malaria episode.

With respect to the effect of malaria on household income, the results show that the coefficient on malaria has the predicted sign and is, in all estimation methods, statistically significant at 10% level and above. Specifically, a 1% increase in 2-week malaria prevalence was associated with a reduction in the logs of household income of 4.54 and 4.55 for the 1994 and 1997 samples, respectively. These results clearly show that households lost approximately 93% and 94% of their income due to malaria in 1994 and in 1997, respectively. A possible explanation for these finding is that malaria incapacitates labour force. In addition to absenteeism from work, malaria exerts debilitating effect on labour supply. Laxminarayan and Klaus, (2003) for example found that the impact of malaria on labour supply was the main cause of loss of income.

The remaining regressors are household characteristics and policy variables. Both household head's age and education level have a strong and positive effect on household income. The results pertaining to the square of age is encouraging in that the sign of the regression coefficient is, in all cases, negative as predicted. This finding concurs with previous studies which find that there is an age at which income earnings reach maximum level. Grossman (1972) for instance, notes in his study that as individuals advance in age, their health stock depreciates at an increasing rate and is likely to depend on past savings. Grossman argues that as health stock depreciation rate rises with age, it is unlikely that old people will earn higher incomes than the young people. Area of residence is also an indicator of household income; as households living in urban areas should have a higher income relative to those residing in the rural areas. Specifically, households residing in urban areas earn 2.7% higher income compared to those residing in rural areas.

The level of education also affects household income in a positive manner irrespective of the estimation method used. The findings show that household heads with secondary level education and tertiary level education had higher incomes relative to a household head with primary education. These results, however, need to be interpreted with caution since we hold occupation of household head constant while estimating the effect of education; this most certainly biases down the effects of to education since earning and educational qualifications differ substantially across occupations. Evidence from other studies using micro data strongly suggest that, household income is influenced by the household size.

With respect to the impact of malaria on wage earnings, our results revealed that wage earnings were lower among individuals affected by malaria relative to healthy individuals. Specifically, a 10% increase in the proportion of individuals affected by malaria was associated with a reduction of 3.3% of wage earnings relative to healthy people. The coefficient for other diseases was also found to be negative and statistically significant at the 5% level. The results further indicate that other diseases reduce wage earnings by approximately 2.2%. Estimates obtained using the 2SLS method indicate that an increase in malaria prevalence is associated with a 44% lower wage earnings relative to individuals not afflicted by malaria. According to Contoyannis and Rice (2001), the wage effects of an illness would be experienced largely through the inability of individuals to continue working because of the disease.

The results indicate that the effects of schooling on wage earnings are consistently higher for secondary, tertiary and university level of education. The estimates of the effects of all levels of education are significant at the 5% level, except for the pre-primary education. The results revealed that wage earnings increases with the education level and are consistently higher for higher levels of education. However, there seem to be no significance difference in the mean wage income between primary and pre-primary levels as depicted by the positive coefficient on pre-primary level. From the results reported in the previous section, it is evident that an individual who attains primary education level would earn 2.7% lower wages. Our results compare well with those of previous studies (see Manda et al, 2002; Fosu and Mwabu, 2007). The author found that the rate of return for primary, secondary and university levels was 7.9%, 17.2% and 32.5% respectively.

From the results obtained using OLS and the 2SLS approaches it can be seen that, the coefficient on the interaction terms, to some extent, is consistent with Laxminarayan, (2004) argument that public investment in malaria control programmes is critical in mitigating the economic burden of malaria. There is also evidence in the literature that the interaction of malaria with schooling mitigates the economic impact of malaria (see Fosu and Mwabu, 2007). The resulting effect of increased investment in malaria control activities or increased public education is a reduction in the intensity of malaria which may have direct productive benefits by increasing crop production. Further, improvement in health status (due to reduction in malaria) may have indirect productive benefits: if an improvement in family labour productivity has no effect on hired labour (by decreasing the demand for it), it may have an effect on crop production through increased farm inputs (Audibert and Etard, 2003).

Based on simulation results, it is evident that Malaria imposes a substantial economic burden on crop output, household income and on wage earnings. The effect may be substantial in endemic regions due to direct health care costs as well as opportunity costs due to lost productivity. The simulation results show that whereas malaria prevalence and other diseases are associated with a substantial decline in crop production, household income and wage earnings, the opposite applies with increased government expenditure on malaria control programmes and schooling. With respect to crop production, the results revealed that if malaria were to be eliminated (even though this may not be a feasible option as demonstrated in chapter two), crop output would have increased by 5% in 1994 and 4.7% in 1997. If other diseases were reduced by 10%, the gain in crop production would have increased by 0.4% in the 1994 sample and 4.7% in the 1997 sample. Similarly, if government expenditure were increased by 10%, then household income for the 1994 and 1997 period would have increased by 0.3% in 1994 and 1.9% in 1997.

6.2 Conclusions

Malaria remains the leading cause of morbidity and mortality in many developing countries, including Kenya. In addition to time and financial resources spent on preventing and treating malaria, it exerts adverse impact on crop production, income and on wage earnings. The study has investigated the effects of malaria on farm output, household welfare and wage earnings using micro household data obtained from the WMS II and WMS III. The main innovation of this study lies in its empirical specification in which the endogeneity of malaria was taken into account. Departing from the previous studies, we estimated the malaria effect on household production functions using 2SLS estimation method. In our estimation also, we introduced two policy variables--interaction between government expenditure and malaria and malaria and schooling to determine their effect in mitigating the economic burden of malaria.

Another important conclusion that can be drawn from the analysis is that the effect of malaria and that of other diseases 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 69% 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. What the results show is 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. This is largely because household members spent time taking care of the sick relatives and therefore have little time to engage in farming. Affected individuals may also remain in the labour force, but their productivity is severely impaired. This is because malaria results in recurrent debilitating bouts of illness, which prevents individuals from supplying their labour productively. Hempel and Najera (1996) indicate that a bout of non-fatal malaria will typically last for 10-14 days including 4-6 days of total incapacitation. Therefore, 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 results showed that the loss in income among households inflicted by malaria was large. We further showed that income losses from malaria were relatively larger than losses due to other diseases. Intuitively, the results imply that sick people are likely to experience lower incomes than healthy people. In particular, the results show that households are likely to experience lower incomes if household members are inflicted with malaria than by any other disease. Available evidence from the literature points out that malaria incapacitates part of the labour force or work ability more relative to other. In view of the empirical evidence of the disease effect, any efforts to reduce malaria within the family would provide additional utility to the household by increasing the time available for work in other activities.

From the empirical results, we cannot underrate the importance of investment in malaria control and schooling in mitigating the negative effect of malaria. We have found clear evidence in support of the hypothesis that government investment in malaria control programmes and in schooling mitigates the economic burden of malaria. Several studies are of the view that investment in malaria prevention may lead to improvement in welfare and adoption of preventive measures against malaria (see for example Audibert and Etard, 1998). It is in this line of argument that one should view the role played by government investment in malaria control and in schooling as critical in mitigating the negative effect of the disease. The simulation results suggest that if malaria prevalence were to be reduced by 10%, crop production would increase by 0.6% in the 1994 sample and by 4.7% in the 1997 sub-sample. A further reduction in malaria prevalence by 50% would result in 2.9%and 23.5% increase in crop production in 1994 and 1997 respectively.

The implications of these results are that the country's goal of eliminating the incidence of poverty will not be achieved unless effective malaria control programmes are put in place. High incidence of poverty means that the cycle of malaria and poverty is maintained or even worsened. Thus, based on simulation results, malaria control can be economically beneficial because malaria control efforts makes 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 be a motivating factor for the government and development partners to inject additional resources in malaria control.

6.2 Recommendations

One of the findings of this study is that investment in malaria control and schooling mitigates the economic burden imposed by malaria. The results have shown that increased government expenditure mitigate the negative effect of malaria on crop production, household income and on wage earnings. In view of this, it is imperative that the government consider increasing budget allocations to malaria control measures especially in areas of high malaria transmission. Although increased government expenditure on malaria control and treatment may in the short run reduce budgetary allocations for other priority areas, in the long run, it would be beneficial because reduction in morbidity due to malaria may enable the government to reduce its expenditures for medical care, thus releasing funds for other priority areas.

The study has also identified education as an important policy variable in mitigating the negative effect of malaria on crop production, incomes and wage earnings; hence, it is imperative that the government intensifies public education awareness about the disease transmission and on prevention measures. A higher level of public awareness or education on malaria in general is positively related to the presence of malaria at the household level. Incidence of malaria is higher for less educated households and in regions with poorer preventive health services. Hence, public health interventions which decrease the households's risk of contracting malaria will improve labour productivity and result in higher output levels. Improvement in health infrastructure will particularly reduce the susceptibility of low income households to malaria shocks. In general, one would expect a negative effect for education on malaria, in the sense that more educated household members are expected to have a better understanding of the malaria -related issues and a better compliance with modern treatment as well as use of prevention measures. Ultimately, these measures are expected to reduce malaria transmission, improve labour productivity, crop production and consequently lead to higher incomes. Thus, poverty reduction programmes geared at: (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.

In addition, policies aimed at ensuring that households living in stable and unstable malaria zones attain at least secondary education level will significantly reduce the economic burden imposed by malaria by almost reduce by almost 5 % whilst increasing government expenditure on malaria control programmes would increase crop production among subsistence farmers by 0.1 %. From a policy perspective, the economic and non-economic benefits of reducing malaria are significant as shown by the large losses imposed by the disease. In view of this, an effective malaria control programme would not only increase subsistence crop output but also household incomes considerable and hence help in addressing the poverty problem in the country.

6.3 Areas for Further Research

While we have provided a detailed description and analysis with regard to the economic burden of malaria at the household level, further work is needed to understand some aspects of the economic burden imposed by malaria. An indication of the need for such an effort is provided in chapter 5. It was found that the disease is responsible for a significant decrease in crop production, household income and wage earnings. Some people have argued that the economic burden differs greatly along socioeconomic groups. In view of this, it would be important to explore in detail the economic burden on households with different socio-economic status

In addition, given that the large economic burden of malaria faced by households and individuals, there is a strong economic justification for intervention that mitigate the disease burden. It imperative to address the effects of malaria by focusing on specific studies that target groups who would benefit most from malaria control interventions. Future studies could focus on health seeking behaviour of households and individuals, household spending on malaria treatment and prevention in Kenya and across socioeconomic groups.

There is also a need for additional research into policy-makers' perceptions of the value of economic evaluations in order to mobilise additional resources for malaria control and treatment. It is apparent that policy-makers frequently are more concerned with 'affordability' issues than with economic evaluation results. While a proposed alternative intervention must be affordable within the country's health budget constraints, policy-makers often merely consider the additional cost of an intervention without considering the potential resource savings or benefits

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Table A1: Determinants of Probability of Contracting Malaria-First Stage Least Squares Estimation Results for Crop Production, (1994).

Explanatory variables	OLS Estimates	Std Errors	t-ratio
Log Age in Years	0.191	0.075	2.54
Age Squared	-0.000	0.000	-3.27
Marital status (1 = Married)	0.003	0.009	0.36
Sex (1= Male; 0 = Female)	0.052	0.021	2.39
Log Household size	0.090	0.013	6.58
Fertiliser use (=1)	-0.054	0.016	-3.24
Log Rainfall	0.068	0.016	4.18
Log agricultural land in acres	-0.003	0.008	-0.39
No Education (=1)	0.002	0.019	0.15
Pre_primary Level (=1)	0.004	0.112	0.04
Secondary Level (=1)	0.013	0.021	0.63
Technical Level (=1)	-0.000	0.059	-0.01
University Level (=1)	0.030	0.130	0.24
Log Actual Hours Worked	0.011	0.008	1.47
Log time to water source during the wet season	0.023	0.008	2.58
Log time to water source during the dry season	-0.004	0.008	-0.51
Log time taken to collect domestic energy (firewood)	-0.013	0.007	-1.90
constant	-0.7617	0.271	2.81
Sample size	4330		
F(17, 4312) = 6.82			
R-squared = 0.0262			

Test for the strength of instruments

(1) Log time to water source during wet season = 0

(2) Log time to water source during dry season = 0

(3) Log time to collect firewood = 0

F (3, 4407) = 3.41

Prob > F = 0.0167

Table A2: Determinants of Probability of Contracting Malaria-First Stage Least Squares Estimates for Crop Production, (1997).

Explanatory variables	OLS Estimates	Std Errors	t-ratio
Log Age in Years	0.005	0.015	0.39
Age Squared	-0.000	.000	-1.63
Sex (1= Male; 0 = Female)	0.008	0.018	0.47
Log Rainfall	-0.026	0.018	-1.43
Log agricultural land in acres	-0.0079	0.009	-0.79
No Education (=1)	-0.032	0.025	-1.27
Pre_primary Level (=1)	-0.041	0.039	-1.05
Secondary Level (=1)	-0.013	0.031	-0.43
Technical Level (=1)	0.339	0.281	1.20
University Level (=1)	-0.211	0.199	-1.06
Log time to water source during the wet season	0.003	0.017	0.18
Log time to water source during the dry season	0.020	0.016	1.28
logtimedisp	-0.023	0.011	-2.04
constant	0.480	0.066	7.24
Sample size	3058		
F(20, 3037)	3.72		

Test for the strength of instruments
Test Log time taken to water source during the wet season
Test Log time taken to water source during the dry season
Test Log time taken to the dispensary

(1) Log time to water source during wet season = 0
(2) Log time to water source during dry season = 0
(3) Log time to the dispensary = 0
F (3, 3037) = 1.98
Prob > F = 0.1152

Table A3: Determinants of Probability of Contracting Malaria- First Stage Least Squares Estimation Results for Household Income, (1994)

Explanatory variables	OLS Estimates	Std Errors	t-ratio
Log Age in Years	0.350	0.070	4.95
Sex (1= Male; 0 = Female)	0.014	0.016	0.86
Log Age squared	-0.000	0.000	-5.97
Pre-primary	0.019	0.112	0.17
Secondary Level (=1)	0.002	0.019	0.12
Technical Level (=1)	-0.001	0.052	-0.04
University Level (=1)	0.116	0.104	1.11
Distance to nearest health facility	0.031	0.018	1.64
Time taken to water source during the wet season	0.017	0.008	2.10
Time taken to water source during the dry season	-0.001	0.007	-0.22
Time taken to collect firewood	-0.009	0.005	-1.86
Constant	-0.566	0.233	-2.42
FF(12, 4775) = 4.36			
Sample size	4788		
R-squared	0.010		

Test for the strength of instruments
Test Log time taken to water source during the wet season
Test Log time taken to water source during the dry season
Test Log time taken to collect domestic energy (firewood)

(1) Log time to water source during wet season = 0
(2) Log time to water source during dry season = 0
(3) Log time to collect firewood = 0

F (3, 4775) = 3.32
Prob > F = 0.0191

Table A4: Determinants of Malaria Prevalence at the Household Level-First Stage Least Squares Estimation Results for Household Income, (1997)

Explanatory variables	OLS Estimates	Std Errors	t-ratio
Prevalence of other Diseases	-0.098	0.011	-8.39***
Log Age in Years	-0.095	0.018	-5.22***
Sex (1= Male; 0 = Female)	0.026	0.005	4.60***
Log Age squared	0.000	3.970	4.72***
Single (=1 if not married; 0 otherwise)	-0.008	0.004	-1.72*
No education (=1)	0.006	0.004	1.25
Secondary Level (=1)	2.210	0.006	0.00
Technical Level (=1)	-0.098	0.0207	-4.75***
Married (=1 if married, 0 otherwise)	0.011	0.007	1.54
Residence (1=rural, 0 otherwise)	0.029	0.007	3.96***
Other_marital status	0.034	0.010	3.33***
Malaria_tertiary (interaction term)	0.985	0.069	14.08***
Malaria expenditure	-0.004	0.001	-3.38***
Time taken to water source during the wet season	0.003	0.001	1.62*
Time taken to water source during the dry season	0.001	0.002	0.85
Time taken to nearest health facility	-0.012	0.003	-4.04***
Constant	0.442	0.066	6.69
F(16, 8397)	25.67	...	...
Sample size	8414	...	...
R-squared	0.0466	...	...

Test for the strength of instruments

(1) Log time taken to water source during wet season = 0
(2) Log time taken to water source during dry season = 0
(3) Log time taken to collect firewood = 0
F (3, 6395) = 4.26
Prob > F = 0.0052

Table A5: Determinants of Probability of Contracting Malaria-**First Stage Least Squares Estimation Results for Household Income, (1997)**

Explanatory variables	***OLS Estimates***	***Std Errors***	***t-ratio***
Log Age in Years	0.050	0.071	0.70
Sex (1= Male; 0 = Female)	0.073	0.021	3.37
Log Age squared	-0.000	0.000	-1.19
Log Household Size	0.059	0.015	3.74
Single (=1)	0.004	0.017	0.27
No education (=1)	-0.012	0.017	-0.74
Secondary Level (=1)	0.043	0.025	1.70
Technical Level (=1)	0.039	0.073	0.53
Married (=1 if married, 0 otherwise)	0.047	0.026	1.79
Residence (1=rural, 0 otherwise)	0.047	0.027	1.71
Time taken to water source during the wet season	-0.005	0.007	-0.69
Time taken to water source during the dry season	0.021	0.007	3.05
Time taken to the dispensary	-0.035	0.010	-3.23
Constant	…	…	…
F(13, 3996) = 5.34	…	…	…
Sample size = 4010	…	…	…
R-squared = 0.0171	…	…	…

Test for the strength of instruments
Test Log time taken to water source during the wet season
Test Log time taken to water source during the dry season
Test Log time taken to the dispensary

(1) Log time taken to water source during wet season = 0
(2) Log time taken to water source during dry season = 0
(3) Log time taken to the dispensary = 0

F (3, 3996) = 6.62
Prob > F = 0.0002

Table A6: Determinants of Probability of Contracting Malaria-First Stage Least Squares Estimation Results for Earnings, (1994)

Independent Variable	OLS Estimates	Std Errors	t-ratio
Log Age of household head	0.286	0.154	1.85
Log of age squared	-0.000	0.000	-1.45
Sex (1= Male; 0 = Female)	-0.024	0.031	-0.78
Marital status (=1 if married)	0.014	0.013	1.07
Log Household size	0.022	0.022	1.00
No education level (=1)	-0.031	0.029	-1.06
Pre-Primary level (=1)	0.102	0.161	0.63
Secondary level (=1)	-0.042	0.027	-1.55
Tertiary level (=1)	-0.045	0.071	-0.63
University level (=1)	0.174	0.098	1.76
Log experience	-0.004	0.007	-0.61
Urban or rural area (urban =1; rural =0)	-0.012	0.036	-0.33
Log working days	-0.025	0.016	-1.56
Time taken to collect water during wet seasons	0.017	0.012	1.42
Time taken to collect water during dry seasons	0.001	0.010	0.14
Time taken to collect firewood	-0.008	0.007	-1.12

Test for the strength of instruments
Test Log time taken to water source during the wet season
Test Log time taken to water source during the dry season
Test Log time taken to the dispensary

(1) Log time taken to water source during wet season = 0
(2) Log time taken to water source during dry season = 0
(3) Log time taken to the dispensary = 0

$F(3, 2034) = 1.48$

Prob > F = 0.2177

Table A7: Estimates of the Impact of Malaria on Crop Output Using a Sample with Malaria and other disease Illness Pooled with Healthy Individuals, 1994

Dependent variable = log (crop production), Standard errors of the estimated coefficients are shown in the parentheses.

Explanatory variables	OLS Estimates	t-ratio	2 SLS Estimates	t-ratio
Malaria_dummy (=1)	-0.175 (0.054)	-3.24***	-1.505 (3.49)	-0.43
Other_dis_dummy (=1)	-0.040 (0.055)	-0.73	-0.096 (0.553)	-0.18
Log Age in Years	0.694 (0.164)	4.23***	-0.141 (0.070)	-2.00**
Log Experience in crop farming	0.065 (0.020)	3.16***	0.086 (0.029)	2.89***
Log Rainfall	0.211(0.030)	6.93***	0.253 (0.138)	1.83*
Log Expenditure in malaria control	0.011 (0.006)	1.76*	...	...
Log fertilizer	0.527 (0.033)	15.80***	...	...
Pre_primary Level (=1)	-0.241 (0.181)	-1.33	-0.075 (0.271)	-0.28
No education (=1)	-0.249 (0.041)	-6.07***	0.174 (0.046)	3.81***
Secondary Level (=1)	0.136 (0.043)	3.12***	0.299 (0.065)	4.59***
Technical Level (=1)	0.335 (0.122)	2.74 **	0.503 (0.145)	3.47***
University Level (=1)	0.171(0.245)	0.70	0.577 (0.324)	1.78*
Log agricultural land	0.336 (0.018)	18.13***	0. 285 (0.032)	8.84***
Log actual hours spent in farming	0.017 (0.018)	0.93	0.021 (0.019)	1.05
Log household size	...	...	0.241 (0.320)	0.75
Constant	4.88 (0.581)	8.40	6.88 (0.380)	18.11
R-Squared	0.1198	...	...	...
F-Test	F(15,6968)= 4.70	...	...	...
Sample size	6984	...	...	...

Note: ***, ** and * significant at 1%, 5% and 10% level. To be deleted after verification

Table A8: Impact of Malaria on Household Income Using a Sample with Malaria and other disease Illness Pooled with Healthy Individuals,

(Malaria =1 if a household member had malaria and 0 if other diseases) Standard errors of estimated coefficients are shown in parentheses

	1994				*1997*			
	OLS Estimates		**2SLS Estimates**		**OLS Estimates**		**2SLS Estimates**	
Explanatory variables	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**	**Coefficient**	**t-ratio**
Malaria = 1 if household member had malaria and 0= if other diseases	-0.099 (0.050)	-1.97*	-3.34 (1.76)	-1.89*	-0.154 (0.067)	-2.30**	-4.51 (1.53)	-.94***
Other diseases = 1 if malaria and 0 if other diseases (comparison group = health household members)	-0.086 (0.051)	-1.70*	-0.749 (0.395)	-1.90*	-0.094 (0.059)	-1.58	-0.033 (0.076)	-0.43
Log Age in Years	0.996 (0.176)	5.65***	-0.218 (0.152)	-1.43	0.635 (0.207)	3.07***	1.40 (0.289)	4.84***
Sex (1= Male; 0 = Female)	…	…	-0.501 (0.084)	-.94***	…	…	-0.021 (0.108)	-0.20
Age of head of household squared	-0.0002 (0.000)	-7.74***	…	…	-0.0002 (0.000)	-.76***	-0.0003 (0.000)	-.50***
Log Household Size	…	…	0.325 (0.048)	6.64***	0.208 (0.040)	5.22***	…	…
No Education (=1)	…	…	-0.732 (0.324)	-2.26**	-0.120 (0.055)	-.17***	-0.067 (0.073)	-0.92
Pre-primary (=1)	0.240 (0.267)	0.90	-0.156 (0.509)	-0.31	…	…	…	…
Secondary(=1)	0.376 (0.046)	8.08***	-0.204 (0.329)	-0.62	0.632 (0.068)	9.25***	0.422 (0.100)	4.20***
Tertiary (=1)	0.669 (0.128)	5.20***	0.171 (0.390)	0.44	1.162 (0.193)	6.01***	0.591(0.283)	2.09**
University (=1)	0.945 (0.283)	3.33***	…	…	…	…	…	…
Residence (1=rural; 0 = Urban)	1.32 (0.117)	11.24***	-0.585 (0.165)	-.54***	…	…	1.100 (0.115)	9.57***
Log distance to the market	…	…	…	…	…	…	-0.183 (0.036)	-0.09***

Gainful Employment (1= if employed; 0 otherwise)	…	…	…	…	…	…	0.337(0.095)	3.53***
Log actual hours worked	0.022 (0.019)	1.16	0.122 (0.040)	3.04***			…	…
Log Experience	0.067(0.023)	2.87***	…	…	…	…	…	…
Occupation of household head	0.082 (0.009)	9.08***	…	…	…	…	…	…
Malaria* education	…	…	0.298 (0.189)	1.57	0.057 (0.015)	3.75***	…	…
Log public expenditure	…	…	0.128 (0.066)	1.94*	0.044 (0.013)	3.26***	…	…
Other marital status	…	…	…	…	-0.102 (0.102)	-1.00	-0.206 (0.159)	-1.30
Single	…	…	…	…	…	…	0.380 (0.101)	3.75***
Married	…	…	…	…	…	…	0.639 (0.175)	3.64***
Malaria* primary education	…	…	…	…	0.092 (0.164)	0.56	…	…
Constant	5.95 (0.582)	10.23	11.99 (0.677)	17.72	4.83 (0.698)	6.92	2.44 (0.936)	2.61
Sample size = 7088 F(12,7075)= 45.92 R-squared = 0.0645	…	…	…	…	Sample size= 8414 F(14, 8399)= 33.92 R-squared = 0.0531		Sample size = 8414 F(14, 8399) = 29.58	

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