Farmers' health and agriculture in low income economies: investigating farm households and wider health interactions in rural Malawi

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Abstract

Food insecurity is closely related to low agricultural productivity, but it goes beyond basic food production. Poverty, inequalities in access to services, food distribution policies and infrastructure networks play a role in influencing people's access to food. In turn, access to food influences health outcomes on one hand, and on the other, the health of the agricultural labour force influences agricultural output. The literature on the empirical investigations of bi-directional linkages between health and agriculture has been growing, but the findings are affected by the critical lack of allowance for the seasonality of agricultural production, and its differential effects on livelihoods, specifically resulting from the seasonal variations in labour, food stocks, prices, wages, income and expenditure.

Using data from the 2010-2011 Integrated Household Survey (IHS3), we use a typology of rural households in the Kasungu-Lilongwe Livelihood Zone of Malawi developed through the technique of cluster analysis. These encompass a diversity of livelihood strategies and outcomes, but the majority of households are very poor with few assets to fall back on in case of shocks. They also suffer regular bouts of ill health. The study then adapts a set of non-linear programming models of the farm household types to simulate and investigate the welfare effects of morbidity, through the interaction between losses in labour and cash resources and the resulting production, consumption and time utilisation responses.

Overall, our findings reveal an abundance of family labour but with very limited demand for off-farm employment, and hence households are severely cash constrained. As such, the welfare impacts of morbidity operate particularly through cash losses, where households have to make strategic adjustments on their production and consumption decisions. In addition, the models effectively describe differential responses to similar changes in labour and cash resources across the household types.

Key-words: Ill heath, seasonality, livelihoods

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Table of Contents

Acronyms and abbreviations

ADMARC	Agricultural Development and Marketing Corporation
ART	Anti-Retroviral Therapy
BMI	Body Mass Index
CGE	Computable General Equilibrium
DFID	Department for International Development
DHS	Demographic and Health Survey
DSP	Discrete Stochastic Programming
EHP	Essential Health Package
FAO	Food and Agriculture Organisation
FEWSNET	Famine Early Warning Systems Network
FISP	Farm Input Subsidy Programme
GAMS	General Algebraic Modelling System
GPS	Global Positioning System
IFAD	International Fund for Agricultural Development
KAS	Kasungu Lilongwe Livelihood zone
LES	Linear Expenditure System
LEWIE	Local Economy Wide Impact Evaluation
LSMS-IHS3	Living Standards Measurement Survey – Third Integrated Household Surveys
MDGs	Millennium Development Goals
MK	Malawi Kwacha
NSO	National Statistics Office
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
RDT	Rapid Diagnostic Test
ROSCAs	Rotating Savings and Credit Associations
SAMs	Social Accounting Matrices
SCT	Social Cash Transfer
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
UN	United Nation’s
UNDP	United Nations Development Programme

US$	United States Dollar
WFP	World Food Programme
WHO	World Health Organisation

List of Tables and Appendices

List of Figures

Chapter 1: Introduction and study’s background

1.1 Study’s background

In low income economies, agriculture continues to be the foundation of economic growth, poverty reduction and improvements in rural economies (Awokuse and Xie 2015; Christiaensen, Demery, and Kuhl 2011; Dethier and Effenberger 2011; Diao et al. 2007; Janvry and Sadoulet 2010; Shenggen and Rosegrant 2008; World Bank 2007). Its role in economic development is particularly important to such economies because most of the farmers are poor, and depend on agriculture and related activities for a significant part of their livelihoods. In these low income economies, the sector is large both in terms of aggregate income and total labour force (Dethier and Effenberger 2011).

The benefits of agriculture in low income economies have been studied immensely and debated for years (Christiaensen, Demery, and Kuhl 2011; Dethier and Effenberger 2011; Diao et al. 2007). Generally, there is a common consensus in economic literature that growth in the agricultural sector is an important instrument for the reduction of poverty, improved food and nutrition security, and an overall economic growth in agricultural economies (Diao et al. 2007; Janvry and Sadoulet 2010; World Bank 2007).

According to the United Nations (UN), investing in agriculture is widely viewed as the most effective type of investment for reducing poverty in Africa (United Nations 2012). Similarly, the Food and Agriculture Organisation (FAO), World Food Programme, and International Fund for Agricultural Development (2012) maintain that agricultural growth involving smallholders, especially women, is likely to be most effective in reducing extreme poverty and hunger when it increases returns to labour and generates employment for the poor. Growth in agriculture enables households to produce more agricultural output thus providing adequate food supply that transforms the populations’ health and nutritional status. The growth of the agricultural sector also helps to generate more income and increase the agriculture’s population resilience to shocks such as those resulting from ill health or natural disasters.

The agriculture sector's importance in contributing to economic growth in developing countries makes it appealing for governments and development agencies to invest in, with continued commitment to uphold smallholder agriculture for its potential in reducing poverty, hence improving the livelihood of poor people (Christiaensen, Demery, and Kuhl 2011; Diao et al. 2007; Shenggen and Rosegrant 2008; World Bank 2007). In fact, the World Bank's World Development Report titled "*Agriculture for Development*" warns that reduced support of agriculture by international donors and governments would be damaging for the progress of growth, development and poverty reduction in poor countries (World Bank 2007).

Despite the potential of the agriculture sector to spur economic growth and food security in low income countries such as those in sub Saharan Africa (SSA), poverty and food insecurity have remained a concern in SSA, despite declining poverty and hunger globally.

In 2015, the United Nations Food and Agriculture Organization (UN-FAO), the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP) announced that hunger was on the decline globally (Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, and World Food Programme 2015). However, in absolute terms, the number of undernourished people was on the increase especially in the developing world, reflecting a slow pace of progress in fighting hunger due to factors such as rising food prices, droughts and political instability in several countries (Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, and World Food Programme 2015).

Similarly, the 2015 Millennium Development Goals (MDGs) report shows significant decline in extreme poverty over the last two decades, and the population in the developing world living on less than US$ 1.25 per day fell from nearly 50% in 1990 to 14% in 2015 (United Nations 2015). In sub-Saharan Africa, the proportion of population living under US$ 1.25 a day fell from 57% in 1990 to 41% in 2015 (United Nations 2015). However, despite progress in the efforts to reduce poverty in the low income economies, poverty remains widespread in SSA where more than 40% of the population still lives in extreme poverty (United Nations 2015).

Malawi, which is the focus of this study, is a landlocked country and one of the poorest countries in the world, ranking 173 out of 188 countries and territories in the Human Development Index (United Nations Development Programme (UNDP) 2015). Nearly 47% of children are stunted (National Statistical Office (NSO) and ICF Macro 2011) and the life expectancy at birth in the country is 57 years for males and 60 years for females (World Health Organisation (WHO) 2015b). Half of the population live on less than US$ 0.66 per person per day and a quarter in extreme poverty living on less than US$ 0.42 per person per day (National Statistical Office (NSO) 2012a).

About 85% of the population reside in rural areas, and smallholder agriculture production in key to their livelihoods (National Statistical Office (NSO) 2012b). The country has an urbanization rate of the 16%, which is among the lowest of Africa, and a population growth rate of 3% per annum (World Bank 2016). Additionally, a combination of climate change, physical environment (e.g. soil fertility, and infrastructure), increase in population, land scarcity, and public policies has impacted agricultural productivity growth resulting in food deficits (Chirwa and Dorward 2013; A. Dorward and Chirwa 2011; A. Dorward et al. 2004).

Unlike the neighbouring Mozambique which is labour abundant, Malawi is characterised by severe land scarcity and land is often under permanent cultivation hence decreasing soil fertility (David E. Sahn, Dorosh, and Younger 1999). As evident in T. S. Jayne, Chamberlin, and Headey (2014), parts of Africa such as Malawi are land scarce and densely populated, while other countries are land abundant.

Malawi geographical location is unique, with the less land scarce Mozambique surrounding most of the country. However, despite the land pressure in Malawi, cross-border movement from Malawi to Mozambique for agriculture production purposes is often limited by land tenure and migration laws. Like in many countries in Africa, Malawi's land policy is designed to clarify and formalise customary tenure (P. Peters and Kambewa 2007; Kishindo 2004), and competition for land and the high value attached to it may prevent farmers from relocating in search of more land. Consequently, farm households that are highly dependent on agriculture are confined in highly populated areas and with small landholdings.

In addition to land scarcity, the country is also plagued with high prevalence of HIV/AIDS (National Statistical Office (NSO) and ICF Macro 2011) and tropical diseases such malaria (Ministry of Health 2011), thus affecting agricultural productivity. For example, Jayne, Thomas et al. (2006) outline the consequences of HIV/AIDS on agriculture in Eastern and Southern Africa which include a decline in crop production, shift to less labour intensive cropping activities, loss of income, and hence increased poverty. HIV/AIDS is the leading cause of death in Malawi, followed by lower respiratory infections and malaria (World Health Organisation (WHO) 2015b).

In the agricultural sector, the health status of the agricultural labour force is critical to agricultural productivity. Ill health diminishes a person ability to work, adopt improved production technologies or acquire technical information from extension services (Asenso-Okyere, Chiang, Thangata, and S.Andam 2011). The cost of treatment and other non-medical expenses such as transportation also create demand on constrained cash resources, thus leading to disinvestment in agriculture production.

In the following section, we elaborate on these health-agriculture linkages, which are of critical importance to rural agriculture livelihoods, and are therefore key to this study.

1.2 Justification of the study

Smallholder farm households in poor rural economies are the locus of critically important health-agriculture linkages. In these systems, health and agriculture are linked within households through labour, capital and disease and nutritional outcomes. These linkages also extend outside households through interactions with markets, such as labour markets, and they have major effects on household members' welfare, poverty and food security status.

On one hand, reduced agricultural productivity, inequalities in access to food or inadequate food distribution systems results in food insecurity, which in turn influences health and nutritional outcomes such as undernutrition. On the other, health shocks, such as morbidity and mortality, affect agricultural productivity by reducing the number, capacity and efficiency of the labour force, as well as creating a demand on households' asset and financial resources as a household attempts to mitigate the shock. The effects of such health shocks on the agricultural labour, off-farm supply of labour and on cash capital resources, and subsequently on farm output, income and consumption expenditure, form the rationale for the current study.

While the conceptual, theoretical and empirical investigation of the linkages between health and agriculture is important for the purpose of informing governments and development agencies in the process of strengthening policy and institutions to better integrate agriculture, food security, health and nutrition, pro-poor policies that incorporate both the development of agriculture and health are lacking in many low income countries (Lipton and de Kadt 1988; Hoddinott 2012b). The lack of such policies has been linked to the limited understanding of the nature and the extent of the interaction between health and agriculture in different contexts (Asenso-Okyere, Chiang, Thangata, and S.Andam 2011; Hawkes and Ruel 2006).

Empirical investigations of health-agriculture linkages are also often affected by the limited ability to consider the seasonal nature of agriculture production, and the resulting seasonal resource constraints, such as cash capital and labour. In much of SSA, agriculture is reliant on rain, and there are substantial variations in resource requirements across different stages of the production cycle.

In Malawi, annual rains for the main cropping year begin from November-December and last through March-April in most of the country. With the onset of the cropping year, farmers begin cropping activities such as land preparation, and planting begins with the first rains, to take advantage of the nutrients that build up in the soil and also get the longest possible season for the crops to mature. The first stage of the production cycle is therefore labour intensive, and with the highest demand on cash resources for investment in farm inputs such as seed and fertilizer, and hired-in labour for those who are able to pay for it.

However, the peak production and high rainfall season is also accompanied by high humidity and temperatures which provide conducive conditions for the development of *Anopheles* mosquitoes, which transmit malaria (Mathanga et al. 2012; National Malaria Control Program (NMCP) [Malawi] and ICF International 2012). As a consequence, sickness among the farming population can result in loss of labour and cash resources during the critical period of the cropping season, and thereby resulting in poor crop husbandry practices that could inevitably affect final harvest outcomes.

In addition to the consequences of malaria, Malawi faces a significant HIV/AIDS pandemic, with about 11% of the adult population infected by the virus (National Statistical Office (NSO) and ICF Macro 2011). The HIV/AIDS pandemic can potentially exacerbate poverty through loss of capital and labour resources when a member of a household becomes ill, and the constrained resources in the household are diverted towards care and treatment of the sick person.

This study therefore seeks to investigate the health-agriculture linkages and provide advances in the theoretical and applied understanding of such linkages. Specifically, the study contributes to literature by providing evidence on the negative welfare effects of ill health on agricultural livelihoods, and the mechanisms through which they are transmitted. We advance on the methodological approaches by using a mathematical programming technique that estimates both the welfare outcomes of health shocks as well as describing the pathways through which the impacts are transmitted to poor agricultural livelihoods. Furthermore, our modelling technique incorporates key livelihood aspects of the households under investigation, and the findings highlight the context-dependent factors that influence the magnitude of the impacts and the households' responses to the effects of health shocks. The study's specific objectives are outlined in the following section.

1.3 Research objectives and organisation of the thesis

In this study, we aim to contribute to a greater understanding of the linkage between farmers' health status and agriculture, and the associated welfare impacts in the livelihoods of poor smallholder farming households in Malawi.

As a starting point, the study advances on the conceptual, theoretical and empirical understanding of the pathways through which health and agriculture interact, in poor farm households in low income economies, in a comprehensive review of literature and detailed methods presented in chapters 2 and 3, respectively.

Next, using survey data from the Living Standard Measurement Survey-Third Integrated Household (LSMS-IHS3) for Malawi, we perform a comprehensive descriptive analysis of the sample data, with the objective of describing the patterns of utilisation of available labour resources in own farm and off-farm activities, and also the occurrence and concentration of morbidity in poor rural farming households in Malawi.

Finally, by adapting an extended farm household model, which integrates key components of rural agricultural livelihoods such as the seasonality of agricultural production and heterogeneity of poor rural households, the study extends on the methodological approaches in modelling and understanding farm households' behaviour, specifically their strategic responses to seasonal losses of family labour and cash capital due to the effects malaria and HIV/AIDS. Towards this objective, we use simulation models of farm households.

Subsequent chapters of this study discuss in more detail current knowledge on the health and agriculture interactions, gaps in this knowledge, methods, models and the research findings. The study is organized as follows. Chapter 2 provides a detailed discussion of the multiple and bi-directional linkages between agriculture and health by setting out a conceptual framework, a review of previous literature, a discussion of knowledge gaps and methods used in previous investigations, and the methodological issues.

Chapter 3 provides a comprehensive discussion of the methods, sample and data. Specifically, we explain the formulation and the components of a set of dynamic non-linear programming models of poor rural Malawian farm households. Chapter 4 presents the results of the cluster analysis and of the descriptive analysis of the sampled households' characteristics, patterns of time utilisation and the distribution and concentration of morbidity.

Chapter 5 details the calibration and validation procedure of the base programming models of the farm households, and the models' results. In chapter 6, we outline the morbidity simulation scenarios and present the results of the simulation models. We conclude by discussing key finding and recommendations for policy and future research in chapter 7.

Chapter 2: A review of literature

2.1 Introduction

For a long time, agriculture, health and nutrition had occupied separate realms in both policy and programmatic levels (Hoddinott 2012a; E. T. Kennedy and Bouis 1993). Often, the analysis of determinants of agricultural productivity does not recognise the effects of health and nutritional status on productivity nor the consequences of agricultural output and production processes on the health of agricultural workers and consumers of agricultural produce. As Hoddinott (2012a) notes, such a separation is odd given that agriculture, health and nutrition are tightly interlinked. In order to strengthen the policy and programmatic links between agriculture, health and nutrition, there is need to discern and explain the pathways through which they interact.

In this chapter, we present a detailed review of key literature findings on the multiple and bi-directional linkages between agriculture production and the health and nutritional status of rural farming households. To contextualise the study in terms of the factors that influence poor rural livelihoods outcomes, we begin by exploring the general relationship between health shocks and livelihood outcomes. To achieve this, we outline the Department for International Development's (DFID) sustainable livelihood framework that explains the core factors affecting livelihoods, and the interrelationships between them in Figure 2.1.

Further, we present two more conceptual frameworks that elucidate the pathways through which health and nutritional status affect agriculture, and the pathways through which agriculture influences health and nutritional outcomes. In view of the complexity of overlapping pathways through which health and agriculture interact, we adopt the conceptual frameworks to structure the discussion. The conceptual framework illustrated in Figure 2.3 forms the linchpin of this study. In the figure, we illustrate the pathways through which health related shocks such as morbidity, mortality and pregnancy and childcare influences rural agricultural livelihoods. In Figure 2.4, we illustrate the various pathways through which agriculture influences the health and nutritional status of the farming households and the general population.

The rest of the chapter explores the methods and methodological issues in the investigations of health-to-agriculture linkages, the key lessons learnt from existing literature and an identification of the gaps in literature that the current study seeks to fill. We conclude the chapter by presenting a detailed background of Malawi.

2.2 Conceptualizing the linkages between health shocks, poverty and rural agricultural livelihoods

2.2.1 Linkages between health shocks and rural livelihood outcomes

The sustainable livelihoods framework is a tool to improve the understanding of the poor peoples' livelihoods. Generally, the framework presents the main factors that affect livelihoods. Chambers and Conway (1991) define a livelihood as one comprising of people, their capabilities and their means of living, including food, income and assets. It is environmentally sustainable when it maintains or enhances the local and global assets on which livelihoods depend on, and has net beneficial effects on other livelihoods. A livelihood that is socially sustainable can cope with and recover from stress and shocks, and provide for future generations. Figure 2.1 below outlines the Department for International Development's (DFID) sustainable livelihoods framework.

In understanding the framework for livelihood analysis, it is important to note that livelihoods are shaped by a multitude of dynamic factors. On the left side of the framework is the vulnerability context that frames the external environment in which people exist. Livelihoods are affected by shocks (e.g. human and livestock health, natural shocks, economic shocks and conflict), trend (e.g. population growth, change in politics and governance, technological and resource trends), and seasonality (e.g. of prices, of production, of health and of employment opportunities).

The core of the framework is the asset pentagon constituting of the human, social, physical, financial and natural capital. These asset categories form the basis upon which livelihoods are built and their utilisation often translates into positive livelihood outcomes. In this study, our emphasis is on the impacts of losses in human and financial capital due to effects of health shocks on rural agricultural livelihoods.

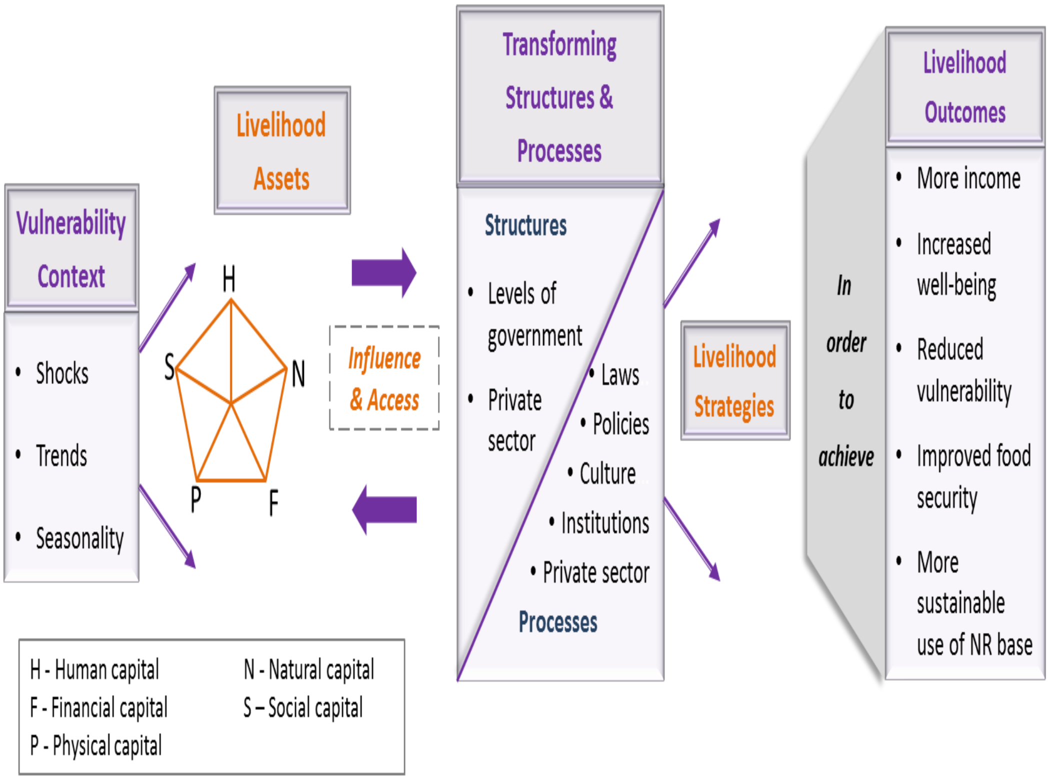

Figure 2:1 Sustainable livelihoods frame work

Source: Department for International Development (DFID) (1999)

The transforming structures and processes within the framework are the institutions, organisations, policies and legislation that shape livelihoods. These transforming structures and processes effectively determine poor households' access to various forms of capital, livelihood strategies and other sources of influence and decision-making. Further, they determine the terms of exchange between different types of capital, and finally, they determine the returns to the livelihood strategies. Livelihood strategies are the combination of activities and choices that people make in order to achieve their livelihood goals.

Finally, the right end of the framework illustrates the livelihood outcomes. These are the outputs of the livelihood strategies. They include increased income, increased well-being, reduced vulnerability, improved food security, and more sustainable use of the natural resource base (Department for International Development (DFID) 1999).

The sustainable livelihoods framework illustrated in Figure 2.1 presents a holistic livelihoods analysis. However, A. Dorward et al. (2002) argue that an important gap in the DFID's conceptual framework is the lack of emphasis of markets and their role in livelihood development and poverty reduction. The authors note that the lack of emphasis on markets can lead to failure to identify and act on (a) livelihood opportunities and constraints arising from critical market processes and (b) institutional issues that are critical to pro-poor market development. They therefore propose an alternative conceptualisation, with markets as one particular set of institutional mechanisms for co-ordination and exchange in an economy (Figure 2.2).

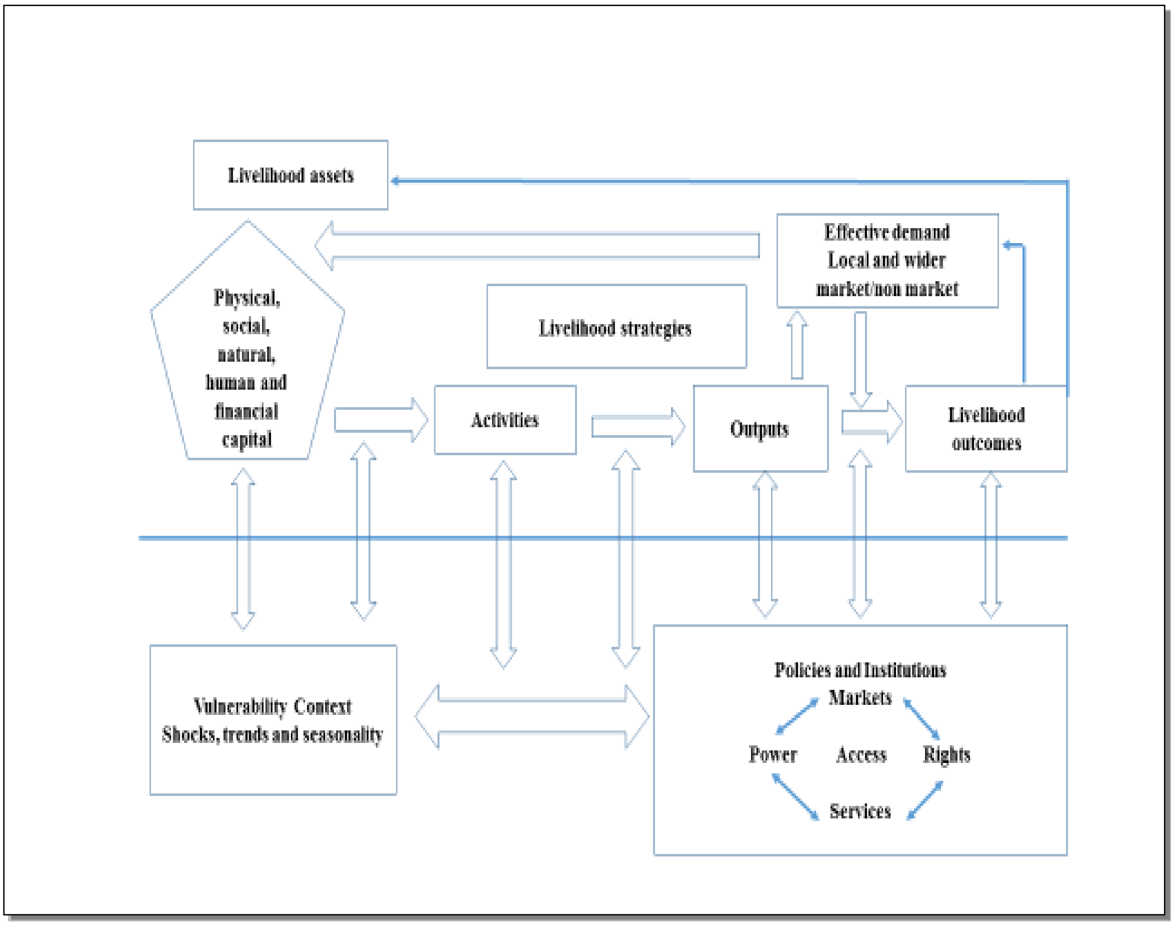

Figure 2:2 Modified sustainable livelihoods network

Source: A. Dorward et al. (2002)

In their study, A. Dorward et al. (2002) assert the importance of markets in pro-poor livelihoods development and poverty reduction by citing a number of observations.

These include: that the livelihoods of poor people are directly dependent on a range of markets either as private players or employees; major current and historical poverty reduction processes have depended on equitable private sector economic growth; poor people often identify problems with markets, including absence of markets, as important to their livelihoods; and if growth of markets is supported, they can provide efficient mechanisms for exchange, co-ordination and allocation of resources, goods and services, although they often fail.

In the current study, we base our analysis of rural agricultural households on the modified sustainable livelihoods framework (Figure 2.2), and focus on the interrelationships between human health shocks and poor rural livelihoods outcomes. Our priori assumption is that health shocks are a major factor that drives people into poverty, through their influence on access to and efficient utilisation of human and financial capital assets. For example, health shocks impact on human capital by reducing the number, the capability and employability of the workers. Financial capital is affected through the demand of medical care expenses, and coping with the consequences of ill health may cause a strain on physical assets in an attempt to satisfy short-term financial demand or smooth consumption expenditure.

Additionally, incapacitation of income earners may reduce their employability in the informal casual (often referred to as ganyu in Malawi) labour market, an important alternative source of income for poor rural households.

In the development literature, risk and vulnerability to shocks have been identified as key features influencing rural livelihoods and poverty, and have been a focus of policy attention (Devereux 2001). Vulnerability has two aspects: external, which includes the stresses and shocks that a household is subjected to; and internal, which refers to the capacity to cope (Chambers 2006). Typically, stresses are pressures, which are continuous and cumulative, distressing to a household and often predictable. They include for example seasonal shortages and declining resources. Shocks on the other hand are sudden, traumatic and unpredictable. They include for example floods, death or disease.

One of the shocks with major livelihood consequences to poor rural households is ill health among members of the household. Health shocks can have adverse consequences for households in both developed and developing countries. In the latter, the consequences of health shocks are likely to have more severe effects on households because they are more likely to be poor, lack health insurance and typically unable to insure consumption against such shocks. Ill health in such households can therefore lead to impoverishment through labour and income losses from incapacitation and medical expenses, and thus triggering a spiral of asset depletion, indebtedness and reductions in essential consumption in coping with the effects of ill health (Kabir et al. 2000; Haines, Heath, and Moss 2000; Russell 2004; Alam and Mahal 2014).

In the developing world, there is a large and growing body of literature on the effects of health shocks on households' livelihood outcomes. Many of the studies have adopted the sustainable livelihoods framework approach to analyse the impact of health shocks on livelihoods. However, there are differences in the approaches adopted in different studies.

On one hand, some studies use the sustainable livelihoods framework not only to estimate the welfare impacts of health shocks on households, but also to determine the pathways through which the impacts are transmitted. In their analysis, such studies may include the shock investigated (e.g. morbidity and prime-age mortality), livelihood strategies of the households (e.g. crop production and off-farm employment), inputs affected by the shock (e.g. family labour and financial resources), household responses to shocks (e.g. changes in cropping patterns, reallocation of labour and consumption smoothing) and the final livelihood outcomes, such as change in per capita income or consumption and the value of crop output (e.g. Kadiyala et al. 2011; Mahmoud and Thiele 2013; Yamano and Jayne 2004; A. Dorward, Mwale, and Tuseo 2006).

On the other hand, some studies have assessed the pathways through which health shocks impact on farm households, but they do not necessarily estimate the welfare changes (e.g. changes in income and consumption) that results from such shocks (e.g. Beegle 2003; Bridges and Lawson 2008). We elaborate on the approaches adopted by various authors in section 2.3.2.

One study of particular interest to the current analysis is that by A. Dorward, Mwale, and Tuseo (2006) who combine both the analysis of outcomes and pathways by using the farm household model approach. The authors investigated the direct impacts of HIV/AIDS morbidity and mortality on the livelihoods of poor rural people in rural Malawi. Their analysis estimated both the welfare outcomes and the transmission of such effects through loss of family labour and cash resources.

In this study, we use a similar approach, but unlike A. Dorward, Mwale, and Tuseo (2006), our analysis incorporates constraints in the informal rural casual labour markets with tighter restrictions on households' supply of labour, and thus income generated from employment in such markets. As we explain later in chapters 4 and 5, there are demand constrictions for such labour in rural Malawi. In addition, the authors adopt both the farm household and informal rural economy wide approaches, but the latter is beyond the scope of the current study. Finally, in our analysis, we show that the importance of the pathways through which health shocks impacts on the livelihoods of poor farm households is context-dependent.

In the following section (section 2.2.2), we explain the pathways through which health shocks and nutritional status influence agricultural livelihoods and in section 2.3, we explore the empirical evidence on this linkage.

2.2.2 Pathways from health and nutritional status-to-agricultural productivity and livelihoods

Figure 2.3 below sets out the pathways through which health shocks such as morbidity, mortality and pregnancy and childcare, affect agricultural production decisions and output, and subsequent livelihood outcomes. As the figure illustrates, health interacts with agriculture production through three pathways.

First, health interacts with agriculture production through the direct and indirect effects of morbidity on individual's wellbeing in terms of their health or body functions, on their supply of active labour and productivity, on household's financial resources and physical assets, and subsequently on the production choices and livelihoods of the farming households.

Second, mortality in the farming population leads to loss of labour and farming knowledge, and often causes increased demand on constrained financial and physical resources in coping with the consequences of death.

Third, through pregnancy and childcare, female farm workers take time off from agricultural activities during the pre-natal and post-natal periods, thus decreasing labour for agricultural production. In other instances, the role of childcare is delegated to younger or elderly members of the households, who are generally less productive.

Our core conceptualisation in this study is that health interacts with agriculture through its effect on the human and financial capital and their efficient use in agricultural production. We do recognise that the consequences of ill health have an effect on accumulation of physical assets and social capital, but the empirical estimation of health influences through them, and subsequent production and livelihood choices is beyond the scope of the current study.

The primary focus of this study therefore is to determine the impacts of health shocks on rural agricultural livelihoods, through their effect on the supply and efficiency of labour and on the short-term financial resources, and the subsequent production responses and welfare changes.

As Figure 2.3 illustrates, the causes of ill health are due to exposure to disease pathogens, poor sanitation, hazardous environment and poor nutrition. Favourable climatic environment, good sanitation, medical inputs, nutritious diet and physical activity all combine to sustain human health. The occurrence of health shocks such as illness, and in extreme cases mortality, has considerable implications for agriculture.

First, poor health status impacts on agriculture by reducing the number, capacity and efficiency of the labour force, and thus likely to reduce output (Croppenstedt and Muller 2000). Of critical importance is the health of agricultural workers. Agricultural workers affected by any debilitating effects of a disease can be expected to be absent from work, to adjust by shifting to work that is less demanding physically or may alter the amount of time worked, hence reducing their productive potential. Some of the available family time that could potentially be engaged in agriculture may also be diverted to caring for the sick persons. Consequently, reduced labour supply and low efficiency in agricultural production may lead to poor productivity, decreased marketable surplus, food insecurity and a decrease in farm income.

Second, ill health diminishes employability in off-farm occupations, consequently reducing complementary off-farm income. In the absence of medical insurance, poor households, and who often have very little asset holdings to mitigate against the effects of shocks, find it difficult to smooth consumption or meet short-term medical needs. Household's facing health shocks may divert constrained capital resources away from agricultural production therefore lowering agricultural output. Thus, in the farming population, health shocks impact on agricultural production by exacerbating liquidity constraints.

Third, the prevalence of malnutrition and disease in the general population influences market demand for agricultural products (Hawkes and Ruel 2006; Asenso-Okyere, Chiang, Thangata, Andam, et al. 2011). This may result from reduced purchasing power due to loss of income, savings and assets in response to health shocks. For example, occurrence of serious illness may lead to high medical expenses where health care is not free, and reduced ability to engage in farm and non-farm economic opportunities for income generation. In addition, where labour is severely constrained due to the consequences of ill health, hiring in substitute labour may be an alternative, further creating demand on households' finances.

Finally, Asenso-Okyere, Chiang, and Andam (2011) note that the long-term impacts of ill health on agriculture include: loss of accumulated farming knowledge; reduction of land under cultivation; shift to less labour-intensive crops; reduction of variety of crops planted; and reduction of livestock.

In the section that follows (section 2.2.3), we explain the pathways through which agricultural production influences household's health and nutritional outcomes. Although the focus of the current study is on the linkage between health shocks and rural agricultural livelihoods, the linkages are bi-directional, and an understanding of the links among agriculture, health and nutrition and the associated livelihood outcomes is of policy relevance in developing countries context.

Agriculture and food systems as suppliers of income, food and nutrients are important determinants of nutrition and consequent health status of consumers, who also include food producers. Failure of agriculture to provide nutritious food and income may therefore lead to poor nutritional and health status, thus affecting production of food. However, the links between agriculture and health are more complex than simply increasing food production for good health. In section 2.2.3, we present a framework of conceptualising key relationships between agriculture production and health and nutritional outcomes (Figure 2.4).

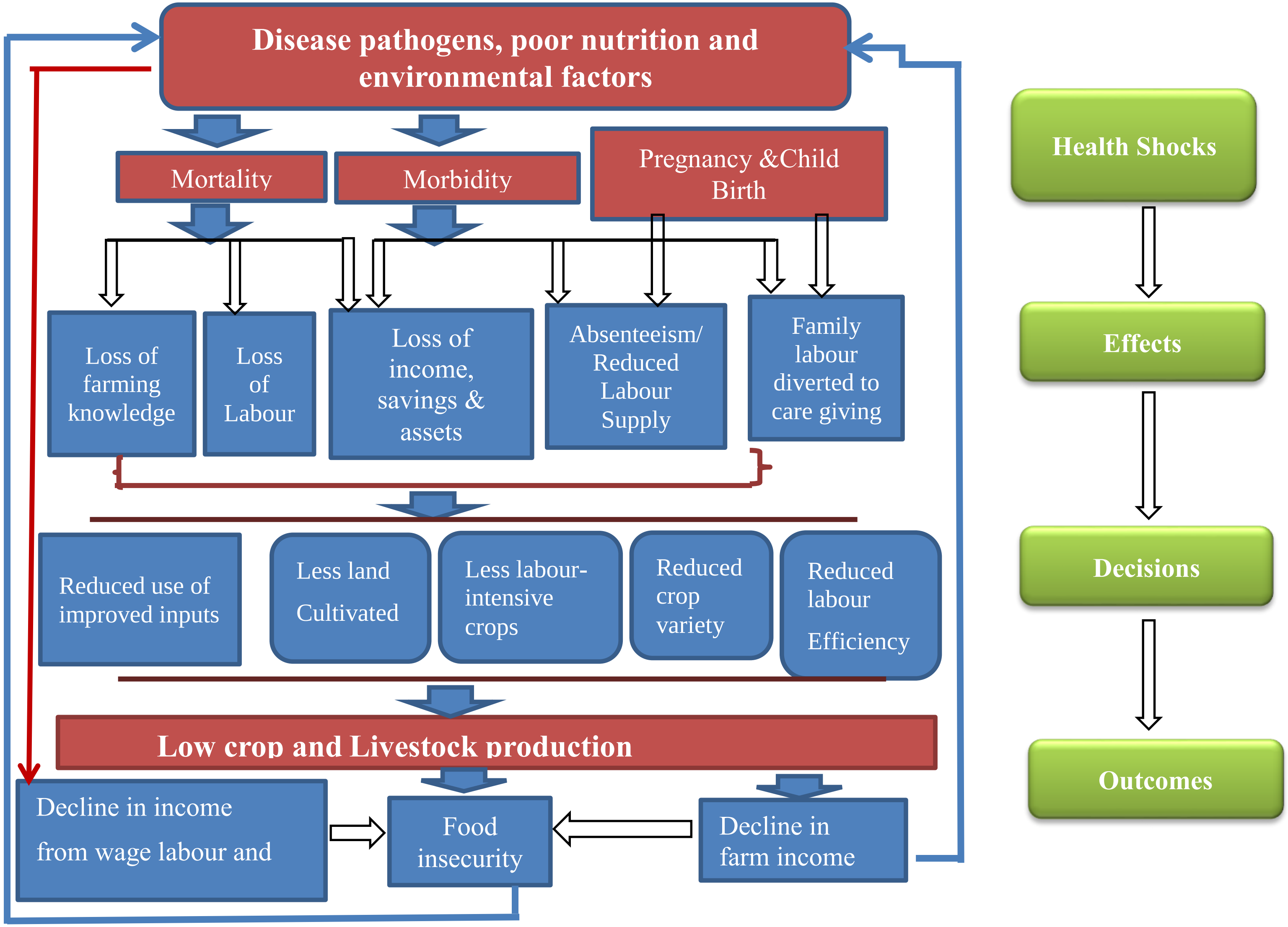

Figure 2:3 Pathways through which health shocks influence agricultural production and livelihood outcomes

2.2.3 Pathways from agriculture- to- health and nutritional status

The interactions between agriculture and health are two-way: agriculture affects health, and health affects agriculture (Asenso-Okyere, Chiang, Thangata, and S.Andam 2011; Hawkes and Ruel 2006; Lipton and de Kadt 1988). Agricultural production can contribute to both good and poor health among producers as well as the wider population, as summarised in Figure 2.4.

The conceptual framework in Figure 2.4 discerns six pathways through which agriculture production influences health and nutritional outcomes. First, agriculture as a source of food for own household consumption. Second, agriculture as a source of income for food and non-food expenditures. Third, agricultural policies and supply of agricultural output impacts on food (and non-food) prices. Fourth, engagement of women in own farm production and employment in agriculture, and their role in intra-household decision-making, resource allocation, child care and feeding influences household's health and nutritional outcomes. Fifth, agricultural production can lead to poor health through exposure to disease pathogens and occupational hazards. Sixth, expansion and intensification of agricultural in unsustainable manner is often associated with environmental degradation.

Agricultural practices determine the level of food production and, to a great extent, the health status and wellbeing of the consumers through provision of food, fibre, fuel, materials for shelter, and in some systems medicinal plants, which all contribute to good health (see Figure 2.4).

Food production, processing and access therefore influence individual food consumption and population health. However, for agriculture to influence health positively, the diversity, nutritional component and safety of agricultural produce for consumption is critical. Access to food in sufficient quantity that is enough in calories, free from toxins and of good quality with vitamins and minerals, is therefore an important pathway through which agriculture impacts on the health of the population.

Dietary diversity and quality of food in terms of its nutrient composition and safety are important aspects that directly determine the nutritional status of consumers (Savy et al. 2006; Masset et al. 2012; Jones, Shrinivas, and Bezner-Kerr 2014). The Food and Agriculture Organisation (FAO), World Food Programme, and International Fund for Agricultural Development (2012) report notes that in Africa, the number of hungry people has been growing not only due to insufficient food, but also because of low dietary diversity and disease pandemics such as the high prevalence of HIV/AIDS in the region. The presence of disease and consumption of fewer nutritionally distinct food groups or low dietary diversity contribute to malnutrition (Ruel 2002) and exacerbate poor health (Mpontshane et al. 2008; Weiser et al. 2009).

Andersen and Watson (2011) depict malnutrition in developing countries as a triple burden of under-nourishment (low or insufficient calorie and protein intake), micronutrient malnutrition (or hidden hunger) and over nutrition (consumption of excess calories leading to overweight and obesity). The Food and Agriculture Organisation (FAO) and World Food Programme (2002) reports that two-thirds of the world's population depend on cereals or tuber-based diets, which tend to satisfy the demand on calories but not essential micronutrients. For example, many African diets lack diversity and consist of a single dominant carbohydrate group as the main source of calories that may maintain body weight. The diet often includes little or no animal products and few fresh fruits and vegetables and often does not provide the micro- and macro-nutrients needed for proper functioning of the immune system.

In addition to provision of food and nutrients, agriculture also influences health by generating income potentially used on food and non-food expenditure such as health care, thus improving households' health and nutritional status. A well-nourished farming population is able to produce more food, and market the surplus. Income generated from agricultural activities can boost access to more land and labour for agricultural production, water and improved production inputs, information and extension services, and education among others, which all contribute to improved agricultural productivity. In addition, income from agriculture enables households to purchase food that they ordinarily do not produce themselves, or is out of stock, and invest in better living conditions, all of which can contribute to better health outcomes.

Agriculture production also influences health and nutritional outcomes through the output supply and demand dynamics, government pricing policies, and subsequently food prices. On one hand, high food supply leads to a dip in food prices, and more food is available to both farming and non-farming households. On the other, reduced supply of agricultural produce often results in high food prices, affecting the purchasing ability of net buyers especially the poor. Consequently, high food prices may lead to diminished supply of food, low dietary diversity, poor quality diets, and hence poor health and nutritional outcomes.

Another pathway through which agricultural production and growth acts as an important driver of nutrition improvement, and can have both positive as well as negative implications for nutrition, is through women's work in agriculture (Gillespie, Harris, and Kadiyala 2012; Pinstrup-Andersen 2012; Meinzen-Dick et al. 2012). Nutrition knowledge amongst women, child feeding practices, women's control over income and assets, and the time allocated to agricultural production may influence the health of nutritional outcomes for the women themselves, and other members of household.

A woman's participation in agricultural production activities may improve her bargaining power within the household, enabling her to participate in the household's decision-making, and hence an increased likelihood for women to make pro-nutrition choices concerning household expenditure (Balagamwala, Gazdar, and Mallah 2015). For example, in Ghana Malapit and Quisumbing (2015) investigated the linkages between women's empowerment in agriculture and the nutritional status of women and children. Their findings suggested that women's empowerment was more strongly associated with the quality of infant and young child feeding practices, but weakly associated with child nutrition status. Further, they found women's empowerment in credit decisions to be positively and significantly correlated with women's dietary diversity, but not body mass index.

Other gender aspects that include women's inability to own land, constrained access to capital (cash or credit) for investment in farm production and domestic use, lacking or limited access to technological training and extension services, the political arena, and their limited ability to participate in non-farm labour markets due to low education levels, have a bearing on production choices and household's wellbeing (Gladwin 1991; Boserup 1970).

Besides the nutritional link, both the agricultural production process and output affect the health status of the population in terms of disease outcomes. Engagement in agricultural production activities and consumption of food and livestock products can lead to poor health through exposure to disease pathogens and occupational hazards.

Specifically, agriculture may affect human health in the following ways:

i) Agricultural development in the form of irrigation dams may create suitable conditions for parasites that cause diseases such as malaria (Asenso-Okyere et al. 2009);

ii) improper food harvesting and storage practices allow mycotoxins (such as aflatoxin) to flourish leading to poisoning if such food is consumed (Set and Erkmen 2010; J. E. Smith et al. 1995; Fink-Grernmels 1999; Wagacha and Muthomi 2008);

iii) labour migration especially of agricultural labour force, can potentially expose agricultural workers to diseases such as HIV/AIDS and malaria, which in turn affects their performance, productivity and income (Asenso-Okyere, Chiang, Thangata, and S.Andam 2011; Hawkes and Ruel 2006);

iv) certain animal diseases such as brucellosis and rabies are transmitted to humans through contact or consumption of contaminated animal products (Zinsstag et al. 2007);

v) occupational disorders such as bodily injuries, back aches and heat exhaustion resulting from physical strain in performing manual agriculture work, and with little or no access to formal risk-coping mechanisms such as insurance, pensions and social assistance (African Union 2009; Cole 2006); and

vi) use of agricultural inputs such as pesticides by untrained farm personnel may cause illness through pesticide poisoning (Pingali, Marquez, and Palis 1994; Antle and Pingali 1995; Wesseling et al. 1997; C. Wilson and Tisdell 2001; Alavanja, Hoppin, and Kamel 2004; London et al. 2005; Ngowi et al. 2007).

Finally, the process of agricultural development often leads to detrimental impacts on the ecosystems. Intensification of agricultural production may negatively degrade the environment through processes such as deforestation, greenhouse gas emissions, and discharge of contaminated waste in water bodies. For example, in their investigation of the linkage between agriculture and malaria, Asenso-Okyere et al. (2009) found that water resource development, cover cropping, wet land cultivation and land use changes to agricultural use were found to expand habitats for malaria carrying mosquitoes. Further, agricultural production competes with water supply and sanitation needs of local communities (Hawkesworth et al. 2010).

In section 2.3, we explore documented evidence that has attempted to investigate the health-to-agriculture linkages. To understand the linkages, we consider two main categories of health interaction with agricultural livelihoods. First, the (two-way) interaction among nutritional status (as indicated by calorific intake and anthropometric measurements), agricultural production (indicated by output, farm profits, or production efficiency) and labour productivity (indicated by wages).

Second, the linkage between health shocks and agriculture that results from the effects of morbidity and mortality, on the supply and efficiency of labour for agricultural activities, and on the constrained financial resources in catering for medical (e.g. prescription medicine and consultancy fee) and non-medical (e.g. transport to a health facility) related expenses.

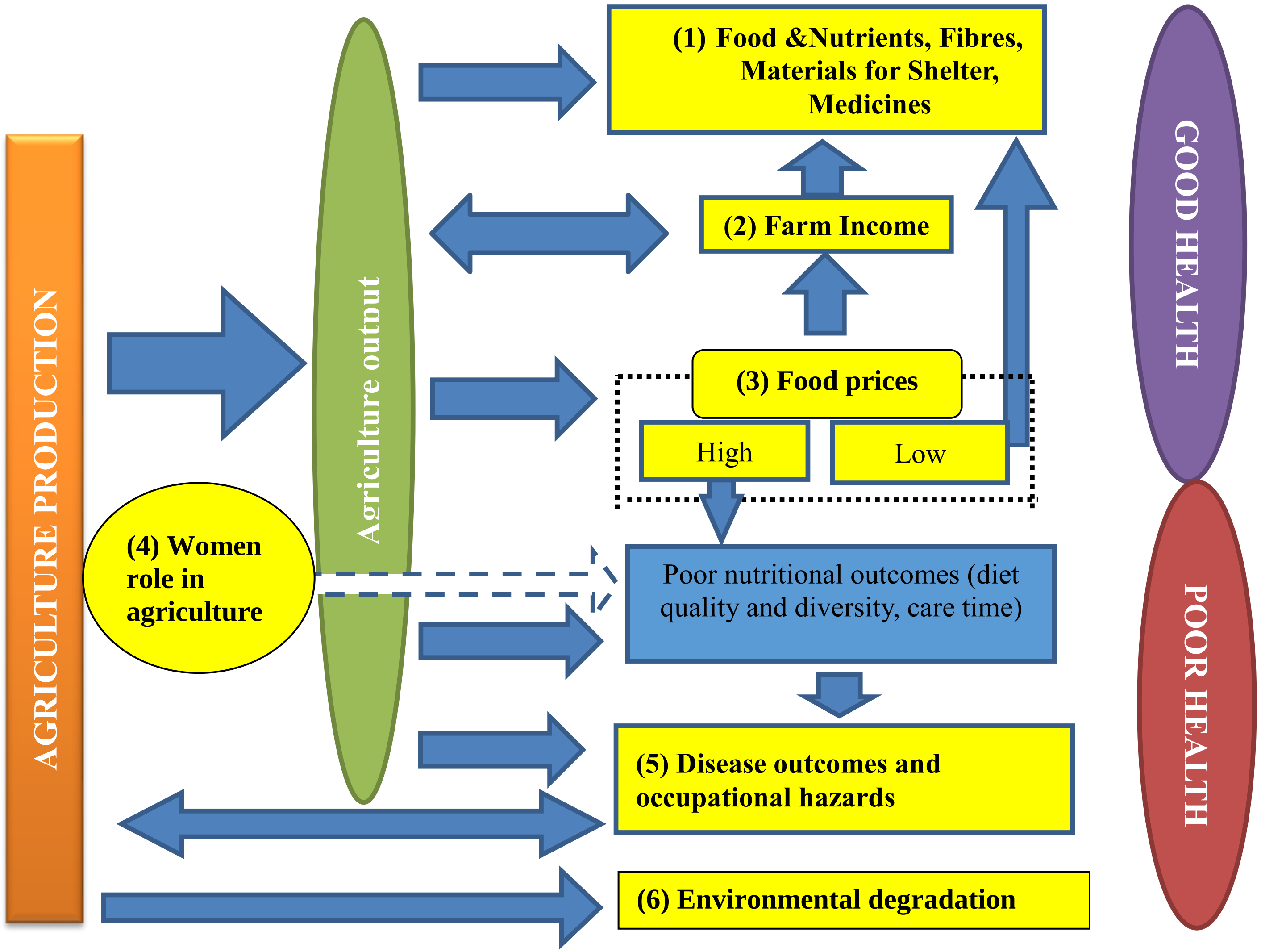

Figure 2:4 Pathways through which agricultural production influences health outcomes

2.3 Empirical evidence of the health and nutritional status impacts on agriculture in low income countries

2.3.1 Empirical literature review on nutritional status impacts on agricultural and labour productivity

In low income economies, agriculture production is labour intensive requiring high levels of energy expenditure, and some studies have shown that health and nutrition status directly affect productivity and wage rates (J. Behrman and Deolalikar 1989; Deolalikar 1988; Strauss 1986; Croppenstedt and Muller 2000; P. Hazell and Haddad 2001; Dasgupta 1998).

With manual labour as a primary input in agricultural production, particularly in low income economies, the health of the agricultural labour force and the timing of labour input for production activities are key determinants of final harvesting outcomes. For example, late planting or weeding of crops can lead to substantial output losses. In labour constrained farming households, poor health, pregnancy and childcare can limit workers productive time and potential, thus affecting income generated, and thereby perpetuating a downward spiral into low agricultural output, food insecurity and poverty, and in some instances worse health conditions. This further jeopardizes economic development for the wider population (Hawkes and Ruel 2006). Death of productive household members especially, leads to loss of labour, farming knowledge and other productive assets. Health is therefore a capital good that can either improve or reduce a households' productive ability.

Over the years, economics literature has documented the impact of nutritional status on: farm output (e.g. Deolalikar 1988; Fafchamps and Quisumbing 1999); farm income (see Pitt and Rosenzweig 1986); farm labour supply (Strauss 1986); and agricultural labour productivity and wages (e.g. Sahn and Alderman 1988b; Deolalikar 1988; Haddad and Bouis 1991; J. Behrman and Deolalikar 1989; Croppenstedt and Muller 2000; Foster and Rosenzweig 1994).

Harvey Leibenstein (1957) cited in Strauss and Thomas (1998), hypothesized that relative to poorly nourished workers, those who consumed more calories were more productive and that at very low levels of calorie intake, better nutrition is associated with increasingly higher productivity. According to Strauss and Thomas (1998), the consequences of poor health on the labour market are likely to be more serious for the poor, who are more likely to suffer from severe health problems and to be working in jobs for which strength (and therefore good health) has payoff. Consequently, those in poorest health are excluded from the labour market and therefore lose income from wage labour and other off-farm activities. This indicates therefore that for a given state of healthiness, those with greater calorie intakes or better anthropometric indicators are more productive or receive higher wages (Deolalikar 1988).

Strauss (1986) used local prices of food as instruments for calorie consumption by family labour force, to estimate a Cobb-Douglas agricultural production function for a sample of farm households in Sierra Leone. The author used "effective labour", specified as a nonlinear (quadratic) function of the number of actual on-farm family labour hours and average calorie intake per consumer equivalent in the household as one of the inputs in the production function. Strauss found the "effective family labour" to increase significantly, although at a diminishing rate, with average calorie intake, suggesting a positive effect of calorie availability on family agricultural productivity.

In Sri Lanka, Sahn and Alderman (1988) tested the relationship between nutrition and labour effort or productivity. The authors found that calories influenced the wage offered, suggesting that better nutrition increases labour productivity. Despite the fact that their empirical estimates were only suggestive, that higher calorie intake results in higher wages, the authors recognized that there was a need to explore the mechanism by which the relationship was mediated. It could have been that remuneration was based on the amount of work accomplished per unit time, and as such, the better nourished workers received higher wages owing to their ability to perform more work in a given unit of time.

In South India, Deolalikar (1988) used average weight-for-height and the average calorie intake as explanatory variables in the farm production function, and individual weight-for-height and calorie intake in the wage equation for persons participating in the casual agricultural labour market. The author found that neither market wages nor farm output was responsive to changes in the daily energy intake of workers. However, both market wages and farm output were highly elastic with respect to weight-for-height.

The author concluded that while the human body can adapt to inadequate nutrition in the short run by depleting its health stock, it cannot adapt as readily to chronic malnutrition that eventually results in loss of weight-for-height. In the medium run, the depletion of the body's health stock can result in morbidity or even mortality in the long run, both of which would result in productivity losses. Medium and long run effects of better health and nutrition are therefore important for better productivity, while short-run effects could be insignificant. The findings by Haddad and Bouis (1991) in Southern Philippines are consistent with this conclusion. In their study, higher agricultural wages appear to result from greater height (which is a cumulative measure of good nutrition and absence of infection in early childhood) rather than from short-run (calorie intake) or medium-run (weight-for-height) proxies of nutritional status.

Behrman and Deolalikar (1989) examined the nutrition and labour productivity link by considering seasonal variability in rural South India. They found that calorie intake was an important determinant of wages in the peak months, whereas weight-for-height was more important during the slack months. Their finding clearly indicates that seasonal variation is an important aspect to consider in the empirical investigations of health, nutrition and agriculture linkages.

In Ethiopia, Croppenstedt and Muller (2000) included both indicators of nutrition and health status to estimate their effect on agricultural productivity. They found that nutrition and morbidity status affect agricultural productivity, and the market wage rate was very responsive to the weight-for-height, body mass index (BMI) and height. Their results show that the elasticity of labour productivity with respect to nutritional status was strong and similar in the technology estimates and wage equations, particularly in a context where separability between consumption and production decisions of the household is rejected. Morbidity status however had a weak effect on productivity and the authors suggest that such weak effect may appear stronger with a higher sample size. In the Philippines, Foster and Rosenzweig (1994) found that calorie consumption augments work effort or labour productivity for workers in self cultivation of own land and those employed on a piece-rate agreement.

Fafchamps and Quisumbing (1999) investigated the human capital effects on productivity and labour allocation of rural households in Pakistan. They estimated a

Cobb-Douglas production function with height and body mass index (BMI) to proxy health and nutrition aspects of human capital. They note that BMI is a commonly used measure of fitness and nutritional status, while adult height captures the cumulative effects of childhood and adolescent nutrition as well as genetic endowments. Other human capital variables included in the estimation are age and education. Their results indicate that in general, the human capital variables were not significant, but height among adult males resulted in higher output in the *kharif* (autumn) season, and higher BMI of adult males was associated with higher output in both *kharif* and *rabi* (spring) seasons. These effects, however, did not influence total crop output.

In the following section, we review empirical literature on the interaction between morbidity and agricultural livelihoods.

2.3.2 Empirical literature review on health shocks impacts on agricultural livelihoods

The literature highlighted in section 2.3.1 is fundamental to understanding the relationship between nutritional status, agricultural output, labour productivity and wages. However, it is equally important to extend knowledge on the link between health related shocks, on-farm labour supply and efficiency, farm output, agricultural labour productivity and income. Detailed reviews of studies that have investigated the economic costs of health shocks on the livelihoods of poor people including their agricultural production can be found in Russell (2004) and Alam and Mahal (2014).

Agricultural production depends on the availability and quality of labour force, but as evidenced in economic literature, labour force and agricultural production in general are often hampered greatly by shocks, among them health-associated shocks such as illness, injury, pregnancy and death. Various studies have examined the linkage between health status (morbidity) on: on-farm family labour supply (Pitt and Rosenzweig 1986; Kim, Tandon, and Hailu 1997); farm profits (Pitt and Rosenzweig 1986); agricultural output or productivity or production efficiency (Ulimwengu 2009; Ajani and Ugwu 2008); and agricultural labour productivity and wages (T. P. Schultz and Tansel 1997; Kim, Tandon, and Hailu 1997).

In Côte d'Ivoire and Ghana, T. P. Schultz and Tansel (1997) employed an instrumental variable estimation approach, instrumenting disability days with local food prices and health services, to estimate the effect of morbidity on productivity of wage earners and self-employed people whose wages could be determined. They found that disability days reduced wages by at least 10% and the hours worked by 3% or more.

Kim, Tandon, and Hailu (1997) analysed the impact of onchocercal skin disease on the productivity of employees at a coffee plantation in southwest Ethiopia. Their results revealed that permanent male employees (who were the core of the plantation labour force) with the disease earned lower daily wages and that labour supply in the plantation was adversely affected by the disease infections.

In Indonesia, Pitt and Rosenzweig (1986) estimated the effect of family morbidity on farm profits using a profit function approach. The authors found no statistically significant effects of the number of sick days (considered as an endogenous variable) on farm profits, but a strong effect of illness of a farmer or their spouse on labour supply.

Pitt and Rosenzweig (1986) however recognise that the lack of an effect of illness on farm profits may be due to substitution of hired labour for illness-induced lost family labour in a well-functioning input and output markets, and not necessarily the absence of an effect of morbidity on labour productivity. They conclude that despite family labour being significantly reduced by ill health, total labour supply, and hence farm profits, would be unaffected when a household has access to an active labour market.

Production performance is therefore independent of changes in farmers' health status in the presence of perfect markets for inputs, consumed commodities or inputs in health production. Such markets are however likely to be non-existent in low income economies where markets are largely imperfect or missing.

Ulimwengu (2009) estimated a stochastic production function using household survey data from Ethiopia to analyse the relationship between farmers' health impediments and agricultural production efficiency. The author found that production inefficiency significantly increased with the number of days lost to sickness and that healthy farmers produced more per unit of inputs, earned more income and supplied more labour than farmers affected by sickness.

Ajani and Ugwu (2008) examined the impact of adverse health (indicated by the average number of days lost to incapacitation) on farmers' productivity, and the share of adverse health on farmers' efficiency in Nigeria using a stochastic frontier approach. They found that the health variable had the largest positive and statistically significant effect in the inefficiency model, implying that health has a greater share in the inefficiency of farmers. They concluded that to achieve food self-sufficiency and growth in the agricultural sector, health issues among the agricultural labour force must be properly addressed.

More recently, Islam and Maitra (2012) used panel data to estimate the effects of health shocks on household consumption and how access to microcredit affects households' response to such shocks in Bangladesh. Their findings suggested that households sold livestock in response to health shocks, thereby attaining short term insurance but at a significant long-term cost. Further, they found that for households that had access to microcredit facilities, they did not need to sell livestock to insure consumption.

A number of authors have investigated the impacts of specific diseases on agriculture. In sub-Saharan Africa, a significant number of studies have investigated the impact of specific diseases and conditions on agricultural labour supply, farm output, farm profits and labour productivity, among others. For example, some studies have investigated the links between agriculture production and: HIV/AIDS (e.g. Asenso-Okyere et al. 2010; Asingwire 1996; Beegle 2003; Chapoto and Jayne 2005; Fox et al. 2004; Masanjala 2006; Rugalema 1998; Jayne, Thomas et al. 2006; A. Dorward, Mwale, and Tuseo 2006); malaria (e.g. Asenso-Okyere et al. 2009; Badiane and Ulimwengu 2012; Girardin et al. 2004; Larochelle and Dalton 2006; Wielgosz et al. 2012); onchocerciasis (e.g. Kim, Tandon, and Hailu 1997); and schistosomiasis (e.g. Audibert and Etard 1998; Audibert 1997).

In their review of empirical evidence of the effects of HIV/AIDS on rural household livelihoods in the Eastern and Southern regions of Africa with high HIV/AIDS prevalence rates, Jayne, Thomas et al. (2006) found that the most common effects of HIV/AIDS burden on agriculture in afflicted households include: a reduction in area cultivated; a shift away from more labour-intensive high-value cash crops to less labour-intensive crops; a reduction in weeding labour thus contributing to lower yields; a reduction in the use of improved inputs due to lack of finances resulting from loss of wage income of the deceased members and health/funeral expenses; a decline in crop production; losses in off-farm income; and increased poverty.

On an economy wide basis however, Jayne, Thomas et al. (2006) make key argument that there is high level of underemployed labour in the informal sector in the Eastern and Southern Africa regions, and as far as agricultural labour was affected by HIV/AIDS, labour could shift from the informal sector to agriculture sector to compensate for labour losses. This raised the possibility that the greater pathway for the transmission of health shocks to agriculture and rural incomes would be via capital rather than labour.

Similarly, A. Dorward, Mwale, and Tuseo (2006) investigated the welfare impacts of HIV/AIDS morbidity and mortality among poor households in Malawi. They found that severe morbidity and bereavement led to income losses resulting from reduction in hired out labour, reduced on-farm labour use especially among the poorest households, change in cropping patterns as affected households shifted out of production of capital intensive crops and reduction in area under cultivation.

Asenso-Okyere et al. (2010) also note that an important effect of HIV/AIDS on livelihoods is through the drain on household labour. Often, there is withdrawal of the labour of the sick person and the caretaker. Women and girls especially are withdrawn from their livelihood activities to care for the sick, thereby reducing labour for on-farm activities. This may result in the decline of farm output, especially in low-income economies where women have a large role in agriculture.

In Zambia, Chapoto and Jayne (2005) found that HIV-related mortality led to a decrease in area of land under cultivation. Fox et al. (2004) analysed the productivity and attendance at a tea estate in Kenya and found that HIV-positive workers plucked 4-8 kilograms per day less tea in the last one and a half years before they died, and that they had more sick leave days as compared to HIV-negative workers.

A Tanzanian study on HIV/AIDS impact on agriculture labour found that males and females with HIV/AIDS lost an average of 297 and 429 days of productive work, respectively, over an 18 months period (Rugalema 1998). In Uganda, Asingwire (1996) found a reduction in labour supply due to death resulting from HIV/AIDS infection led to a reduced variety of crops planted by households. Masanjala (2006) found that households affected by HIV/AIDS in Malawi faced an income shock that lasted for about 18 months, taking the households to a lower-than-average equilibrium monthly income level. HIV/AIDS infected persons were found to have a decline in work participation by 16 days over a one year period, and income losses due to illness and caregiving was estimated to be about 56% of the annual income per capita in affected households in Nigeria (Mahal et al. 2008).

Similar to HIV/AIDS, malaria has direct negative impacts on rural agricultural livelihoods. Asenso-Okyere et al. (2009) identifies a number of ways through which malaria affects agriculture. First, malaria parasites cause morbidity leading to incapacitation of the economically active population. Consequently, there is a reduction in the quantity and quality of labour supplied to the household due to absenteeism by the infected persons. Second, reduced farm labour due to ill health may adversely affect adoption of labour-intensive but highly yielding crop technologies thus affecting food supply and nutrient intake.

Third, diversion of family's productive time to caring for the sick persons may significantly affect agricultural production, particularly where labour is a constraining production factor. Fourth, in the event of death of productive household members, there is loss of farm labour and accumulated farming knowledge, potentially affecting acquisition and diffusion of agricultural innovations. Knowledge that is passed over from one farmer to another is often considered an effective way of disseminating technology in rural areas, and would be lost after death.

Finally, there is a potential reduction in agricultural investments due to high expenditures on malaria treatment and prevention. In coping with the health shock, households may borrow money, spend their savings or sell assets to meet the cost of treatment, and thus disinvesting in agriculture. Consequently, potential production responses may include: reduction in area under cultivation; planting of less labour-intensive crops; changes in cropping patterns; adoption of labour-scarce innovations that may be less productive farming techniques; reduction in the use of farm inputs; or hiring in labour, which has cost implications.

Larochelle and Dalton (2006) investigated the impacts of transient shocks such as malaria, on family labour use in irrigated rice fields in Mali and found a reduction in labour supply due to illness, thus affecting final harvest outcomes. In Cote d'Ivoire, Girardin et al. (2004) studied farmers engaged in intensive vegetable production. The authors found that farmers who had suffered from malaria produced about half the yields and earned half the incomes of healthy farmers.

Badiane and Ulimwengu (2012) analysed the impact of different types of household level health expenses on disease incidence and agricultural production efficiency in Uganda. They found that increasing the consultation, medicine, and hospitalization expenses would not only reduce malaria incidence, but also decrease agricultural inefficiency.

In West India, Baldwin and Weisbrod (1974) examined the productivity effects of five parasitic diseases: schistosomiasis, ascariasis, trichuriasis, strongyloidiasis, and hookworm infection. They hypothesised that the parasitic diseases debilitated their victims' productive potential leading to reduced earnings, a shift to jobs that were physically less demanding, reduced productivity per day worked on any given type of work, and fewer working days per week. Although their analysis did not show any evidence of an effect of schistosomal infection on daily labour productivity, their findings as a whole indicate that parasitic infection appears to cause few statistically significant adverse effects on agricultural labour productivity. However, the authors note that one possible reason for not finding large effects is simply errors in measurement and possible model misspecification.

Audibert (1997) and Audibert and Etard (1998) collected data from a quasi-experimental study to measure the impact of schistosomiasis on rice production in Mali. They found that treatment for schistosomiasis had a significant effect on technical efficiency, and that better health increased labour productivity and reduced the number of people required to accomplish the agricultural tasks. Audibert (1986) measured the influence of health status on paddy output in Cameroon and found that reduction in the incidence of urinary bilharziasis resulted into an increase in paddy production.

In Ghana, Mock et al. (2003) established secondary economic effects of injury and found that almost half of the rural households registered losses of family income, about one third reported a reduction in food production, and 41% had experienced a decline in food consumption. Illness or injury of adult males and females over a 30-day reference period lowered formal labour market participation by 4%-6% in Uganda (Bridges and Lawson 2008).

In the recent past, increasing attention been paid to individual level economic consequences of health shocks. In Tanzania, Beegle (2003) draws on a panel data in the Kagera region to estimate the impact of HIV/AIDS related mortality among prime-age household members on household activities (wage employment, non-farm self-employment and farming) and time allocation of individuals among surviving household members. The authors found small and insignificant change in the supply of labour by surviving individuals in households that has experienced death of a prime-age adult, implying that irrespective of shocks, households labour supply remained largely unaffected.

However, Beegle (2003) found reduction in the area under cultivation of certain crops, for example coffee and bananas, in the six months following the death of an adult male, thus suggesting temporarily scaling back of some crop production activities in response to the effects of mortality. In contrast to Beegle’s findings, Bales (2013) found an increased labour supply by remaining household members to compensate for income losses resulting from sickness or death in Indonesia.

Yamano and Jayne (2004) examined changes in household composition, agricultural output, asset levels, and off-farm income among rural households in Kenya, and found a significant decline in the net and gross value of crop output associated with the death of a male household head. The decline in the value of net agricultural output was particularly statistically significant and severe in the bottom half of the wealth distribution, indicating that the impacts of prime-age mortality are more severe on households that were already relatively poor to begin with, as they are less able to cope.

The reductions were attributed to reduced area under high value crops, and their results did not show significant impacts from mortality of other household members. Their findings however highlight the importance of disaggregating the effects of health shocks by gender, age and position in the household of the persons affected.

Wagstaff (2007) investigated income and consumption changes among rural and urban households as a result of health shocks affecting working-age households’ members in Vietnam. Their findings revealed that a negative and significant effect on earned income among urban households due to death of a working-age household member. Among rural households however, the effect of death on earned income was smaller. Further, the author found that earned income was not adversely affected by other types of health shocks in urban areas, but in rural areas, a lengthy hospitalization of a working member of the household has a significantly negative effect on earned income. Wagstaff (2007) concludes that the effects of adverse health shocks on earned income are negative in both rural and urban areas, whatever measure of health shock is used.

Kadiyala et al. (2011) used propensity score matching and difference-in-difference techniques on an Ethiopian panel data to estimate the impact of prime age adult (15-54 years) mortality on household outcomes that included demographic composition, household expenditures on food and non-food items, and dietary diversity. They found that irrespective of the economic status, sex or status of the deceased adult in the household, poor households labour and expenditure patterns were not adversely affected by adult mortality. However, increased dependency ratio and decreased dietary diversity were observed, especially among the poorest households thus reflecting nutrition insecurity due to adult mortality. Using the same Ethiopian panel data (1994-1997) as Kadiyala et al. (2011), Skoufias and Quisumbing (2005) also found no significant impact on households' food and non-food expenditures as a result of illness. On the contrary, Dercon, Hoddinott, and Woldehanna (2005) used a panel data set of Ethiopian rural households, and covering a longer interval, 1999 to 2004, and found evidence that illness reduced consumption expenditures by 9%. The authors' findings point to the possibility that panel data with longer duration panel may capture longer-term impacts of illness.

In the recent past, Mahmoud and Thiele (2013) also used difference-in-difference and propensity score matching techniques on a longitudinal survey (2001-2004) to investigate the impact of HIV/AIDS related prime-age mortality on per-adult equivalent incomes of surviving household members in rural Zambia. In their findings, they found evidence that death of a prime-age person had no significant short-run effect on per-adult equivalent income in the affected households due to demographic and income coping strategies. In the medium and long-term however, the authors argue that poor rural households may be limited in sustaining the income coping strategies, as sale of assets for example, may only provide short-run relief.

The review of literature presented in sections 2.3.1 and 2.3.2 clearly indicates that both health and nutritional status affect livelihoods, and are important determinants of labour productivity and hence wages, and agricultural productivity. However, the importance of the proxies for nutritional status such as calorie intake or anthropometric measurements may vary from short-term to long-term periods, and across agricultural cropping seasons. Moreover, the agricultural productivity effects of health and nutritional status may also be determined by the conditions of the input and output markets. For example, where perfect markets exist, labour lost to illness may be substituted with hired in labour.

The general conclusion however is that farm workers in poor state of health and nutrition are less able to work, and therefore are more likely to earn lower wages, or excluded from the wage labour market, thus leading to a decline in income from wage labour. Loss of income leaves a household worse off, thus falling into poverty, food insecurity or deteriorating health (see Figure 2.3). Reduction or loss of agricultural labour may also result in reduced agricultural output.

Further, we note that the studies reviewed adopted different indicators for health and nutritional status. In the following section, we present a discussion on the methods and methodological issues in the empirical investigation of health and nutritional status impacts on rural agricultural livelihoods.

2.4 Methods used in health-agriculture investigations and methodological issues

In this section, we explore the use of various estimation methods and approaches in assessing the impacts of health and nutritional status on agricultural output, labour supply and productivity. To begin with, we highlight the documented general shortcomings in the empirical investigations of the relationship between health and nutrition, and productivity. Further, we scrutinise the methods adopted by some key authors, and the methodological shortcomings and strengths in their use.

The idea that in low income households there is a technically determined link among nutritional and health status, labour effort and agricultural productivity has persisted in development literature. This is often summarized as the "wage efficiency hypothesis", which dates back to the work of Leibenstein (1957) cited in J. Behrman and Deolalikar (1989). The “wage efficiency hypothesis” argues that productivity of workers increase with higher wages. Bliss and Stern (1978) , Deolalikar (1988) and David E. Sahn and Alderman (1988b) are examples of other authors who have subjected the theory to some theoretical investigations of its implications. For example, Bliss and Stern (1978) investigated the notion that higher wages provided a better diet which led to greater work effort and output.

In their empirical investigation of the nutritional status and productivity link, Deolalikar (1988), J. Behrman and Deolalikar (1989) and J. R. Behrman and Deolalikar (1988) note that although the “wage efficiency hypothesis” has important implications for the labour markets, it has been subjected to little systematic empirical testing. This is for a number of reasons.

First, the relationship among productivity, wages, health and nutrition cannot be established by mere correlations between variables, since a correlation could be picking up the effect of increased productivity, and thereby income, on nutrition or health, rather than the reverse. Correlation between the explanatory variables and the error term leading to the problem of endogeneity (Wooldridge 2012), may also occur in health and productivity relations. In estimating a health production function for example, simultaneity often occurs, and correlation between a health or nutrition variable, such as nutrient intake, and the disturbance term results in biased Ordinary Least Square (OLS) estimates of the health production function.

Second, there are methodological challenges in controlling for unobserved individual specific genetic endowments, such as levels of inherited immunity to diseases and tolerance to infections. This results in an overestimation of the effect of health or nutrition on productivity, since such endowments generally are positively correlated with nutrition (Deolalikar 1988). The exclusion of such unobserved characteristics causes omitted variable bias in parameter estimates (Wooldridge 2012).

Third, the appropriate concept of productivity is marginal, not average productivity. The measurement of marginal productivity often requires the estimation of a technical production function or the acceptance of the assumption that wages equal the marginal products for labour (Mas-Colell, Whinston, and Green 1995).

Fourth, there may be substantial interpersonal variations in nutrition, health and productivity, such as those due to intra-household consumption variation, and the effects of health and nutritional status on productivity may vary across the agricultural cropping seasons, depending on the energy requirements for different production activities (see Chambers 1982). In nutrient measurement for example, aggregation of calorie or nutrient intakes presents a possible measurement problem as it ignores substantial intra-household and inter-seasonal variation in nutrient or calorie intake and requirements.

Fifth, representation of health status relations in micro empirical studies is either by clinical measures of bodily attributes, anthropometric measures, individual nutrient intake, respondent reported disease symptoms and mortality histories, or reports on incapacity for undertaking normal farm or household activities. J. R. Behrman and Deolalikar (1988) argue that these measures differ significantly with regard to their cost of data collection and the extent of measurement error. In his study, Deolalikar (1988) also notes that on one hand, data on individual's food intake is usually difficult to collect and is often measured with some degree of error. On the other hand, anthropometric data such as weight and height are more accurate being easily observable and verifiable.

J. R. Behrman and Deolalikar (1988) further note that respondents' reports are subject to measurement errors due to incorrect self-diagnosis of health status and recall error. Random errors in measurement lead to biased estimates if the health or nutrition variables are independent variables, and imprecise parameter estimates if they are dependent variables. Responses may also be conditioned by other variables, such as level of education and socio-economic status. For instance, whether one is healthy enough to perform normal duties is likely to be endogenous, such that an individual though in poor health will still try to be productive if he is from a poorer household than if he is from a richer household due to diminishing marginal utility of consumption goods.

In Pakistan, Fafchamps and Quisumbing (1999) found that women reported fewer days lost to sickness compared to men. They concluded that the self-reporting bias among women was because they spent most of their time within the home, and hence illness was less disruptive to their activities and less noticeable. In contrast, most of the men were involved in activities outside the home, and reduced mobility due to ill health would be more disruptive to their routines. J. R. Behrman and Deolalikar (1988) state that biased self-reported responses are likely to understate health problems among the poor. Moreover, the measurements may refer to different dimensions of health status, rather than a one-dimensional construct.

On his part, Schultz (2005) also highlights the basic limitations in health evaluation methods in respect to the multiple indicators of health. The author notes that although self-reported health status has shown to be significantly related to subsequent morbidity and mortality of the individual, it may not be an objective index of health. This is because reported status of health may be conditioned by a person's socio-economic behaviour and outcomes, rather than their real state of being.

Further, Schultz (2005) argues that in low income countries, data on morbidity rates derived from administrative records often lack evidence of clinically confirmed incidence of illness and self-reported responses on morbidity or disability days tend to be subjective and affected by culture. The author further argues that the physical capacity to perform Activities of Daily Living (ADLs), which is a health indicator based on individual limitations to perform duties, tend to be less biased by socio-economic endowments, conditioning factors, and perceptions, and thus more likely to be objective.

Sixth, sample selectivity that arises when the selection procedures influences the representation of healthy and unhealthy subjects in the sample, and the specification of appropriate time lags for change to be evident, are other potential sources of estimation problems in health and nutritional impact on productivity studies (J. R. Behrman and Deolalikar 1988). For example, estimation of nutrition impacts on health using current data may miss most of the considerably time lagged effects. In addition, aggregation of data, for example calorie intake, to the household level disregards intra-household consumption variation and may produce misleading results for the individual welfare.

Finally, a number of studies on the health and nutritional impacts on agricultural productivity fail to address the seasonality of rain-fed agricultural production. There are often great seasonal fluctuations in environmental conditions, food availability, food prices, and labour (J. Behrman and Deolalikar 1989), and as Chambers, Longhurst, and Pacey (1981) suggest, such variations may have substantial impact on nutrition and health status of a farm household.

Regrettably, there is a dearth of empirical studies that have addressed all these methodological shortcomings. In fact, some of the studies that have investigated the effect of health or nutritional status on productivity have faced some of the forth-discussed methodological challenges. There are however few notable studies that have attempted to address some of these methodological issues by rigorously testing key aspects of the relationship between productivity and nutrition (J. Behrman and Deolalikar 1989; Deolalikar 1988; Haddad and Bouis 1991; Pitt and Rosenzweig 1986; David E. Sahn and Alderman 1988b; Strauss 1986). All these empirical studies find evidence of some health and nutrition effects on labour productivity as measured by wages for agricultural labourers, or on farm labour supply, own-farm output and farm profits.

Deolalikar (1988) uses panel data from rural south India to measure the wage and farm output effects of nutritional status. The author estimates a fixed-effects individual wage equation and a household level Cobb-Douglas farm production function, with daily individual calorie intake (as opposed to household's calorie availability) and weight-for-height of workers as explanatory variables in both equations.

The author includes weight-for-height, an anthropometric or stock measure of calorie intake (and a longer time measure of nutritional status), to complement current calorie intake (a short-term measure of nutritional status) which is a poor proxy for changes in energy expenditure or energy available for work effort (as opposed to changes in health status) for a cross-section of individuals. As the author notes, the inclusion of weight-for-height in the production and wage functions controls for past calorie intakes and for body size in the relationship between current calorie intake and productivity, and its coefficient may also be interpreted as the returns to endurance, strength, or health.

Additionally, Deolalikar (1988) use of panel data allows the author to control for the unobserved time-invariant individual and household effects in the estimated wage and farm production functions, hence eliminating potential bias in coefficient estimates. In both the wage equation and production function, a Hausman's specification test was employed to test between the random and fixed effects treatment of the individual unobserved characteristics. Further, the author controlled for selection bias by using the least-squares selectivity correction procedure. However, the author did not address seasonal effects.

Similarly, Haddad and Bouis (1991) used panel data to examine the impact of individual nutritional status on agricultural wage rates in southern Philippines. They used height, calorie intake and weight-for-height as indicators of nutritional status. Their estimation procedure shows methodological improvements in a number of ways. First, they undertake a complete decomposition of nutritional status into short and long run effects, specifically by adding individual's height as an explanatory variable in the wage equation. They argue that unlike in previous empirical studies that omitted height (e.g. Deolalikar 1988; David E. Sahn and Alderman 1988a), higher wages seem to result from better height, a cumulative measure of the absence of poor diets and infection, thus controlling for genetic endowment in early childhood, rather than from short-run (calorie intake) or medium-run (weight-for-height) proxies of nutritional status.

Second, their analysis of nutritional status effects on agricultural wage rate is segregated by age to control for height and weight gains in adolescents. Third, the authors estimate the wage relationships within a framework that permits a more disaggregated investigation of the sources of nutritional status endogeneity. Specifically, they control for bias due to correlation between time-varying unobserved effects and included explanatory variables by employing an array of methods for comparison. These included estimation of the wage relationship using ordinary least squares (OLS), two-stage least squares (2SLS), fixed and random effects techniques. The authors however did not consider seasonality aspects in their analysis.

Strauss (1986) estimated an output-elasticity of calories using an instrumental-variable estimation method, and estimated a Cobb-Douglas agricultural production function in Sierra Leone. The author used average calorie intake per consumer equivalent, instrumented by local food prices, as the relevant nutrient intake variable.

By using the average calorie intake per consumer equivalent, Strauss assumes that the per person food consumption within the household is proportional to calorie requirements that vary by age and sex, an assumption that Deolalikar (1988) is critical of. Deolalikar (1988) argues that if the intra-household allocation of food varies systematically with food prices, an instrumental variable used by Strauss (1986), then, Strauss' estimate of the calorie effect on productivity is likely to be biased.

Moreover, Strauss (1986) has current calorie intake as the only relevant variable for nutritional status, which is a short-term proxy for energy available for work effort (Deolalikar 1988). Finally, as Strauss used cross-sectional data, he is unable to appropriately control for unobserved time-invariant effects in testing the nutrition-productivity link. The author does attempt to control for such effects by using instrumental variable estimation procedures. However, such procedures implicitly treat individual or household effects as random variables, and this leads to inconsistent parameter estimates if the type of unobserved effects that influence labour productivity also affect nutritional requirements and intake (Deolalikar 1988). This study is also silent on seasonal effects.

The study by David E. Sahn and Alderman (1988b) also attempts to test the link between better nutrition and improved worker productivity by including family per capita calorie intake as a variable in a rural sector wage equation. The authors treat per capita calorie intake as an exogenous variable, and it is predicted with household composition, land ownership and prices as instruments, therefore eliminating the potential problem of reverse causality.

David E. Sahn and Alderman (1988b) employed a two-stage least squares (2LS) approach to derive a predicted calorie value which was generated by fitting a regression, which only relies on prices, household composition and land ownership as instruments. These variables influence the choices made by households, but have no direct effect on labour productivity and thereby not susceptible to simultaneity bias. This approach accounts for the simultaneity involved between household decisions regarding food purchases and the wages received, while ensuring that the standard errors are correct. David E. Sahn and Alderman (1988b) however ignored the effects of seasonal variation in their analysis.

J. Behrman and Deolalikar (1989) used panel data to explore how seasonal changes in nutrient intakes and health status affected labour market productivity, as reflected in market wage rates in South India. Their approach attempted to improve on earlier studies by treating health and nutrition as simultaneously determined with wage rates and by taking account of seasonal variations in the health-nutrition-productivity relationship. In their analysis, they extended the standard wage equation to test whether the parameters of the wage equation varied between the peak and slack agricultural seasons. They also treated health and nutrition as endogenous variables in the wage and labour supply equations, and similar to Strauss (1986) instrumental variable approach, they used agricultural consumption, product prices and farm assets as instruments for health and nutrition.

Further, the authors included measures of both health status and nutrient intake as explanatory variables in their wage equation to allow nutrient intakes to have an additional impact on labour productivity, over and above the impact through health status.

J. Behrman and Deolalikar (1989) used average daily intake of calories (as opposed to per capita calorie intake, which accommodates intra-household variation in calorie intake) as the relevant measure of nutrient intake and argued that calories were widely recognized to be the most important nutrients. For health status, they used weight-for-height, an anthropometric measure that is widely assumed to reflect medium-run to long-run nutritional status.

A study by Pitt and Rosenzweig (1986) aimed to determine how food prices and health program interventions affect the health, nutritional status and profits of farm households in Indonesia. The authors extended the conventional agricultural household models, and developed a framework that made it possible to estimate the following: the effects of short term illness of the farmer and his/her spouse on farm profits and labour supply; the effects of changes in food prices, health programs, and farm profits on the probability and severity of illness of the farmer and his/her spouse; and the effects of alterations in food consumption on the level of household health.

The authors' extension of the agricultural farm household model involved incorporating a household health production sector in which the household produced goods and health status, which could both affect the production of farm output and provide direct additional utility to the household.

Pitt and Rosenzweig (1986) argued that other than consumption of goods and leisure, a farmer also derived utility from his/her level of health (assumed to be influenced by the levels of goods consumed, a health input that yields no direct utility, the farmer's work time, environmental factors and by the individual's health endowment beyond the control of the household). In the farm output production function, farmer's health was allowed to affect production, through its effect on the productivity of farm inputs directly (by affecting quality of labour input supplied by the farmer) or indirectly (by affecting farmers' ability to utilize, supervise or allocate resources).

2.5 Summary of key issues and knowledge gaps

In this section, we summarise the key findings from the various studies reviewed, focusing on salient points of divergence and convergence. Further, we identify the existing gaps in literature, and elaborate on how the current study contributes to filling the identified knowledge gaps.

The preceding review of theoretical and empirical literature reveals a rather diverse body of scientific knowledge in the relationship between health and nutritional status, agricultural productivity, and consequently rural agricultural livelihoods. The literature unveils broad empirical evidence that poor health and nutritional status have far-reaching impacts on labour supply and efficiency, on wage earnings, and on farm productivity.

The consequences of poor health and nutritional status therefore have important effects on households' livelihoods and welfare outcomes (J. Behrman and Deolalikar 1989; Croppenstedt and Muller 2000; Deolalikar 1988; Pitt and Rosenzweig 1986; Strauss 1986; David E. Sahn and Alderman 1988a; Haddad and Bouis 1991; Foster and Rosenzweig 1994; Fafchamps and Quisumbing 1999; Kim, Tandon, and Hailu 1997; Ulimwengu 2009; Ajani and Ugwu 2008; Fox et al. 2004; Rugalema 1998; Asingwire 1996; Masanjala 2006).

From the reviewed studies, we identify a number of key aspects. First, as much as the findings converge with the priori intuition that poor health and nutritional status poses negative effects on agricultural output and labour productivity, many of the studies may not be directly comparable as different authors and studies used different estimation methods ranging from wage equations (e.g. David E. Sahn and Alderman 1988b; Haddad and Bouis 1991; Croppenstedt and Muller 2000; Deolalikar 1988; J. Behrman and Deolalikar 1989), profit functions (e.g. Pitt and Rosenzweig 1986), to

Cobb-Douglas production functions (e.g. Strauss 1986; Deolalikar 1988) and Stochastic production frontiers (e.g. Ulimwengu 2009; Ajani and Ugwu 2008).

Second, we recognize important estimation and modelling challenges that beset health and nutritional status, and productivity relationship, such as the common problem of endogeneity that may arise due to simultaneous effects. For example, better-nourished and healthier individuals are more efficient, but causality in the relationship between nutrition, health, and productivity is difficult to establish. This is because improved nutritional status and better health could lead to increased productivity, but it is equally plausible to conclude that increased productivity leads to higher incomes, thereby improving nutritional and health status (Garcia and Kennedy 1994).

Consequently, the bi-directional relationship between individual health and personal productivity makes health status an unsatisfactory estimate of the causal-effect in only one direction, as causality is bi-directional (T. Schultz 2005).

Third, different studies have adopted different indicators for health and nutrition status to investigate their effects on productivity, and hence livelihoods. For example, Strauss (1986) uses current calorie intake as an indicator of nutritional status, Deolalikar (1988) opts for daily individual calorie intake and adult weight-for-height (wasting), Haddad and Bouis (1991) choose adult height, calorie intake and weight-for-height, while Croppenstedt and Muller (2000) adopts weight-for-height, BMI and height, as indicators of nutritional status.

As T. Schultz (2005) notes, there is no consensus among health specialists on conceptualizing and measuring health status at the individual level. Despite the little consensus among scientists on how to estimate health and nutritional status or quantify their benefits to livelihoods, there exists a strong priori intuition in the studies highlighted in favour of positive effects from improved health and nutrition to increased productivity of an individual worker.

However, the findings sometimes diverge due to the type of data (whether panel or cross-sectional data) as well as conceptual and methodological differences. The differences in findings may also stem from specification errors in the estimated models or from unreliable data that do not allow for accurate estimation of these effects. For example, T. Schultz (2005) finds that self-reported health status contains measurement errors, even when continuous health indicators of a relatively objective form are analysed.

Fourth, medium and long run measures of health and nutritional status resulting from accumulation of nutrients, heath care, reduced exposure to disease pathogens and reduced engagement in strenuous activities, and estimated by a variety of anthropometric dimensions such as height and weight, are more important in impacting productivity than short term calorie intake. For example, adult height is an easily measured and relatively fixed indicator of health and nutritional status, and is particularly sensitive to early childhood nutritional and health status (Croppenstedt and Muller 2000; Fafchamps and Quisumbing 1999; Haddad and Bouis 1991) . Other indicators of nutritional status such as weight-to-height or Body Mass Index (BMI) reflects medium-run nutritional and health status (e.g. see Deolalikar 1988; J. Behrman and Deolalikar 1989; Croppenstedt and Muller 2000; Haddad and Bouis 1991).

Finally, loss of active labour days due to ill health has significant impacts on agricultural labour supply, farm profits, wages and production efficiency (e.g. see T. P. Schultz and Tansel 1997; Kim, Tandon, and Hailu 1997; Pitt and Rosenzweig 1986; Ulimwengu 2009; Ajani and Ugwu 2008).

Despite the increasing number of studies and the rapidly expanding base of theoretical knowledge in the health-productivity relationship, knowledge gaps still exist. In fact, there is very little prior research on the impacts on seasonal health shocks on rural agricultural livelihoods in low-income economies. For example, a majority of studies reviewed so far, with the exception of J. Behrman and Deolalikar (1989), who investigated the nutrition-labour productivity link, are oblivious of the seasonality aspect in agricultural production. Consequently, there remain serious deficiencies in available empirical research in this field as regards to incorporation of seasonality effects.

J. Behrman and Deolalikar (1989) and Chambers (1982) emphasise that there are important seasonal variations in nutritional and health status of the agricultural population. For example, in many tropical environments, the wet season is the most critical time of year, especially for the poor people, as malnutrition, morbidity and mortality peak, while the demand for on-farm labour is also at its highest (Chambers 1982).

In his study, A. Dorward (2012) concurs that although farm household modelling has been resourceful in providing a sound theoretical basis for the empirical and conceptual analysis of the interaction between production and consumption decisions of poor rural people in resource allocations, they often fail to incorporate the seasonal nature of agriculture production and of the rural financial markets in their application.

The author further emphasises that the lack of attention to seasonal finance market failures in the application of agricultural farm households modelling represents a critical flaw for the following reasons.

First, a key focus of agriculture farm household modelling is the attainment of future consumption (in the harvest, post-harvest and subsequent pre-harvest seasons), but not with consumption for current survival (i.e. in the immediate pre-harvest season). According to the author, attainment of food for current survival is a major pre-occupation of poor rural people, and it has the potential to compromise their ability to invest in future production.

Second, aggregation of farm household income from crop production at or after harvest with pre-harvest income and expenditure associated with buying and selling of labour and other production inputs fails to describe seasonal capital constraints on livelihood options. Seasonal finance constraints restrict poor people's options, and overlooking them in empirical analysis can lead to serious errors in the investigation of the problems facing poor rural people and in policy and other recommendations to address these problems (A. Dorward 2012).

In this study, we follow the lead of studies that have taken into consideration the seasonal influence in the investigation of health-agricultural productivity relationship (e.g. J. Behrman and Deolalikar 1989). Specifically, we build on the methodological developments applied in previous studies by Andrew Dorward (A. Dorward 2012; A. Dorward 2006; A. Dorward 2011; A. Dorward 1994; A. Dorward 1999; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2003). Using a rural Malawi household survey sample, we investigate the welfare impacts of morbidity on rural agricultural livelihoods, through their effect on seasonal agricultural labour and short-term capital.

In our investigation of the health-agriculture production linkage, we adopt two methodological approaches, to help us disentangle the precise nature of the relationships between farmers' health and agricultural livelihoods outcomes. In the first analytical approach, we apply descriptive statistical analysis in order to understand the nature, types and distribution of health shocks and coping strategies in the study area, as well as distribution and allocation of available time and resources by households.

In the second approach, we adopt a non-linear programming farm household model of Malawian agriculture to determine the potential welfare impacts of malaria and HIV/AIDS, through losses of family labour and capital, and the subsequent production and consumption responses. We explain the methodological approaches in more detail in chapters 3 and 4.

2.6 Background on Malawi

In this section, we elaborate on the Malawi's country profile, with the aim of providing an understanding of the country's context.

Malawi is a predominantly rural country with an agriculture-based economy. The landlocked country is located in the Southern part of Africa, and is one of the poorest countries in the world (United Nations Development Programme (UNDP) 2015). The findings of the 2010/11 the Living Standard Measurement Survey -Third Integrated Household Survey (LSMS-IHS3) showed that about half of the population (50.7%) lived below the national poverty line of $0.66 per person per day and 25% lived in extreme poverty, under $0.42 per person per day (National Statistical Office (NSO) 2012a).

In the 2015 United Nations Human Development Index values, the country was ranked 173 out of 188 countries and territories (United Nations Development Programme (UNDP) 2015). The most recent estimation of the population in Malawi by the United Nations (UN) is approximately 17.2 million people (United Nations, Department of Economic and Social Affairs, Population Division 2015).

The country is divided into Northern, Central and Southern regions. Generally, the highland areas of the Northern region are less urbanised, commercially isolated, and are more sparsely populated than the Southern and Central regions (National

Statistical Office (NSO) 2008). However, the soil conditions in the North are more favourable, and as a result a greater proportion of the Northern population is more or less food self-sufficient and owns notably more livestock than elsewhere in the country (A. R. Dorward 1996).

By contrast, most of the country's urban population and commercial sector is in the Central and the Southern regions. This positively affects the livelihoods of the rural people in the Central and Southern regions, both in the prices they can obtain for their surplus food crops, and in the opportunities for casual employment as well as opportunities for petty trading (for example, the sale of products such as firewood and charcoal to the urban population). The country is further divided into 28 districts, with 6 of them located in the in the Northern, 9 in the Central and 13 in the Southern regions. Within each district, they are smaller administrative units known as the traditional authorities (TA's).

A different classification of the country is by livelihood zones. A livelihood zone is an area within which people share broadly the same pattern of livelihood, including options for obtaining food and income and market opportunities. There are 19 livelihood zones developed principally on the main biophysical and socio-economic variables. These include agro-ecological characteristics, land cover patterns, climate, topography, principle crop production patterns, cattle or livestock activities, access to markets, rural population density, and infrastructure, among others. The current area of study is the Kasungu-Lilongwe Plain (KAS) livelihood zone, located in the densely populated Central region of the country. The zone is made of six districts and accounted for 28% of the total population during the last population census in 2008 (National Statistical Office (NSO) 2008). Figure 2.5 shows the livelihood zones in Malawi.

The Kasungu-Lilongwe Plain is a relatively productive with maize as the staple crop and tobacco as the main cash crop. There are very limited local livestock production activities (MVAC and SADC FANR Vulnerability Assessment committee 2005). Centrally located, the zone benefits economically from its proximity to the Lilongwe's urban market in the country's capital. However, similar to most of the livelihoods zones in Malawi, the Kasungu-Lilongwe Plain is prone to drought and erratic rainfall, increasing population pressure on the land, low wage rates, reduced crop earnings and rising prices of inputs (for example fertilizer) for maize and tobacco production. Consequently, this combination of factors threatens food security and economic advancement in the zone.

Most of the households' income in the KAS zone comes from sale of crops. Tobacco is the single most important crop, providing between 65%-85% of income, and hence incomes in the zone are relatively higher compared to elsewhere in the country (MVAC and SADC FANR Vulnerability Assessment committee 2005). Although income from tobacco is in theory expected to reduce the vulnerability of poor households to shocks and improve their welfare, this income is often received in a single lump sum. As such, it is likely to be spent on non-food items almost as soon as it is received, rather than being used to build up food stocks for future consumption needs. Sale of food crops is largely a secondary income source, especially for the less poor households, while casual farm or non-farm employment provides the second most important source of cash income for the poor (MVAC and SADC FANR Vulnerability Assessment committee 2005).

Malawi's economy is heavily dependent on agriculture which employs an estimated 80% of the labour force and contributes to 41% of gross domestic product (African Development Bank 2011). Approximately 85% of Malawians live in the rural areas and depend on agriculture for their livelihoods (National Statistical Office (NSO) 2012b). Tobacco and maize are the two most important crops. Other secondary crops include fruits, vegetables, cassava, and legumes such as beans, pigeon pea and groundnut, cotton, sorghum, millet and ground beans.

Maize, which is the main staple crop is grown by 97% of farming households (Chirwa and Dorward 2013), and accounts for 60% of total calorie consumption (Famine Early Warning Systems Network (FEWSNET) 2007). Almost all maize is rain-fed and grown during the single rainy season starting from October/December to April/June the following year. The main cropping season may however be subjected to rainfall variability, and maize is particularly vulnerable to dry spells, which are increasing in the Southern Africa because of climate change (D. Taylor 2012; Tadross et al. 2009).

Majority of the households are net buyers of maize (A. Dorward et al. 2008) and the high dependence on maize often leaves poor households vulnerable to hunger particularly after a bad season. Households often experience food shortages especially during the lean season from January to March coupled with high maize prices (A. Dorward et al. 2008; Sassi 2012).

Dorward and Chirwa (2011) and Chirwa and Dorward (2013) illustrate several interacting household, local and national vulnerability, poverty and productivity traps that constrain Malawi's agricultural, rural and national economic development.

These include: high dependence on agriculture; continual cultivation of maize on land without organic or inorganic fertilizers leading to low yields and consequent inability to afford input purchases; volatile maize prices that makes investment in inputs risky; low demand for inputs inhibiting development of input supply systems in the remote areas; poverty and vulnerability to shocks such as low yields, high food prices, sickness, loss of income, further constraining farm production activities; thin output markets and low traded volumes of output leading to limited investments in maize market development; and government intervention in maize markets as a result of the high price variability.

Other factors include: lack of exploitable natural resources; isolation and high import and export costs due to its land-locked location and poor external transport systems; poor physical infrastructure; chronic poor health, with very high infant mortality from malaria, water-borne diseases, malnutrition and under-nutrition, and high rates of HIV/AIDS infection; low levels of literacy and education; high population densities and small landholdings (particularly in the south); and falling soil fertility.

Chirwa and Dorward (2013) note a further set of policy and governance failures that emerged from the mid-1990s and have affected Malawi's economic development. These include: the collapse of the industrial economy due to exposure to outside competition; poor macro-economic management with large budget deficits, high interest and inflation rates, and the devaluation of the Malawi Kwacha (MK); rising rate of crime in both rural and urban areas; and weak governance.

Similarly, Binswanger and Rosenzweig (1986) illustrate a number of market constraints in the Malawi's agriculture sector. The authors find that in Malawi, market imperfections are a result of the basic characteristics of tropical agriculture production that include the: seasonality of rain-fed agriculture; immobility and spatial dispersion of land; externally sourced production inputs and time delay from input allocation to harvest; riskiness of production due to high input prices and climate variability; moral hazard related to hiring of labour; and bulkiness and perishability of produce with long distances to markets and consumers. More recently, Holden (2014) has argued that policy interventions such as the farm inputs subsidy programme (FISP), are a source of market imperfections.

Over the years, the government of Malawi has adopted a range of strategies to promote the agricultural sector. For example, in the 1960s and 1970s policies were geared toward promotion of large-scale estate farming through a state run input and output intermediary (Chibwana et al. 2010). Following reforms under the World Bank's backed structural adjustment program (SAP), the government turned away from estate oriented policies and moved towards small-scale farming policies (Chibwana et al. 2010).

To ameliorate crop productivity in the smallholder sector and improve input use, the Malawi government launched a Farm Input Subsidy Program (FISP) in 2005 explicitly targeting poor smallholder farmers who lacked resources to purchase inputs, specifically improved maize seed and fertilizer. The programme's objectives were to increase food sufficiency, crop incomes and better the livelihoods of poor farmers (A. Dorward and Chirwa 2011; Harrigan 2008).

Through this program, coupons were allocated to poor smallholder farmers to enable them to buy fertilizer (a maximum of two 50kg bags of Nitrogen fertilizer) sufficient to grow maize on one acre (0.4 Ha). The targeted households also received three kilograms of improved maize seed. The seed supplied was however insufficient as 10 kg of seed would be needed for a 0.4 Ha plot. The insufficiency in inputs was necessitated by funding constraints.

The inputs coupons were allocated across regions and then distributed to districts and traditional authorities (sub-district government entities), who allocated them to village development committees, which then identified the recipients. All of the subsidized fertilizer and seed was distributed through government agencies, and the maximum allocation of two 50 kg bags of fertilizer per household was intended to reduce the potential for capture of subsidies by larger farmers (A. Dorward et al. 2008).

As a result of investing in hybrid maize seed and fertilizer, there is evidence, although disputed (see Jayne et al., 2008), that the country turned itself around from food deficit and started producing enough maize to fulfil its national requirements in 2006, and even exported maize in 2007 (Denning et al. 2009). For example, after the rollout of the farm input subsidy program, a good harvest coupled with good rains was reported for the 2005-2006 cropping season.

The total maize production was reported to have been more than double the 2004-2005 harvest, producing a surplus of 510,000 metric tonnes above the national maize requirement (Denning et al. 2009) and some of the incremental maize production was attributed to the fertilizer subsidy (Imperial College London et al., 2007).

Despite the reported increase in maize production country wide, food insecurity remains a critical issue in Malawi. In fact, some researchers have argued that the supposed increases in maize are likely to be exaggerated. For example, production estimates in the 2007-2008 cropping year were thought to be unreliable and possibly overestimated by at least 25% in the official government records (Thomas S. Jayne et al. 2008).

However, evidence from some of the studies that have explored the Malawi farm input subsidy programme suggest that the programme has had a positive impact in raising fertilizer use, average yields, and agricultural production, but their design and implementation is the weak link that needs improvement (Buffie and Atolia 2009; Chibwana, Fisher, and Shively 2012; Chirwa and Dorward 2013; A. Dorward et al. 2013; A. Dorward et al. 2008; Filipski and Taylor 2012; S. Holden and Lunduka 2010a; S. Holden and Lunduka 2010b; Lunduka, Ricker-Gilbert, and Fisher 2013).

In addition to the incremental production of maize, A. Dorward et al. (2013) find wider impacts of the FISP to Malawian livelihoods. For example, the authors' simulations show a small but positive impact of FISP on wages, but note that the change is likely to be underestimated due to structural challenges in their modelling. As the authors conclude, subsidised farm inputs are one of the pathways that influences growth and poverty through its effects on wages within the rural economy. In Malawi, informal casual labour (ganyu) is one important source of income for the poor and a common coping strategy for food deficit households. For the poor households, an increase in wages, and therefore purchasing power, can help alleviate poverty and stimulate growth in the economy (A. Dorward et al. 2013).

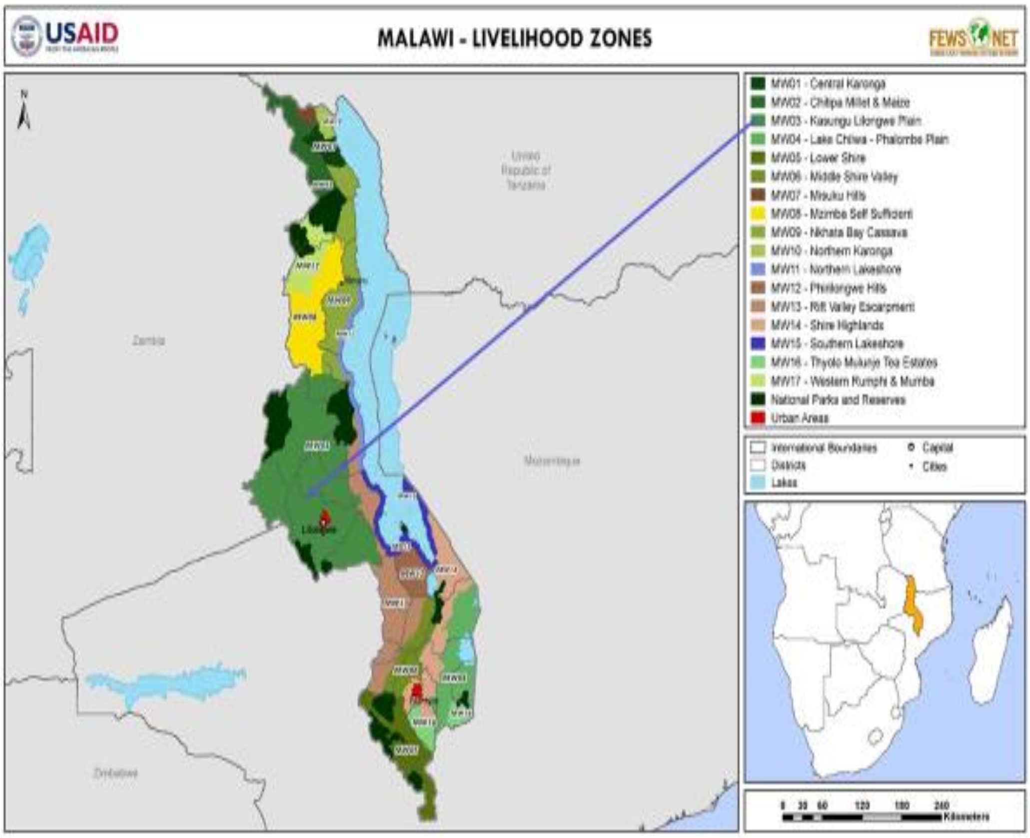

Figure 2:5 Malawi’s Livelihood zones

Source: MVAC and SADC FANR Vulnerability Assessment committee (2005)

Chapter 3: Data and methodological approaches

3.1 Introduction

In this chapter we explicitly describe the study's methods. As a starting point for our modelling logic, we begin the chapter with a synthesis of the history of the agriculture farm household modelling in section 3.2. The section includes a discussion on their evolution and the strengths and limitations of the technique. We then advance the discussion by presenting a detailed description of the farm based mathematical programming approaches and dynamic stochastic programming techniques in sections 3.3 and 3.4 respectively. The formulation of a non-linear mathematical programming (NLP) model of rural agricultural farm households is outlined in section 3.5. We discuss the data and sampling in section 3.6, and point out the data limitations and modelling challenges experienced in the implementation of the model and how to overcome these limitations in section 3.7.

3.2 An overview of agricultural farm household models

Agriculture production in low income economies is primarily in smallholder production units and is a principal source of income for farmers who are both producers and consumers of farm output. Their mode of production is therefore either subsistence or semi commercial, and they regularly interact with the often imperfect markets as buyers and sellers of output, labour and other production inputs. As a result of their interaction with markets, any change in the policies governing agricultural activities, such as pricing policies, affects not only production, but also consumption and supply of labour (Inderjit Singh, Squire, and Strauss 1986).

The specificity of agricultural farm households' behaviour therefore arises from their integration in a single institution for decisions regarding production, consumption and reproduction time (Sadoulet and Janvry 1995). Their production and consumption decisions are linked because the deciding entity is both a producer, who allocates labour and other inputs to crop production, and a consumer, who decides the allocation of income from farm profits (implicit profits from goods produced and consumed by the same household) and labour sales across the consumption of commodities (both purchased and self-produced goods) and services (J. E. Taylor and Adelman 2003). Consequently, the microeconomic behaviour of agricultural households, in terms of production and consumption decisions, and their response to policy or other external interventions and shocks is often analysed in the context of the farm household model.

In the farm agricultural household model, the production side influences consumption decisions through its impact on total household income and therefore expenditure. As such, the integration of the production and consumption decisions allows the model to determine both farm profit and wage income, an important feature of the model that determines the policy significance of the farm household theory (H. N. Barnum and Squire 1979a). In farming households where agriculture is the main source of income, the farm profit effect on household welfare is an important distinguishing characteristic of the farm household model (Inderjit Singh, Squire, and Strauss 1986).

Inderjit Singh, Squire, and Strauss (1986) further note that agricultural household models are designed to capture the production and consumption relationships in a theoretically consistent way so that the results of the analysis can be applied empirically to show the consequences of external interventions.

Agricultural farm household economic models have been widely used to describe, explore and explain farm household behaviour since their original development in the 1920's by the Russian economist Alexander Chayanov (Chayanov (1925)) cited in F. Ellis (1993). Chayanov introduced the "peasant economy theory" based on the characteristics of peasant farming households in Russia. In his theory, he argued that a peasant farm household works till it achieves an equilibrium between the increasing drudgery of family labour and the decreasing marginal utility of goods produced. That is, households act to maximise utility by striking a balance between the satisfaction of consumption and a distaste for labour (Chayanov 1986).

Further, Chayanov argued that most peasant families were in a position to either work more hours or more intensively, or both, but the degree of "self-exploitation" of family labour or the greater effort depended on the presence of a reason to believe that it would yield an increase in output, which could be devoted to either increased consumption, enlarged investment in the farm, or both. Without the consumption or investment incentives, families would not push their work effort beyond a point where the possible increase in output was outweighed by the effort of the extra work (Chayanov 1986).

In Chayanov's "theory of peasant economy", the shapes of the drudgery and utility curves were subjective in character and thus likely to change depending on the households' demographics, specifically the age structure. In the absence of a labour market, Chayanov emphasized the role of demographic composition of a household as a determinant of the "subjective equilibrium" for peasant households. Such households primarily relied on family labour, and the supply of farm labour was dependent on the family size and age composition (Chayanov 1986).

On one hand, the author argued that for different families, the balance between consumer satisfaction and the degree of drudgery was not only affected by the family size and the dependency or consumer-worker ratio, but other factors such as, rents, debts and interest on debt, capital accumulation and the desire for urban goods, all which were likely to affect the marginal utility curve. On the other, soil fertility, market prices of crops, distance to markets and availability of machinery were likely to affect the drudgery curve.

Since the introduction of Chayanov's "theory of peasant economy", the evolution and the usefulness of the farm household models has improved over time, especially with the modification of Chayanov assumptions (these are: absence of a labour market; sale of surplus farm output at a market price; flexible access to land for cultivation; and the presence of a social norm for the minimum consumption level) and the extension of the model framework (for example see Barnum and Squire, 1979; Low, 1986; Sadoulet and Janvry, 1995; Singh et al., 1986).

Notably, some assumptions of Chayanov's approach, such as the absence of a labour market and its indeterminate supply response, have not been useful for policy purposes. His micro theory was based on a peasant farm in Russia that did not use hired labour, and so, Chayanov's theory may not be applicable in economies where labour markets exist and households hire in and hire out labour, or where peasants could not readily buy or take in more land (Chayanov 1986).

From a policy point of view, there is therefore little or no incentive to apply Chayanov's approach as without markets, there are no instruments or outcomes that can be influenced by policy (J. E. Taylor and Adelman 2003). However, as F. Ellis (1993) notes, the main contribution of the Chayanov framework has been to suggest caution in predicting peasant responsiveness to exogenous changes in technology or prices due to the ambiguity or subjectiveness that surrounds household production and consumption responses resulting from changes in the production function. For example, an increase in the price of the main staple will only result in an increase in output and consumption for farm households with a marketable surplus, if the resulting profit effect outweighs the substitution effect.

Another important contribution of Chayanov was his demonstration that the behaviour of peasant households depended crucially on their age structure. Specifically, he showed how the consumer-worker ratio changed through the life cycle of a family, rising to a peak as the number of non-working children increased, and falling as children contributed to production as well as consumption (Levi 1987).

Following Chayanov's "theory of peasant economy", Becker (1965) introduced a class of models that were based on Chayanov's ideas, and are commonly known as "New Household Economics" models. According to F. Ellis (1993), the key features of the "New Household Economics" models include the following: (a) the household acts as a unified unit of production and consumption which aims to maximise utility subject to its production function, income and total time constraints; (b) utility is not only derived from market commodities but also from the objects of final consumption of home produced goods; and (c) the production of goods within the households requires inputs such as households' time and also purchased goods and services, hence a key emphasis of the theory is on time allocation between farm production and wage work.

In his review of Becker's contribution to family and household Economics, Pollak (2003) notes that Becker's economic approach assumes that individuals maximize their utility from basic preferences that do not change rapidly over time, and that the behaviour of different individuals is coordinated by explicit and implicit markets. The author therefore specifies the three foundational assumptions of the Becker's economic approach as; utility maximizing behaviour; market equilibrium in implicit or explicit markets; and stable preferences.

The "New Household Economics" framework and its foundational assumptions have provided a base for the application of household decision-making models to the different types of production and consumption decisions that are household is faced with.

Using cross-sectional data of semi-subsistence rice producing households in Malaysia, H. N. Barnum and Squire (1979a) used a farm household model to analyse the impact of migration, output price and technological change on the agricultural sector. For the production side of the model, they employed a Cobb-Douglas production specification, and a modified version of the Linear Expenditure System (LES) to specify the consumption side of the model. The authors' model incorporated the following: an active labour market for on-farm and off-farm wage work with a market determined single wage rate for men and women; single crop (rice) sold at a market determined price in the output market; planning duration of a single agricultural cycle; perfect foresight as decisions relating to the total supply of household factors of productions were assumed to be known and therefore the model ignored risk; and fixed land resource.

However, compared to later modelling approaches that extend the basic agriculture farm household model to include seasonality of the agricultural production cycle (S. T. Holden 1993; S. T. Holden 1993; A. Dorward 2003; A. Dorward 1999), the Barnum-Square model has some shortcomings. First**,** by modelling a single cropping season, the approach is oblivious of the seasonality of agricultural production and the associated seasonal constraints, such as supply of labour and liquidity and credit market failures.

Second, in the Barnum-Square model, the authors assume certainty, with perfect information at the beginning of the cropping season thereby ignoring the risks and uncertainties associated with agricultural production such as, in prices, in yield and those resulting from natural disasters. Third, all produce is sold at a single market determined price that does not account for transaction costs, a common feature in imperfect markets.

On his part, Low (1986) recognises that farm households depend on diverse sources of income and investigates the production impacts of wage work in Southern Africa. The author investigates the likely influence of off-farm income opportunities on households' production decisions that may cause stagnation in food production or per capita drop in output. Low (1986) adopts Becker's "New Household Economics" approach (Becker, 1965) and Chayanov's "theory of peasant economy" (also referred to as the Subjective Equilibrium theory) (Chayanov 1986) to explain the stagnation in food production in Southern Africa.

In Low's model, the wage rate is allowed to vary between men and women as opposed to a single wage rate in the Barnum-Square model (H. N. Barnum and Squire 1979a), and household demography is affected by the off-farm wage work of household members.

Similar to Chayanov's model, families in Low's model have flexible access to land according to the family size. The semi-subsistence farmers have a farm gate price of food that differs from the food market retail price, a contrast with the single food price assumed in the Barnum-Square model (H. N. Barnum and Squire 1979a). Further, there is wide spread occurrence of food deficit for farm households with hiring out of family labour to meet consumption needs in Low's model. Low's model however makes no mention of the seasonality of agricultural production, and does not consider seasonal liquidity and labour market constraints in the discussion, a shortcoming of the model.

C. Nakajima (1986) extended the "New Household Economics" and Chayanov's "theory of peasant economy" to agricultural households in his seminal work on "The Subjective Equilibrium Theory of the Farm Household", where he developed farm households models depicting various agricultural household situations (these include the farm firms, commercial farms, farm households and subsistence farms) and the conditions affecting work decisions and income flows under each alternative.

In studying the economic behaviour of agricultural farm households, C. Nakajima (1986) conceived a farm of pure subsistence production that uses only family labour on one extreme, and another of pure commercialization using only hired labour, on the other. In the models, the economic behaviour of the farm household is said to be rational when the family farm has achieved a subjective equilibrium, that is, when it has realised the maximisation of its utility, subject to its income equation and quantity of family labour used, or leisure. His "subjective equilibrium theory of the farm household" provides an approach for gaining insights into the households' responses or adjustment to changes in external economic or market conditions, environmental forces that influence farm and nonfarm decisions, social structures and norms, as well as policy, by assessing the complex interrelationships between production, consumption and labour allocation decisions (C. Nakajima 1986).

Unlike Chayanov's model, Nakajima allows for the presence of a labour market, and therefore gives the household the choice between farm work, obtaining additional off-farm work, and 'home time', leading to determinate supply responses (F. Ellis 1993; C. Nakajima 1986). Similar to Chayanov, Nakajima assumed a 'physiological limit of family labour' and a 'minimum subsistence income' resulting in upper and lower limits for what can be produced by the household (S. T. Holden 1993). Further, Nakajima introduced the assumption of diminishing marginal utility of income and increasing marginal disutility of labour (or decreasing marginal utility of leisure) (C. Nakajima 1986).

Nakajima's theory therefore extends well beyond the peasant theory of a farm production unit where profit maximization is assumed, and integrates farm production, household consumption and labour decisions into a joint framework of farm household utility maximization. These integrated agricultural household models have been important in providing a framework for predicting the responses of farm households to external interventions and are particularly useful for understanding farm household-firm unit decisions.

J. E. Taylor and Adelman (2003) review the evolution of the agriculture farm households' model with the explicit objective of providing a starting point for students and researchers to build models to investigate impacts of policy and market changes. In their review, they use a farm household model programmed using the General Algebraic Modelling System (GAMS) to highlight the limitations of farm households' models by presenting a set of policy experiments under different market scenarios in Mexico. The production side of the authors' model is specified by a Cobb-Douglas production function and a Linear Expenditure System (LES) on the consumption side. The alternative model specifications are: (1) a perfect market neoclassical specification in which the household is a price taker in all markets with the exception of capital and land, which are in fixed supply; (2) a missing labour market scenario in which household resource allocations are guided by implicit household "shadow wages"; and (3) a missing market for staples.

From the policy experiments and a comprehensive review of studies that adopted the farm household model methodological approach, the authors highlight three limitations of the farm household model. First, they note that majority of the household-farm models assume that preferences and incomes are shared by all household members. Such assumptions are convenient as they allow the modeller to treat the household as the unit of analysis engaged in production and consumption activities, and ignore the alternative of specifying behavioural equations for each individual household member and a more complex model of joint decision making within households.

Second, farm household models focus on individual household production and consumption units, and such a micro focus misses some of the indirect influences that are as result of the fundamental features of rural economies. For instance, exogenous shocks that may influence production and consumption decisions within the households directly affected may also generate linkage effects on other households and on other aspects of farm behaviour that is beyond the purview of household-farm models (J. E. Taylor and Filipski 2014; Filipski and Taylor 2012).

Third, empirical and applied theoretic research often take alternative market scenarios as given in their analysis, but in reality, decisions on production, consumptions and market participation are made simultaneously within households. A key limitation however in modelling market participation is in the demand for detailed market data, particularly on prices and household-specific transaction costs. In addition, theoretical and econometric extensions of household farm models to include production and consumption responses under changing market scenarios may be challenging to modellers.

In the recent past, Filipski and Taylor (2012), J. E. Taylor and Filipski (2014), and J. E. Taylor (2012) move beyond the microeconomic focus on household units and the limitations of existing agricultural farm household model in their study of rural agricultural economies. The authors analyse farm households' behaviour in the context of the wider local economy that they are embedded in, in terms of the internal conflicts over resource use as well as external market and non-market relationships in which agricultural households interact with. They introduce a local general equilibrium impact evaluation model commonly referred to us the Local Economy Wide Impact Evaluation (LEWIE) (Filipski and Taylor 2012; J. E. Taylor and Filipski 2014; J. E. Taylor 2012).

Generally, the LEWIE nests distinct household groups within the larger economy (or the zone of influence (ZOI)), in order to simulate the inter-households' groups impact of projects or policy interventions. As J. E. Taylor and Filipski (2014) explain, the basic idea behind the LEWIE is the creation of models of beneficiary and non-beneficiary households, and then link them together within a general equilibrium (GE) model of the local economy.

In Malawi and Ghana, Filipski and Taylor (2012) employed a simulation model of heterogeneous and interacting agents (household groups) to compare the impacts of alternative income transfer schemes on production, income and welfare of rural households. They calibrated their simulations to existing fertilizer subsidy schemes in both countries, and then compared them to other cash transfer schemes implemented in each of the countries: in Malawi the Social Cash Transfer (SCT) scheme, and in Ghana, the Livelihood Empowerment Against Poverty (LEAP).

Filipski and Taylor (2012) use the LEWIE approach, where a set of farm household 'sub-models' with the basic structure of a Computable General Equilibrium (CGE) model representing a very small economy, are nested within a CGE of the rural economy by imposing rural economy-wide market clearing and trade balance constraints. Each household model is representative of a group of rural households defined according to the specific eligibility criteria of each transfer programme.

The authors' disaggregated general-equilibrium modelling approach has some key strengths. First, it makes it possible to capture the heterogeneity of households in the rural economy, with household-specific asset endowments as well as production and consumption decisions. Second, by linking heterogeneous households into an economy-wide general equilibrium framework, the spill over effects of transfer schemes from beneficiary households to non-beneficiaries, and from targeted markets to non-targeted ones are revealed. Finally, similar to the basic farm household model, it highlights the dual nature of households as producers and consumers of food.

Despite the evident advantages of the LEWIE approach, the use of a local general equilibrium framework is beyond the scope of the current study due to data limitations. The development of the Social Accounting Matrices (SAMs) in a CGE framework requires vast amount data on both household and market variables, and in the current analysis, data on markets and transactions details is not sufficient for an informal rural economy wide model estimation.

S. T. Holden (2014) uses three waves of panel data from the period 2005/06 to 2008/09 to formulate rural household models for smallholder agricultural households in Malawi. The author adopts a mathematical programming approach to formulate an optimization problem, where household utility is measured as net household income after having subtracted the costs of household labour based on the shadow wages used in the models. In his formulation, S. T. Holden (2014) takes into account of the seasonality of agricultural production by splitting the cropping year into eleven seasonal periods of varying length.

The seasonal periods are based on the cropping activities and peak season activities are allocated shorter seasonal periods of up to half a month. In addition, a number of cropping technologies and the associated market imperfections are modelled. Off-farm employment opportunities are also allowed and inter-households differences are integrated through the inclusion of heterogeneous households, disaggregated by the gender of the head of the household and on the size of the landholdings.

S. T. Holden (2014) calibrates the base model parameters using averages from the three waves of panel data and uses the base model formulation to simulate the effects of variation in access to land and changes in the quantity of subsidised hybrid seed and fertilizer received by households on their welfare. A limitation of the Holden's approach is that he ignores production risks, an important aspect of smallholder tropical agriculture. However, his modelling approach can be extended to incorporate non-embedded risks by allowing stochastic variation in for example yield and prices, and embedded risks through a sequential decision making process across the multiple seasonal periods as information on external shocks unfolds progressively. The simulation model approach is also potentially useful in testing the plausibility of the findings of econometric approaches where it is hard to establish strict causality.

In an extensive research of rural Malawian smallholder agricultural sector, Dorward formulates an extended theoretical model of peasant household behaviour (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006). The author's formulation is based on the simple farm household model as conceived by Barnum-Squire (H. Barnum and Squire 1979b), and whose structure is extended to include additional model components, as a starting point.

The major extensions of the Dorward's farm household modelling approach include; the integration into a farm household model of the seasonality of agriculture production and the subsequent seasonal labour and liquidity constraints, and hence consideration of risks and uncertainties resulting from random events that may occur throughout the length of the planning horizon for farm production activities; heterogeneous household groups to capture differences in asset endowments and off-farm opportunities ; multiple on-farm and off-farm employment activities; households interaction with imperfect product and factor markets; incorporation of households' food security objectives which is integrated into the model through the creation of a "wedge" between farm gate and market purchase prices; and (6) non-separability of households' production and consumption decisions.

On one hand, the incorporation of seasonality is a key strength of the Dorward's approach, and it implies the model's capability to represent seasonal resource constraints and analysis of embedded risk. A seasonal model allows for sequential decision making where the farmer makes tactical adjustments to resource allocation or production choices as risky situations unfold.

On the other hand, a shortcoming of the Dorward's modelling approach is in its specification of long seasonal periods. Unlike S. T. Holden (2014) who models seasonality of agricultural production with several short periods, Dorward (A. Dorward 2003; A. Dorward 1994; A. Dorward 2006; A. R. Dorward 1996; A. Dorward 1999) splits the cropping year into four seasonal periods of between two to four months (i.e. November-January; February-March; April-June; and July-October).

However, as P. B. R. Hazell and Norton (1986) and S. T. Holden (2014) note, shorter seasonal periods should be defined especially in the peak season. For some peak season activities, their execution is often within a very short period, and by defining longer periods, the availability of constrained resources such as family farm labour could be overestimated, while the effect of external shocks affecting availability of production resources could be underestimated, thus resulting in a non-optimal solution.

Characteristically, the definition of very short time periods has its own demerits as it leads to larger models with large data requirements, potentially reducing their usefulness. For each time period defined, information on activities and constraints for all the relevant decisions is required.

A synthesis of the literature on the application of agricultural farm household modelling techniques already reviewed is presented in Table 3.1.

In the current analysis, key characteristics of the households under investigation point us to the analysis of the microeconomic behaviour of the poor rural Malawian agricultural households and their responses to external health shocks, under the framework of a seasonal agricultural farm household model.

These include: the subsistence and semi-subsistence nature of production; the significance of smallholder households' production of food within a seasonal rain-fed production cycle; the importance of casual off-farm wage work (*ganyu*) as a source of household income and the subsequent seasonal labour supply and liquidity constraints; differential resource endowments across households; and households' engagement with imperfect output and input markets with volatile prices.

We follow the lead of Andrew Dorward (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006), and employ a mathematical programming based simulation model of heterogeneous households, multiple seasonal periods, and with multiple on-farm and off-farm income activities, to estimate the welfare impacts of malaria and HIV/AIDS on poor rural households under alternative simulation scenarios.

This dynamic modelling technique is valuable in enabling us to trace out differential households' production and consumption responses to external health shocks, in terms of the adjustments made in the level of agricultural production, in farm enterprise choice, in the allocation of the family labour resources and the subsequent welfare changes arising from the adjustments in the level of consumption of food and cash resources, and leisure time.

Unlike the traditional static single period farm household model and quantitative analysis methods that are often limiting in terms of simultaneous analysis of multiple subjects and tactical decision making, a mathematical programming model of farm households has a flexible structure. It allows for the simultaneous analysis of multiple agents in a single model, and integration into the model of seasonality of agricultural production, and hence increased capability for both embedded and non-embedded risk analysis.

Further, multiple farm enterprises and off-farm opportunities, heterogeneous households, differential pricing of marketable goods and interaction with imperfect markets are all integrated into a single model. The model also highlights the dual role of a farm household as a producer and a consumer through the non-separability of production and consumption decisions.

In addition, the flexible nature of the model allows us to overcome data challenges, with the possibility of using data from a range of secondary and primary sources to calibrate the model parameters, where data is scanty or missing in the primary data set. Its implementation is relatively cheaper compared to econometric techniques. In agricultural development literature, a wide range of quantitative techniques to farm management problems are adopted, but their use especially in smallholder agriculture in developing countries, is often prohibitive due to high demand for data and the costs associated with the implementation of large scale surveys.

In section 3.3, we provide a review of the farm based mathematical programming techniques in literature.

Table 3.1: A synthesis of the application of the agriculture farm household models in key literature

	(Chayanov 1986): *Theory of peasant economy*	(Becker 1965): *New Household Economics (NHE) models*	(H. Barnum and Squire 1979b; H. N. Barnum and Squire 1979a)	(Chihiro Nakajima 1969; C. Nakajima 1986)	(Low 1986)	(S. T. Holden 2014)	(J. E. Taylor and Adelman 2003; J. E. Taylor 2012)	(A. Dorward 2003; A. R. Dorward 1996; A. Dorward 1994)
Assumptions/ model capability	No labour market; flexible land access: sale of surplus farm output at a market price; social norm for minimum consumption level; demographic composition determines family labour supply and output;	Utility maximizing behaviour; market equilibrium in implicit or explicit markets; and stable preferences.	Labour market and a market determined single wage rate for men and women; single price for the main agricultural output; fixed land resource; no risk	Labour market present; utility maximisation subject to income and quantity of family labour used or leisure; physiological limit of family labour; minimum subsistence income; diminishing marginal utility of income and increasing marginal disutility of labour; no land markets and produce is assumed to be sold to the market	Labour market present; gender disaggregated non-farm and farm wage; flexible land access; price wedge between farm gate and market retail price; wide spread occurrence of food deficit	Fixed land access (simulates varying access to land); labour market present; imperfect markets;	Labour market exists; fixed land resource; interaction with imperfect markets	Labour market; fixed land resource; capability for differentiated wage rates; risk and seasonality considerations; imperfect product and factor markets

Seasonality	No	No	No	No	No	Yes, the model covers one year and includes seasonality such that the year is split in 11 periods of varying length.	Seasonality can be incorporated into LEWIE by including seasonal accounts in the Social Accounting Matrix (SAMs)	Yes, cropping horizon divided into four seasonal periods
Multiple farm and off-farm activities	Multiple on-farm activities but no off-farm activities	Yes	Single cropping activity (rice production) and multiple off-farm activities	Yes	Yes	Yes, several agricultural production technologies and off-farm activities	Yes, Agricultural and non-agricultural activities	Yes, several cropping and off-farm activities
Heterogeneous households	No, but there was demographic composition (intra-household) that determined labour supply and effort	No	No: Semi-subsistence households only	His classification is based on the level of commercialisation. Either subsistence family farms or commercial farms	No	Yes, female- and male-headed households. male-headed further split into land-poor and land-rich households	Yes, households are grouped based on household-specific asset endowments as well as production and consumption decisions	Yes, rural households categorised on resource endowment among others
Partial engagement with imperfect markets	buying and selling of produce and non-farm products but it was mainly for the "use value"	Yes	Yes, both labour and output market	Yes	Yes	Yes, imperfect input and output markets	Yes	Yes, both product and factor markets with transaction costs

	than profit; no labour market and transaction costs in output market							
Non-separability	Yes, production and consumption decisions are non-separable	Yes, production and consumption decisions are non-separable	Yes; integration of the production and consumption decisions allows the model to determine both farm profit and wage income.	Yes, direct and close interrelationship between production and consumption	Yes, production and consumption decisions are non-separable	Yes, production and consumption decisions are non-separable	Yes, the model highlights households' dual nature as producers and consumers of food	Ye, integration of the production and consumption decisions allows the model to determine both farm profit and wage income.
Price or yield risk (non-embedded)	No	No	No: Risk is ignored.	No, Nakajima does not allow for uncertainty	No	No, but possible to model yield and price risk (sensitivity analysis)	Possible	No: states of nature capability not being used.
Embedded risk	No	No	No	No	No	Yes, possible with seasons	Possible with integration of the seasonality of agriculture production	Yes. Incorporation of seasonality and the use of a dynamic stochastic model allows

								for sequential decision making as more information becomes available
Inter-household interactions	No	No	No	No	No	No	Yes, heterogeneous households are linked in an economy-wide general equilibrium framework	No, but possible with the introduction of a labour demand function in the model structure

3.3 Mathematical programming techniques for solving deterministic and stochastic problems in whole farm planning

In this section, we aim to explicitly describe the mathematical programming approaches for solving farm management problems. We begin our discussion with a definition of the types of risks in agricultural production and an overview of the advantages and disadvantages associated with mathematical programming techniques. We develop the discussion further by highlighting static deterministic modelling approaches that ignore the seasonality of agricultural production and markets, and the consequences of embedded risks associated with production and market uncertainties. In addition, we discuss dynamic stochastic programming approaches that incorporate the seasonality aspects in production or in supply of resources through multiple periods, and with considerations for risks and uncertainties inherent in rural smallholder agriculture in the low income economies.

Risk in agriculture is categorised as either embedded or non-embedded (A. Dorward 1999; A. Dorward and Parton 1997). Non-embedded risk arises from "known unknowns". For example, at the start of the cropping year, decisions are made on resource allocation, and farm production activities are assumed to have known resource requirement combinations but to yield uncertain returns due to stochasticity of the yield, inputs and output prices. By definition then, the "known unknowns" are the yield and price uncertainties that a decision maker is aware of to a certain extent and has some expectations of, probably from previous experience.

With embedded risk, farm production decisions are made initially and then the uncertainty unfolds subsequently in terms of risky consequences of the choices taken (J. Brian Hardaker, Pandey, and Patten 1991). Embedded risks can therefore be described as the "unknown unknowns" and they require the decision maker to make tactical adjustments to their pre-seasonal plans as more information on risky events becomes available during a production period.

In their study examining the relationship between production resources uncertainty and embedded risk in complex, diverse and risk prone agriculture, A. Dorward and Parton (1997) noted that generally, agricultural economists focussed a lot of attention on non-embedded risk. The authors offer two explanations for the lack of interest in embedded risk. First, they state that explicit analysis of embedded risk may be less important in farming in developed countries as uncertainty may not be so great. In the high income economies, the more developed capital, labour and machinery hire markets encourage market mediated tactical adjustments rather than whole farm adjustments. J. B. Hardaker et al. (2004) also cite effective elimination of some sources of risk in developed countries as a major reason for the dearth of studies addressing embedded risk in agriculture using programming techniques. The authors note that due to the protection measures provided by governments in high income economies, prices of inputs and output are reasonably well known, and hence a reduced attention to risk analysis in the context of developed economies.

Second, the lack of attention to embedded risk in complex, diverse and risk prone agriculture may lie in the difficulties that analysts face in modelling tactical whole farm adjustment to embedded risk (A. Dorward and Parton 1997). Hardaker et al., (2004) also note that although the methods for risk analysis have been available for many years, they are more complex compared to the more familiar and simpler methods that assume certainty.

P. B. R. Hazell (1971) and P. B. R. Hazell and Norton (1986) note that in the formulation of farm planning models that predict the behaviour of farm households, ignoring the risk-averse behaviour of farmers often leads to results or farm plans that are unacceptable to the farm operator on the basis of previous experience, or those that bear little relation to the decisions they actually make. Often, farmers prefer farm plans that guarantee some level of security and would be willing to take some income losses on average (P. B. R. Hazell and Norton 1986). It is therefore important that in whole farm planning, modellers should take account of the farmer's attitude to risk. However, risk analysis requires expertise and a good understanding of the nature of the risks.

In their review of farm planning under uncertainty literature, Hardaker et al., (1991) state that "accounting for risk in mathematical programming models complicates the task, and accounting for embedded risk is especially difficult". Furthermore, they argue that in the case of non-embedded risk, it is more appropriate to regard the uncertainty as being confined in the objective function coefficients only, while for embedded risk, both the objective function and constraints coefficients may be stochastic. However, advances in computer software and hardware have made the application of decision analysis methods simpler and quicker.

In agricultural production management, prescriptive and predictive models that predict the behaviour of an individual decision maker or a farm household in response to external shocks are often based on mathematical programming methods. For several years, mathematical programming models have had wide application in agricultural management problems (Rae 1971b; Adesina and Sanders 1991; A. Dorward 1994; Boisvert and McCarl 1990; J. Brian Hardaker, Pandey, and Patten 1991; Fafchamps 1993; Maatman et al. 2002; Torkamani and Hardaker 1996; Garoian, Conner, and Scifres 1987; S. T. Holden 2014; Simler 1994), and have been shown to be powerful tools for modelling farmers' strategies or management decisions.

Garoian, Conner, and Scifres (1987) note that the usefulness mathematical programming techniques such as the dynamic programming models is due to a number of their capabilities. First, the diversity of problems that may be formulated in a multi-period manner as it allows for a built in form of sensitivity analysis based on varying input variables in different decision stages. For example, variation of the parameter values of resource endowments, such as the landholdings, cash and supply of farm labour allows the investigation of welfare impacts of changes in external factors. Second, the ease with which integer restrictions and uncertainty (stochasticity of model input and output coefficients) may be included. Third, their ability to break down a complex problem into a series of interrelated sub-problems often providing a better insight into the nature of the problem; and finally, the efficiency of the solution algorithms.

There are however some limitations of the dynamic programming techniques. These include: 1) the problem of size or dimensionality as formulation requires including activities for all decision stages, and simple problems can generate large matrices with even a limited number of periods, hence large data requirements (A. Dorward 1994; Budnick, Mojena, and Vollmann 1977); 2) the lack of a general algorithm like the simplex method due to the restrictions on computer codes that limit inexpensive and widespread use (Budnick, Mojena, and Vollmann 1977). In contrast to linear programming, a standard mathematical formulation for a dynamic programming formulation does not exist. Dynamic programming is a general approach to problem solving and its formulation requires a certain degree of ingenuity and insight into the problem by the modeller; and 3) more expertise is required in solving dynamic programming problems than in other methods (A. Dorward 1994; Budnick, Mojena, and Vollmann 1977).

Originally, linear programming was used to solve static and deterministic farm management problems, but the framework has been extended overtime to solve more complex whole-farm management problems with models classified as static deterministic, static stochastic, dynamic deterministic and dynamic stochastic (Anderson 1972). Figure 3.1 illustrates examples of the static and dynamic mathematical programming models applied in decision making under certainty and uncertainty.

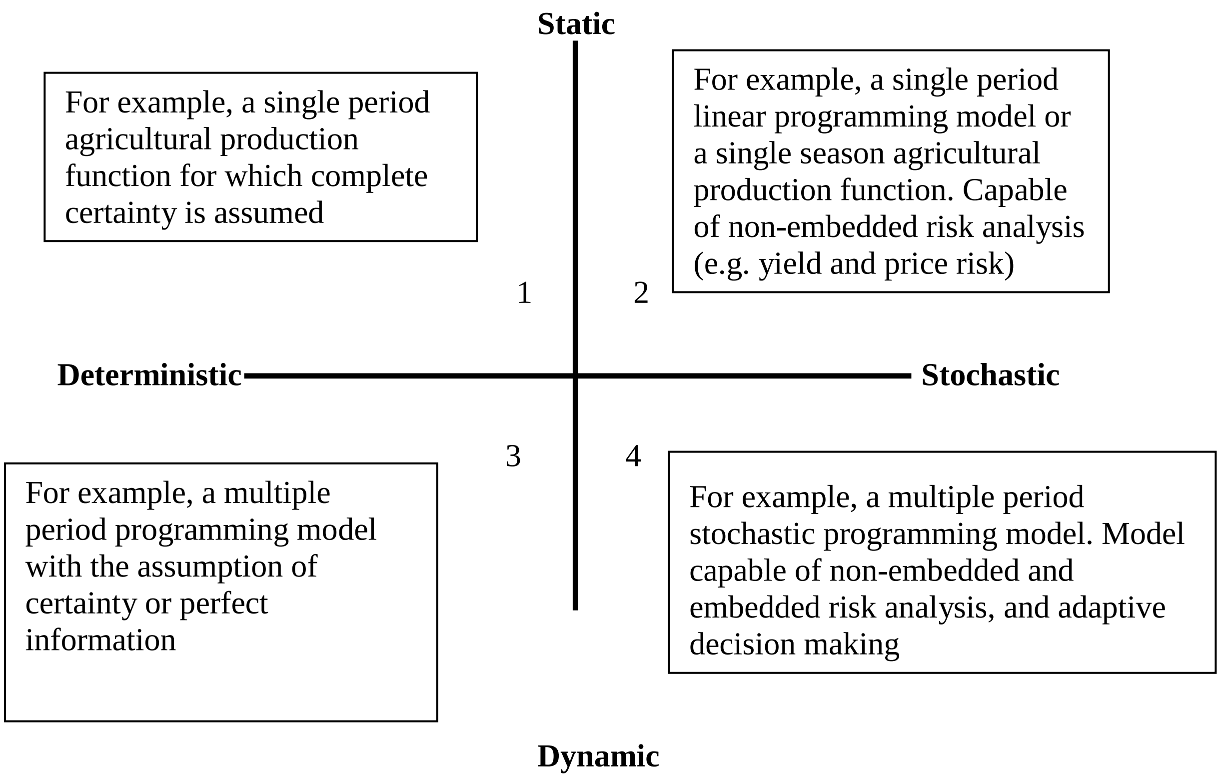

Figure 3:1 Illustrative figure of static and dynamic models in decision making under certainty and uncertainty analysis

Single fixed period production or static models, such as the simple agricultural production function and the multiple enterprises and products linear programming approach, maybe analysed in a static framework that is either deterministic or stochastic. Static deterministic models assumes complete certainty, while in a static stochastic model, probalistic elements are allowed. Static stochastic models are explicitly useful in the analysis of non-embedded risk.

The agricultural production function for example, is usually estimated by econometric techniques in a linear regression analysis by Least Squares or manipulated in marginal analysis in optimization problems, to indicate optimal resource use subject to resource constraints within a fixed planning period. A multiple farm activities single period linear programming approach uses mathematical programming techniques to determine an optimal profit maximizing combination of farm enterprises that is feasible with respect to fixed farm resource constraints. In both cases, considerations for non-embedded risks, such as in the expected yield and price of output maybe modelled, but due to their static nature, their capability in the analysis of embedded risk is restricted.

In agricultural management, static deterministic models have been applied successfully, but as Anderson (1972) notes, they model an unreal situation as agriculture production is seasonal, and is dependent on random biological, physical, market and environmental processes. These include weather, animal and plant health, human health, changes in agricultural markets and a range of macroeconomic factors such as government policies. The seasonal nature of agriculture production and the unpredictability in these factors results in uncertainty over supply of labour, yield and prices for both output and inputs, the key determinants of farm income. Traditionally, farmers relied on experience, intuition or comparisons with their neighbours to make production decisions (P. B. R. Hazell and Norton 1986), although considerable uncertainty about the planning period ahead remained.

Farm planning decisions are therefore made, but the outcomes or implications of those decisions are not known with certainty by the farmer Rae (1971b). The uncertainty surrounding production outcomes may often result in serious effects on livelihoods, such as deprivation or chronic food shortages especially among the poor and vulnerable producers. Consequently, attention has been given to dynamic or time-dependent programming models that take into account the importance of seasonality in agriculture production (A. Dorward 2011; A. Dorward 2006; A. Dorward 1999; A. Dorward 1994; Rae 1971b).

Dynamic programming refers to a multiple periods or decision stages mathematical programming approach. It is a systematic or recursive optimization method of determining mathematically the optimum plan for the choice and combination of farm enterprises so as to capitalize on an objective function (e.g. maximise income or minimize costs) with respect to fixed farm resources (J. Kennedy 2012; Burt 1982). In multiple period programming models, an appropriate number of production periods are modelled and solved simultaneously (A. Dorward 1994; Maatman et al. 2002). Their importance therefore is in the analysis of resource allocation over a time horizon at firm/farm and sector level (P. B. R. Hazell and Norton 1986; A. Dorward 1994; A. R. Dorward 1996).

In dynamic programming, decisions made at each stage are dependent on either information observed from unfolding random events, decisions made in the previous stages and experience and probabilistic information about the future. Their formulation in agricultural management problem is either deterministic or stochastic, but since production is seldom deterministic with physical and market conditions changing over time, deterministic simulation models are infrequently used (Anderson 1972). In the implementation of dynamic simulation problems involving multiple periods in an agricultural production cycle, information generated in the first period is the most useful, while that generated in the subsequent periods may not be very useful except in finding an optimal solution to the first-period decision (Anderson 1972).

In agricultural economics empirical research, time dependent mathematical programming models that capture risk (embedded or non-embedded) and uncertainty or stochasticity of variables are classified as dynamic stochastic programming models (J. Brian Hardaker, Pandey, and Patten 1991; Birge and Louveaux 2011). On the contrary, multiple periods optimization problem models that assume certainty or non-stochasticity of variables are classified as dynamic deterministic programming models.

In the application of the dynamic stochastic programming models, the modeller either adopts a non-sequential or a sequential stochastic programming approach (A. Dorward 1994). Dorward describes a "non-sequential" model as one where the resource allocations are fixed before information about specific values taken by stochastic variables becomes available. In these models, random parameters are replaced by their expected values. On the contrary, the author describes a "sequential stochastic programming model", as one where there is allowance for sequential gathering of information and decision making after the initial period.

For example, in developing countries where crop insurance and information such as weather forecast is hardly available, many of the farm management problems involve making decisions on variables, such as labour supply or output prices, while in reality, demand and supply of labour and output vary stochastically throughout the production season resulting in volatile supply and prices. Consequently, decision making on the farm is often a continuous sequence through time as the uncertainties unfold and more information becomes available to the decision maker (A. Dorward 1999; A. Dorward 1994; A. Dorward and Parton 1997; J. Brian Hardaker, Pandey, and Patten 1991).

In making sequential decisions under uncertainty, farmers may have additional pre-seasonal information regarding for example weather, sickness and prices, but the predefinition of all possible actions may not be feasible. The number of acts may be infinitely large, or acts may have to be chosen from within the confines of a set of limited resources (Rae 1971b). Tactical responses to uncertainty are therefore only made as more information becomes available.

Such adjustments may involve abandonment of some activities or modification of resources allocated to certain activities (for example hiring in labour, more efficient use of pesticide and fertilizers). The adjustments may be aimed at capitalising on favourable circumstances affecting particular activities and resources in order to maintain output, or to reduce resource allocations to affected activities and/or reallocate to the more favourable activities (A. Dorward and Parton 1997).

The introduction of dynamic stochastic programming models comprising of multiple time periods (this allows for model capability in solving sequential decision problems or embedded risk analysis) and structures that make it possible to consider risk and uncertainty in the selection of enterprise combinations, marked a major milestone in the advancement of programming analysis (P. B. R. Hazell and Norton 1986). For a detailed review of literature on incorporation of uncertainty in programming models see (Anderson, Dillon, and Hardaker 1977; P. B. R. Hazell and Norton 1986; Boisvert and McCarl 1990; J. Brian Hardaker, Pandey, and Patten 1991).

Despite the recognition of the importance of sequential responses to risk in farmers' decision making and the methodological advances in mathematical programming, few studies have adopted dynamic stochastic programming models that address seasonality and risk**,** and particularly embedded risk and sequential responses to uncertainty among poor rural farming communities in low income economies. Furthermore, models addressing embedded risk often differ in the elements that are allowed to vary stochastically and in the flexibility allowed for gathering information and revising decisions after the first period or stage (A. Dorward 1994). In addition, evaluation of risk (embedded or non-embedded) in programming models also varies where on hand, some modellers assume risk models that optimise some subjective expected utility function, while on the other, they use 'safety first' models designed to ensure that a farmer's priority objective, for example attainment of minimum calories or income to meet the living costs, is attained (P. B. R. Hazell and Norton 1986).

There are however a few exceptions of empirical studies that have addressed seasonality, embedded risk or investigated sequential decision making in an agricultural households in the context of a low income economy (Maatman et al. 2002; Fafchamps 1993; A. Dorward 2012; A. Dorward 1999; A. Dorward 1994; A. R. Dorward 1996; Adesina and Sanders 1991; Jacquet and Pluvinage 1997).

Fafchamps (1993) estimates the structural parameters of a stochastic control model that describes smallholder farmers labour allocation decisions in response to external shocks, and the flexibility in production and intertemporal substitutability in consumption in Burkina Faso. The author's results confirmed that uncertainty in the availability of labour during the peak productions periods, such as for weeding activities, played an important role in the labour decisions of the surveyed households.

In Malawi, A. Dorward (1994) and A.R. Dorward (1996) adopted both static and dynamic stochastic programming approaches which addressed embedded risk and described farmers' ability to respond sequentially to uncertainties. The authors' modelling approach assumed that farmers are able to make tactical adjustments (e.g.

adjust the timing and methods for planting and other activities and resource allocation) to their pre-seasonal plans as more information (for example on rainfall, crop health, human health and output prices) becomes available during the production period.

In Niger, Adesina and Sanders (1991) used a discrete stochastic programming model to determine sequential decision making under rainfall uncertainty and its effects on the adoption of cereal technologies and on other farm-level effects, while in Algeria, Jacquet and Pluvinage (1997) used the same approach to investigate the effects of climatic variability on the production choices for cereal and livestock farms.

A. Dorward (1999) used a semi-sequential and a discrete stochastic programming (DSP) model to investigate the conditions under which peasant farm-household models would allow for the investigation of embedded risk in Northern Malawi. The author found that sequential responses to uncertainty were more important to poorer and labour constrained households, and compared with semi-sequential programming approach, the discrete stochastic programming (DSP) provided more efficient solutions for problems involving embedded risk. An explanation of the semi-sequential and the discrete stochastic programming models is presented in section 3.4.

In Burkina Faso, Maatman et al. (2002) used a dynamic stochastic programming model to describe sequential decision making by farmers in their strategies of production, consumption, storage and marketing, in response to erratic rainfall patterns from the start of the growing season until one year after the harvest period.

More recently, A. Dorward (2012) adopts a seasonal mathematical programming approach to model the effects of pervasive seasonal finance market failures on the behaviour and welfare of poor rural people in Malawi.

In section 3.4., we discuss two stochastic programming approaches, the fully sequential discrete stochastic programming and a semi-sequential stochastic programming, whose application addresses seasonality and risk, and particularly embedded risk with sequential response to uncertainty throughout the planning horizon.

3.4 Dynamic stochastic programming techniques

3.4.1 Discrete stochastic programming

Dynamic programming is a widely used approach for optimizing sequential decision problems, and has had wide application in agricultural management problems (see for e.g. Garoian, Conner, and Scifres 1987; Torkamani and Hardaker 1996; Adesina and Sanders 1991; Kaiser and Apland 1989; A. Dorward 1994; Maatman et al. 2002). However, the only fully sequential stochastic model developed to date is the Cocks' Discrete Stochastic Programming (DSP) or the Discrete Stochastic Sequential Programming (DSSP) model (Cocks 1968).

Dantzig (1955) developed a multiple stage linear programming model in which only the allocations and quantities of activities in the first stage were required to be determined in advance as those in the later stages depended on the choices made in the earlier stages and on the random events or uncertain demands. Cocks (1968) and Rae (1971a) extended the application of the model in solving sequential decision problems with uncertain outcomes in their use of the Discrete Stochastic Programming (DSP) technique.

Discrete Stochastic Programming (DSP) is a rigorous and fully sequential mathematical programming technique that is potentially capable of providing solutions to sequential decision problems under uncertainty, and in which any number of the input-output coefficients or the resource supplies could be described by discrete probability distributions (Rae 1971a)**.**

Typically, the application of DSP technique in economic analysis of farm management problems is stated in terms of decision theory, and it requires the specification of all possible actions, the states of nature and the probabilities of their occurrence, the consequences of the actions given the various states of nature, and a utility function to be maximized (Rae 1971b).

The DSP model was first suggested by Cocks (1968) who discussed an example of an agricultural household whose labour decisions were made sequentially in two stages. The author formulated a discrete and multistage stochastic optimization problem for agricultural decision making where the objective function coefficients, input-output coefficients or resources endowments were subject to uncertainty. The

DSP approach allows for random coefficients in both the objective function and the constraints set, and allows a multi-stage decision process (Cocks 1968; P. B. R. Hazell and Norton 1986; Kaiser and Apland 1989). Cocks (1968) optimization problem was formulated in a linear programming framework.

Rae (1971b) and Rae (1971a) further developed the Cocks's model and applied it in the analysis of annual production strategies in a New Zealand vegetable farm. Over the years, there have been a number of studies that have applied the DSP approach to sequential decision making problems under uncertainty (e.g. Garoian, Conner, and Scifres 1987; Jacquet and Pluvinage 1997; Kaiser and Apland 1989; Torkamani and Hardaker 1996; Adesina and Sanders 1991).

The formulation of the stochastic programming problem using the DSP model to solve sequential decision problems where the objective function, input-output coefficients and resource supplies are represented by discrete probability distributions requires the following: 1) definition of the probability model structure and the specification of the decision-maker's objective function and its conversion into a functional form suited to the programming model; 2) determination and division of the planning period into a number of stages, for example the number of seasonal periods in a cropping year; 3) definition of a set of decision variables that need to be determined for each stage, for example area under each cropping activity; 4) definition of possible discrete random events (or "states of nature") within each stage, and the specification by the decision-maker of his subjective probabilities that each state of nature will occur; and 5) specification of the activities, resource supplies and constraints for each state of nature within each stage of the planning horizon (Kaiser and Apland 1989; Rae 1971a). Determination of a logical representation of the flow of information/resources from one period to another, or the linking of decisions between the discrete periods of the planning horizon is also critical. For example, actions taken in a subsequent stage are based on decisions made in the preceding stage or in the same stage.

A key assumption of the DSP approach is that some farm management decisions are made after the "state of nature" has been observed (P. B. R. Hazell and Norton 1986). That is, the approach relies on the hypothesis that whereas some farm planning decisions are made on the basis of expected yields and prices, others are made after observing the unfolding events, such as health status, weather and market conditions in the planning horizon (e.g. cropping year). Farmers therefore make sequential and adaptive decisions in response to the unfolding events.

For example, a farmer makes the decision to allocate resources for crop production at the beginning of the season, but as the season progresses and more information on the "state of nature" such as rainfall patterns or illness becomes available, the decision maker adopts adaptive strategies. These may include a change in the level of application of variable inputs such as fertilizer and irrigation water, reallocation of available family labour resources to farm and non-farm activities, hiring in labour to supplement family labour lost or hiring out family labour to meet immediate consumption needs, use of different crop management techniques such as reducing the number of weeding, sale of assets to generate liquidity for medical expenses or food purchases, and buying food stocks to meet household's consumption objectives. The DSP approach therefore is seasonal and provides an insight into the sequence of decisions made by a farm operator throughout the production horizon.

Despite its intuitive appeal and flexibility, the use of DSP model is often overlooked in empirical research because of the large matrix size and data requirements (Garoian, Conner, and Scifres 1987). Similar to other dynamic programming approaches, the size of the programming matrix in a DSP model formulation becomes large as the number of the "states of nature" and stages increases (P. B. R. Hazell and Norton 1986; Kaiser and Apland 1989). Since its formulation requires including activities and resources for all possible random events in all stages, simple problems often generate large matrices.

A. Dorward (1994) states that "to realise the theoretical advantages of the DSP approach, a range of possible "states of nature" should be defined and the probability of occurrence estimated for each. Joint probabilities of prices, yields, unit resource requirements and resource availabilities may demand consideration of a large number of "states of nature" and hence even a simple deterministic model may develop into a large and complex DSP model unless the number of decision stages and the "states of nature" described are very limited.

For each "state of nature", data must be defined in terms of yield, prices and constraint function coefficients, hence large-scale data requirements. Its use is thus often impractical and inappropriate particularly in peasant agriculture where reliable data is often hard to obtain, farm units are small and analytical resources are more limited. The difficulties in acquiring reliable data allowing, for example, the specification of the subjective probabilities that a random event, such as ill health, will occur and therefore allow decision making based on the probalistic information, and for each period of the cropping season makes the DSP model technique a less viable option in this study.

To overcome the modelling challenges associated with the DSP technique, A. Dorward (1994) developed a farm household model formulation that allows adaptation of non-sequential and multi-stage linear programming models into a "semi-sequential" framework describing problems with stochastic resource supplies and input-output coefficients. In his study, the author noted that there was a need for a wider choice of and greater flexibility in the development of models appropriate for the study of small farms in peasant agriculture, and with limited data and resources available to the analysists. We discuss the "semi-sequential" stochastic programming formulation in the section 3.4.2.

3.4.2 The semi-sequential stochastic programming approach

The "semi-sequential" approach is a flexible stochastic programming model that addresses embedded risk and allows a sequential response to uncertainties in resource supplies and prices. It is a useful alternative modelling approach where stochastic variation is important but analytical and data collection resources are limited (A. Dorward 1994). The semi sequential strategy allocates resources to maximise an objective function, such as income or expected utility, under different "states of nature". For example, in favourable and adverse conditions, such that resource allocations under favourable conditions allow retreat to a different set of resource allocations that provide a recommended or safe level of income should adverse conditions prevail (A. Dorward 1994).

The method uses a "safety first" approach whereby the aim is to maximise an objective function, for example income, under favourable conditions subject to a minimum acceptable income being assured should adverse conditions prevail. The method therefore mitigates risk by including a "safety first" constraint, which requires a minimum acceptable level of income to ensure that households meet food consumption requirements, either from own production or from market purchases.

In the semi-sequential framework, a flexible response to seasonal conditions is described first by identifying “safety activities” as a high priority core of activities to be maintained under favourable and adverse conditions. The safety activities represent a fall back plan to adopt should adverse conditions prevail and the decisions maker’s planned range of activities suited for favourable conditions cease to be viable (for details on the development of the semi-sequential approach see Dorward (1994)).

In the current analysis, we draw on the A. Dorward (1994) “semi-sequential” farm household programming model framework, and formulate a multiple seasonal periods (dynamic) stochastic programming model of Malawian farm-households. Details of the model formulation are discussed in section 3.5.

3.5 Formulation of a seasonal non-linear stochastic programming model of Malawian farm households

3.5.1 Overview of the models’ formulation procedure

We adopt a dynamic stochastic programming approach to investigate farm planning decisions with considerations for variations in the seasonal supply of unskilled family labour and cash resources. The farm model is designed to effectively describe farmers’ production and consumption responses to stochastic variation in short term capital and family labour resources due to effects of external shocks, such as morbidity.

Unlike the “semi-sequential” stochastic programming approach described in A. Dorward (1994), our model formulation is not designed on a “safety first” basis as we do not identify priority “safety activities” that are to be maintained in both the favourable and adverse (health shocks risk) conditions. In addition, we do not set a minimum level of income that must be assured should adverse conditions prevail, and instead, adjustments in the basic level of cash and caloric consumption is allowed.

P. B. R. Hazell and Norton (1986) suggests that although “safety-first” models are applicable in modelling poor farm households with minimal resources to fall back on should adverse conditions prevail, they are more appropriate where the risk of a catastrophic event occurring is large, either because the farmers’ environment is inherently risky and the farm households are poor.

Initially, we formulate a seasonal deterministic optimization problem with multiple activities and constrained resources coefficient values that are closest to farmers' actual plans, for each type of household. The models' coefficients are estimated either from the LSMS-IHS3 survey data or from secondary sources. However, information on the proportion of households' available labour that is hired out to the ganyu wage labour market was gathered through face to face interviews conducted by this author in Malawi. The aim of the primary data collection exercise was to determine households' use of time resources, availability of off-farm employment opportunities in the ganyu labour market in rural Malawi and how such labour is mediated.

In addition, we use the information to verify and justify the restrictions in the amount of households' time resource that is hired out to the ganyu labour market in our model formulation. A detailed explanation of the supplementary data collection exercise is elaborated in section 3.6.4, and in section 5.2.3 in chapter 5, we further explain the rationale of the primary data collection exercise in explaining the ganyu labour market constraints and in the calibration and validation of the base models of rural farm households.

The model is set up in a dynamic mathematical programming framework, and is designed to describe key characteristics of rural agricultural livelihoods. A detailed explanation of the key model components is presented in section 3.5.2.

In the estimation of the base deterministic model, certainty is assumed with no stochastic variation of the objective function coefficients and resources constraints, and the expected utility is maximised over a set of constrained resources using a non-linear programming model. We use the multi-period deterministic optimization model to determine the feasible level of activities and enterprise combination (farm plans) that maximises the households' utility under "good health" conditions. The "good health" state in the model context denotes the absence of external health shocks, and therefore perfect foresight in the decision making process.

We then use the base model to simulate the welfare impacts morbidity, denoted as the "bad health" state, on different types of rural households. In the simulation models, we introduce health shocks into the constrained set of resources by varying the parameter values of resources that are directly affected by ill-health. These are the seasonal supply of unskilled family labour and short-term capital.

The stochastic variation of the amount of family labour and cash capital available to a household within a seasonal period enables in the simulation of alternative ill health shocks scenarios for the determination of differential welfare impacts of ill health on poor rural livelihoods and to explicitly track the households' responses to changes in the severity of morbidity.

Such responses may include adjustments in resource allocation, abandonment of some production activities, shift to less labour intensive production activities, substituting family labour with hired in labour, change in the level of consumption, and other coping mechanisms employed by poor rural households. A description of the simulation scenarios is presented in chapter 6.

3.5.2 Models' components

The process of model development, it's structure and components in the current study draws from earlier publications and modelling activities of Andrew Dorward (A. Dorward and Parton 1997; A. R. Dorward 1996; A. Dorward 1999; A. Dorward 1994; A. Dorward 2006; A. Dorward 2006; A. Dorward 2012; A. Dorward 2003).

A. Dorward (2002), A. Dorward (2003) and A. Dorward (2006) develop farm household models for rural households in Malawi, based on a broad typology of household categories, with a focus on own farm production and participation in labour markets, and their implications for poverty and agricultural growth. The author formulated a multiple seasonal periods non-linear programming model for different types of poor rural farm households who practice semi-subsistence farming, and each household type is representative of a large number of households in rural Malawi. Similar to the authors' methodological approach, we adopt a farm based dynamic stochastic programming model to investigate the impacts of malaria and HIV/AIDS on rural agricultural livelihoods in the Kasungu-Lilongwe Livelihood zone in rural Malawi.

We use the model to determine farmers' responses to the effects of ill health that affect their supply of unskilled family labour and create cash demands on their cash capital resources, and the subsequent impact on their livelihood strategies and welfare. The model therefore allows us to establish the strategic adjustments made by households in order to maintain a base level of welfare or improve on their welfare in terms of food, cash and leisure time consumption.

The choice of the dynamic programming model in the current study is therefore on the basis of its flexibility, as it allows us to incorporate the various components that characterise the livelihoods of the poor rural agricultural households under investigation in a single model framework, and to simulate the effects of ill-health while making use of data from a wide range sources for model calibration.

Similar to Dorward's formulation (A. Dorward 2002; A. Dorward 2003; A. Dorward 2006), our model incorporates the following aspects of rural agricultural livelihoods: (1) the seasonality of agricultural production captured through multiple seasonal periods; (2) multiple cropping and off-farm income earning activities; (3) heterogeneity of rural households which is represented by a typology of rural households; (4) partial engagement with imperfect markets through the inclusion of transaction costs; (5) households' food security objectives represented by differences in market and farm-gate process, and seasonal variations in staple food prices; and (6) non-separability of production and consumption decisions by farm households. These features are relevant to this study and we discuss them further in turn.

1. The seasonality aspect

The inherent seasonality of agriculture and the consequent seasonal variation in the use of labour, in food prices and wages, and in income and expenditure, and their effects on the welfare of poor rural agricultural communities are key aspects in this study.

In low income economies, seasonal constraints that include for example fluctuating food prices and supply, supply of labour and wages, credit and liquidity constraints and output market imperfections are inherent in smallholder agriculture. For example, smallholder agriculture in developing countries is predominantly rainfed, and the seasonal nature of agricultural production coupled with imperfect output markets results in reduction in the supply of food and therefore high food prices during the pre-harvest season. As such, poor and vulnerable households with reduced purchasing power often cope either by reducing food intake or by seeking off-farm employment opportunities to meet their immediate consumption requirements.

Seasonality is also closely associated with farm labour supply constraints especially during the peak periods for agricultural activities. The peak agricultural season, which is usually the rainy season, often coincides with the hunger and high food price period, and food insecure and cash constrained households may engage in off-farm opportunities at the expense of own farm production activities. For example, delay in planting or weeding may bear a cost in the expected yield loss. In addition, the peak agricultural season is rainy, and the wet and warm weather conditions create a suitable vector environment for tropical diseases such as malaria and occupational hazards as a result of the labour intensive cropping activities. Increased disease incidence may then result in labour losses and consequently losses in final harvest outcomes. Seasonality is therefore a key aspect to factor in farm household modelling.

To address seasonality in agricultural production, we define four major seasonal periods in the unimodal rainfall system in Malawi. These include: (1) cropping period (November to January of the following year); (2) growing period (February to March); (3) harvest period (April to June); and (4) post-harvest period (July to October).

In Malawi, rain-fed agriculture dominates with a rainy season from November/December to March/April. Peak agricultural seasons are therefore in November/January (cultivation, planting, weeding, fertilizer application) and April/May (harvesting). The cropping and the growing periods are also regarded as the “lean season,". They are the periods preceding the harvesting of crops, and often, there is diminishing stock of food for most rural households and the price of key staples tend to rise.

The cropping period is the beginning of a new cropping season. During this period, cropping activities such as land preparation (for example ridging), planting, pest control, fertilizer and manure application, and weeding make heavy demands on labour. Consequently, there are potential trade-offs between on-farm work that generate returns at the time of harvest and off-farm work that generate lower but more immediate returns. For the poor households, such income is needed to sustain minimal levels of cash and food consumption prior to harvest (A. Dorward 2006; A. Dorward 2012; A. Dorward 1994). Additionally, seasonal capital constraints are highest at the onset of the cropping season as the stocks of food from the previous harvest may be running low, and there are high human and financial capital requirements for labour and other farm production inputs such as seed and fertilizer.

In the growing period (February to March), there is limited on-farm labour demand and hence diminished demand for off-farm work. Food prices are however at the highest level while ganyu wage rates dip (A. Dorward 2012). Consequently, poor households are often at risk of hunger.

During the harvest period, crop prices fall and farm labour demand and the off-farm wage rates rise. Crop harvesting, transportation and storage are the main activities performed. On the contrary, crop prices rise in the post-harvest period and there is some demand for farm labour required for early land preparation activities, and also there are more off-farm employment opportunities (for example in petty trading, in building and in collecting grass for thatching houses). The post-harvest period is usually less labour intensive and activities mainly include drying of produce, bagging and storing, and sales and marketing of produce for net sellers.

2. Multiple farm and off-farm activities

The agricultural sector in Malawi is dominated by smallholder farm households with farm sizes ranging from 0.3 ha to 5 ha and most of the land cultivation is done with hoe (S. T. Holden 2014). Farmers predominantly grow maize as the main staple crop, with approximately 97% of farm households producing the crop (Chirwa and Dorward 2013). Other important crops include: legumes such as groundnuts, pigeon peas, cowpeas and beans; root crops such as cassava and sweet potatoes; fruits and vegetables to a lesser extent; and cotton and tobacco as cash crops. Typically, they intercrop two or more crops in a field. For example, maize is usually intercropped with beans, groundnuts or cowpeas. Intercropping is often preferred when some crops are deemed minor to occupy their own field, or to plant more crops where land is limited and to diversify food and income sources.

The model also explicitly includes on-farm and off-farm labour allocation, capturing households' allocation of time between own farm production activities and limited wage employment. Off-farm employment opportunities provide an alternative source of income for households. Borrowing of credit is permitted with certain restriction tied to input receipt, although different levels of credit acquisition may be permitted in alternative simulation scenarios.

3. Heterogeneous households

An important aspiration in the current analysis and modelling is to capture the diversity that exists across poor rural households with varying level of resource endowments, and therefore determine the differences in their consumption and production responses to the effects of health shocks and in welfare changes under different simulation scenarios. We adapted a typology of rural Malawian households developed using the LSMS-IHS3 data set. The development of the typology of rural Malawian households is detailed in chapter 4.

4. Partial engagement with imperfect markets

To capture households' engagement with imperfect rural markets, the model structure incorporates different local market and farm-gate purchase prices. The farm-gate sale price is lower than the market price as it is calculated as the market price of a commodity less a pre-determined mark-down. A large mark down depresses the farm-gate price, a representation of imperfect markets and price uncertainty in food markets in the model structure.

The rural labour market dynamics are incorporated by the inclusion of market transaction costs in the search for employment and in the supervision of unskilled workers in the ganyu labour market. Oversupply of labour in the ganyu labour market and a wage above the market clearing wage (due to social norms and non-market relations affecting employer/employee relations) is therefore allowed for by the transaction costs (search of labour cost) imposed on those seeking ganyu employment. Financial market failures are demonstrated in the model by credit rationing, where input credit is tied to tobacco production at the onset of the cropping year and repayment of the principle amount and interest required after the sale of the produce.

5. Food security objectives in uncertain markets

The importance of households' food security objectives in the context of an uncertain food market is emphasised through the creation of a "wedge" between farm-gate and consumer prices in produce markets, and seasonal variation in the price of maize, the key staple in Malawi. Consumption of food is modelled in terms of recommended calorific requirements, and can be achieved either through own production or through purchases. The model design therefore encourages subsistence production of food through the difference between food purchase and sale prices.

6. Non-separability of households' production and consumption decisions

The integration of production activities, households' consumption objectives, and a set of constrained resources in a single model formulation generates interaction and competition for resources between consumption and production activities, more so for the severely cash constrained households affected by seasonal resource stock constraints and lack access to alternative sources of income such as credit. Production and consumption decisions in the farm household model structure are interdependent and non-separable.

3.5.3 The empirical models' formulation

The seasonal model formulation presented below is for a semi-subsistence poor household that produces multiple crops, hires out family labour to the formal or informal labour market, and interacts with imperfect product and factor markets in rural Malawi. The households' goal is to maximise a future expected utility through consumption of cash (for acquisition of market purchased goods and services), of food or calories (from own produced goods) and of leisure or reproduction time, subject to a constrained amount resources.

The achievement of the farm households' objective is therefore dependent on the optimal allocation of constrained resources to own farm production activities, to off-farm employment opportunities, and to leisure and reproduction time, from which income to cover the consumption expenditure is generated.

In the development of the model, it is assumed that the household is rational, and prioritises provision of calories and cash over leisure time. The household is therefore expected to allocate resources to meet its consumption needs first, and must therefore make decisions to allocate the constrained resources to on-farm production and off-farm wage activities, given an externally determined market price for input and output prices and wage rate.

P. B. R. Hazell and Norton (1986) argue that when income rises above the subsistence level and the required drudgery to meet the desired level of consumption is reduced, farmers typically display a strong preference to reduce manual labour. Demand for leisure is therefore income elastic.

Following Dorward's model approach (A. Dorward 2003; A. Dorward 2006; A. Dorward 1999; A. R. Dorward 1996), we present a whole farm based non-linear programming model of Malawian farm/ rural households. The structure of the model is illustrated in Equations 3.1 to 3.4. The modelling procedure begins in the previous season's post-harvest period whose activities determine the amount of stocks of cash and maize grain that are transferred to the first period (November to January) of the cropping year.

The planning horizon is a single cropping year that is split into four seasonal periods. Each period's activities are determined and the constrained resources are allocated. For example, the amount of labour allocated to the first period is consistent with the period's activities such as land preparation, planting and weeding.

Transfer of stocks of cash and maize grain between periods is allowed in the model formulation, with the requirement that the closing stocks of cash and grain are equated to their opening stocks. In his formulation, A. Dorward (2003) states that equating the closing stocks to the opening stocks of cash and staple grain ensures that the programming model does not generate artificial windfall gains resulting from changes in households' portfolio. For example, households may replace stocks of maize grain with cash.

The opening stock of cash can be allocated between the purchase farm inputs such as seed, fertilizer and other farm inputs, and households' consumption expenses. Off-farm activities are described in terms of hiring out of labour at seasonally varying wage rates. There is allowance to hire in unskilled farm labour in case of a labour deficit.

The households' objective function of future expected utility maximisation is defined over consumption of cash, calories and leisure at various periods of the cropping year (Equation 3.1), and is specified using a Linear Expenditure System (LES). Households maximize their utility subject to the first to second and third to fourth seasonal periods' resource constraints outlined in Equation 3.2 and 3.3, respectively. Equations 3.2 and 3.3 describe the utilisation of constrained resources (these include labour, land, variable production inputs such as seed and fertilizer, stocks of cash or capital, stocks of grain, post-harvest cash crop stocks) and production opportunities (these include cropping activities) within each seasonal period, with buying and selling of those commodities and resources for which there is a market, stock transfers between periods where appropriate, and household consumption where appropriate. In Equation 3.4, the end of season stocks of maize grain and cash are equated to their pre-seasonal stocks.

$$\mathbf{Max\ E\ (U) = \sum (C_{j*m} - \gamma_{j*m})^{\beta j*m}}$$

$$\mathbf{Max\ E\ (U) = ln\ U = \sum ln\ \beta_{j*m}\ (C_{j*m} - \gamma_{j*m})} \qquad (3.1)$$

Under the following seasonal resources constraints, such that

for m =1 to 2

$$-t_{jm} + t_{j\ (m+1)} + \sum e_{ijm} x_i + C_{j*m} \leq 0 \qquad (3.2)$$

for m =3 to 4

$$-t_{jm} + t_{j\ (m+1)} + \sum e_{ijm} x_i + C_{j*m} \leq D_{jm} \qquad (3.3)$$

for m =4

$$-\ t_j\ (m+1) = t_j\ (m=1) \qquad (3.4)$$

where

m are four periods within a year *(i.e. 1= November-January; 2= February-March; 3= April-June; and 4= July-October)*

j_m constrained resources *j* include: land; supply of labour; cash stocks; maize stocks; purchased crop inputs; and post-harvest cash crop stocks in period *m*

$j*_m$ is the subset of commodities/ resources directly consumed by the household and for which consumption is included in the objective function: cash consumption by seasonal period, consumption of maize (or calorific equivalents from other crops) by seasonal period, leisure (‘slack’ labour) by seasonal period, and end of season cash savings.

C_{j*m} represent total consumption of commodity $j*$ in period m

γ_{j*m} are minimum consumption requirements for commodity $j*$ in period m

β_{j*m} are the marginal propensities to consume commodity $j*$ in period m

x_i the *ith* activity undertaken by the household, $i = 1...n$. and includes: cropping activities, buying and selling of stocks and labour, and cash and maize grain stock transfers between periods

t_{jm} represent transfers of resource j from period m to period $m+1$

e_{ijm} are technical and price coefficients of use/ production of resource/commodity j by activity x_i in period m

D_{jm} are supply constraints on commodity/ resource j in period m

3.5.4 Rationale of the methodology

In the economic analysis of farm management problems, a wide range of quantitative farm management techniques are often adopted to examine the problem, predict farmers' decisions and prescribe to the decision and policy makers courses of action that would lead to the realization of the desired goals. However, such techniques are too demanding of data that is often too costly to acquire. Consequently, their application in smallholder agriculture in developing countries is often hindered by the inadequacy of good quality data, or data that is poor at describing smallholder farm problems and features. These may include among others, the multiple interactions between enterprises, interdependency between production and consumption decisions, uncertainty about future events and prices, and non-monetary objectives.

For example, in econometric analysis, relationships between production and income or consumption and income, are often easily directly estimated with survey data. A farm equilibrium can be derived from a two-stage process where first, a farm production problem is solved for maximum income given market determined prices and wage rate. Second, given income and the wage rate, households' consumption of goods and leisure is determined. This type of analysis separates households' production and consumption decisions, and indirect utility functions can be derived in prices and income, and estimated independent of the farm's production function (P. B. R. Hazell and Norton 1986).

However, when decisions about production, leisure and consumption are interdependent, and the farm household has a welfare maximising or cost minimizing goal, as it is usually the case in smallholder agriculture in poor economies, a choice of a model that simultaneously determines production, leisure and consumption is required.

Besides the interdependency among production, consumption and leisure decisions, rural smallholders often interact with imperfect markets in trading surpluses or acquiring inputs such as labour and other goods and services from the market. Where goods and inputs are traded in perfect competitive markets, H. Barnum and Squire (1979b) note that interdependence between production, consumption and leisure breaks down. In developing economies, farm households transact in imperfect markets, and they also often diversify into off-farm and on-farm rural agricultural sector activities such as non-farm enterprises and employment in the informal rural economy for wages.

Such markets have a number of distinguishing features that results in market imperfections. First, the physical setting is characterised by poor road and market infrastructure often resulting in high transaction costs and volatile input and output prices. Their physical environment may also include challenges in the accessibility to amenities such as safe water, health services and good sanitation that directly affect human health and wellbeing.

Second, agriculture production is majorly rain-fed and seasonal, and cropping activities are confined to the months when rainfall and temperatures are conducive for plant growth. Consequently, fluctuating output supply, seasonal labour and liquidity constraints, and commodity market price and wage rate volatility may ensue as result of demand and supply dynamics.

Third, the seasonality aspect of agriculture production means that there is a lag between the time decisions to allocate production resources are made and the time the farmer gets the output. This time lag and the risky nature of agricultural production exposes producers to a wide range of predictable and non-predictable factors that determine the output at the end of the cropping season. In other words, seasonality coupled with random shocks to the agriculture systems due to the dependence of agriculture to biological process makes it susceptible to uncertainties.

Uncertainty may arise in the expected yield, input and output prices, enterprise requirements for fixed resources and the supply of the total amount of resources required. Consequently, individual farmers repeatedly make decisions on what commodities to produce and enterprise combinations, planting dates, seed varieties, method of production, how much of the inputs to use and in which seasonal period. These decisions are made considering the prevailing physical and financial resource constraints. Further, since production is rarely deterministic and conditions change over time, farmers must be able to respond to among others changing market, labour, financial, technological or environmental conditions, either at the start of the season, or as the season progresses and more information becomes available.

As such, interdependences between production, consumption and leisure exist in the imperfect market environment, and depending on the characteristics and resource endowment of a household, differences in household responses to external factors or random shocks are expected. Therefore, to determine the responses of different types of rural households to random shocks (risks and uncertainties) that may arise in the course of the cropping year, we require a flexible farm model structure that allows simultaneous analysis of farm production, consumption and leisure decisions under the framework of a whole farm system model. Such a model must be dynamic or time-dependent (not static to allow changes across the season) to integrate multiple seasonal periods and allow for the investigation of the inter-seasonal variation in activities and resource constraints, and therefore embedded (and partial analysis of non-embedded risk) risk analysis.

In addition, the model structure must incorporate multiple on-farm and non-farm activities, and also heterogeneity of rural farming households to determine difference in household responses to external shocks. These modelling aspirations led to the application of a mathematical programming model of the farm household.

The mathematical programming technique is flexible and allows incorporation of the desired model features and addresses whole farm system planning and decision making under uncertainty and stochastic variables. By variation of particular model parameters, e.g. supply of unskilled family and cash resources, we simulate and explore the adjustments made by different types of households in response to the effects of ill health. Moreover, integration of seasonal periods into the model allows for determination of sequential decision making across the periods and hence the possibility for embedded risk analysis.

3.6 Data and sample selection

3.6.1 Data set

Our analysis and calibration of the set of base farm household nonlinear programming models is data intensive and capitalizes on a wide range of data sources. Our major source of data however is the World Bank's Third Integrated Household Survey (IHS3) 2010/11 for Malawi. The survey data set was chosen on the basis of its multi-topic nature, providing sufficient and dependable information relevant to our modelling aspirations. The LSMS-IHS3 is a cross-sectional survey with data collected over a 13-months period, between March of 2010 and March of 2011.

The survey was implemented by the National Statistical Office (NSO) in Malawi, with support from the World Bank Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) project. The survey had been designed at baseline to provide information on the various aspects of household welfare in Malawi. The sampled observations are representative at the national, urban and rural, regional, and district levels, enabling for further disaggregation. The total LSMS-IHS3 sample comprised of 12,271 observations in 768 enumeration areas (EAs).

3.6.2 Sampling procedure

The sampling procedure of the LSMS-IHS3 was founded on the 2008 Malawi population and housing census listing of information. The selected observations are nationally representative and covers 31 districts in Malawi. Likoma district was excluded on the basis of its small size relative to the size of the other districts and difficulties in accessibility, hence costly to implement a survey. Also excluded from the survey were communities living in institutions such as hospitals, prisons and military barracks.

A stratified two-stage sample design was used for the LSMS-IHS3. At the first stage, the primary sampling units (PSUs), which were the census enumeration areas defined for the 2008 population and housing census (PHC) were selected by probability proportional to size (PPS) method within each district, where the measure of size was based on the number of households in the 2008 Malawi census frame. In the second stage, a random but systematic sampling method was used to select households from each of the enumeration areas sampled.

The primary sampling units (PSUs) selected at the first stage are the census enumerations areas (EA's) as defined for the 2008 Malawi population and housing census. The EA is the smallest operational area established for the census with well-defined boundaries, often covering two to three villages corresponding to the workload of one census enumerator. The EAs have an average of about 235 households each. A total of 768 EA's were selected across the country. In each district, a minimum of 24 EA's were interviewed while in each EA a total of 16 households were interviewed, totalling to a sample of 12,271 households (National Statistical Office (NSO) 2012a).

For the purposes of this study, our analysis focuses on a sub-sample of 1448 observations in the Central region of Malawi, specifically the six districts in the Kasungu-Lilongwe Plain livelihood zone. The observations are unevenly spread across the six districts namely, Dedza, Dowa, Kasungu, Rural Lilongwe, Mchinji and Ntichisi. Table 3.2 below presents the distribution of the sub-sample.

Table 3.2: Sample distribution across the districts

District	Number of observations	% of the sub-sample
Dedza	39	2.7
Dowa	287	19.8
Kasungu	314	21.7
Rural Lilongwe	375	25.9
Mchinji	241	16.6
Ntichisi	198	13.3
Total	1448	100

3.6.3 Survey tools

The LSMS-IHS3 data were collected using four instruments administered at either the household or community levels. The household level tools included a multi-topic household questionnaire, an agricultural production activities questionnaire and a questionnaire on fishing activities for communities around Lake Malawi. All sample households were geo-referenced. A community level questionnaire was administered to key informants in each village.

The multi-topic household questionnaire was used to collect information on: household members' demographic characteristics; health status and child anthropometrics; utilisation of time in domestic, on-farm and off-farm activities; income and consumption expenditure; food security and safety nets; ownership of durable and agricultural assets; housing and access to social amenities; access to credit; shocks and coping strategies; and self-assessment of wellbeing.

Information of the sample households' agricultural activities was collected using the agriculture questionnaire. This included information on crop production activities and yield in the previous complete rainy and dry (referred to as *Dimba* season in Malawi) cropping seasons. Depending on the timing of the interview, the reference rainy season was either in 2008/09 or 2009/10, and 2009 or 2010 for the dry season. Additional information collected using the agriculture questionnaires include: land ownership and size of cultivated plots measured using the Global Positioning System (GPS) based locations estimates and also by farmer estimates; land tenure systems; physical plot characteristics; commercial and subsidized inputs use, and receivership of coupons for subsidised inputs; input and output prices; storage and marketing of agricultural and livestock produce; family and hired-in labour utilisation; livestock production; and access to extension services.

The community questionnaire was administered by the leader of a group of enumerators to a focus group in each Enumeration Area (EA). The focus groups were composed of 5 to 15 long-term and knowledgeable residents of the community, who were also diverse in terms of sex, age, religion and ethnicity.

The focus group members typically included the village chief(s) and the advisors to the village chief(s), a subset of members of the village development committee (VDC) or the area development committee (ADC), the local school headmaster and/or teacher, health worker(s), an agricultural extension officer, leaders of religious and political entities, local merchants, leaders and members of community-based organizations/committees, and members of community policing.

Information collected at the community level was on: agriculture production and other economic activities; access to basic services such as water, education and health facilities; development achievement within the locality; resource management; community organisations; and commodity prices.

Finally, a household level tool for information related to fishing activities was administered specifically to fishing communities. This tool was used to collect information on the fishing calendar, labour and other input use in fishing activities, fish output and trading. In the current analysis, fishing activities are absent among the sampled observation and therefore disregarded.

The data collected using the various tools has been utilised in this study in the computation of key variables useful in the classification of households and in the calibration of the base models for the different types of households. A detailed description of the procedure followed in the classification of households and in calibration of the base model are presented in chapters 4 and 5, respectively.

In addition to the information gathered in the primary data set, additional information to complement the survey data was gathered using qualitative and participant observation techniques. Section 3.6.4 details the data gathering procedure.

3.6.4 Gathering of supplementary data

To supplement the information gathered in the LSMS-IHS3 data, I carried out additional data collection in Kaunda village in Kasungu District of Malawi in March of 2016. The selection of the village, which is located in the area of study, the Kasungu-Lilongwe Livelihood zone, was done pragmatically through a series of contacts. The village characteristics were also suitable for the purposes of our study.

Kaunda is a remote village located approximately 220 Kilometres from the capital Lilongwe, in the Central region of Malawi. The village’s road infrastructure is underdeveloped, and as result, there are no public service vehicles into the village. The normal mode of transport to the village is by motorcycle taxi. The nearest tarmac road from the village dwellings is 40 Kilometres away. Within the village, there is a primary school with approximately 500 pupils. However, the school is severely understaffed, with only three teachers. Due to the shortage of teaching staff, pupils’ attendance is very poor.

The nearest health facility from the village is approximately 10-12 Kilometres away. The facility is government funded and thus provides free health care. However, as it a village level health facility, there is no qualified doctor. The facility’s staff include a clinical officer, a nurse and a midwife. Health surveillance officers who are trained to diagnose and treat minor ailments are also part of the facility's staff. Patients often walk to access health care, and where they can, they use bicycles or motorcycles. Malaria is the most dominant disease in the village, particularly among children below five years of age.

The village is predominantly occupied by smallholder farmers producing mainly maize, soybeans, groundnuts, beans, cassava and burley tobacco. Livestock production largely consists of small livestock such as goats and chicken.

The key purpose of the survey was to understand the livelihoods of poor Malawian households during a food deficit month, their access to services such as health care, diseases burden and coping strategies, and labour utilisation. In addition, the survey aimed at understanding the labour supply and demand dynamics in the ganyu labour market, particularly the role of social networks. The checklist used in the survey is provided in Appendix A1, and key findings from the survey are presented in chapter 5.

During the data collection exercise, I employed both the "participant observation" and "in-depth interviews" qualitative research approaches. My methods consisted of living in the village for a period of 7 days, while observing all aspects of the villagers' ways of life, including time utilisation, access to key amenities such as hospitals, sources of water and energy, quality of infrastructure and access to food.

In addition, I interviewed a number of people who were purposively selected and included: fifteen individuals who were regularly engaged in the ganyu labour market as labourers; two medium scale (with over 10 hectares of land) tobacco producers who regularly hired in ganyu; five medium scale (with over 10 hectares of land) food crop farmers who regularly hired in casual ganyu workers on their farms; one volunteer health worker and one government health surveillance personnel; one teacher from the local primary school; and the village chief.

3.6.5 Methods of analysis

In the first instance, we adopted a descriptive analysis approach to explain the sample distribution and other key characteristics. For the analysis, we used both the SPSS and STATA statistical software. The descriptive statistics against which we calibrate and validate the set of base models are elaborated in chapters 4 and 5.

Next, we set up the non-linear programming farm household model using the General Algebraic Modelling System (GAMS) software. We use the parameter coefficients estimated from the LSMS-IHS3 data and from other data sources to calibrate the models. A detailed explanation of the models' calibration and validation procedure is presented in chapter 5.

3.7 Data limitations and attempts to overcome them

In quantitative research, availability of data that covers all the livelihood variables is often challenging, often so with large sets of multi-purpose secondary data. In the current analysis, the use of the LSMS-IHS3 data set presented a few difficulties as regards to the scope of data collected and the quality of some of that data. Some of the information on some key variables required for our modelling purposes was either completely omitted or scanty in the LSMS-IHS3 data set.

One key omission for our purposes relates to the pre-seasonal stocks of maize grain and cash, two of the key resources affecting the options open to rural households and their ability to meet consumption expenditure requirements at the start of the period under analysis. The limitation is intensified by the lack of a panel data source with information on the previous season's stock of cash and maize grain that is carried over to the first seasonal period of the following cropping year.

A simple explanation to the lack of information on cash stocks is the difficulty with which data on cash resources is gathered due to the sensitivity surrounding such information. However, there have been many surveys that have successfully gathered such information.

Second, for the estimation of the linear expenditure system utility function, the LSMS-IHS3 data on consumption and expenditure was only sufficient to compute the marginal propensities to consume staples and cash, but not for leisure. Information on households' saving was also omitted and therefore we could not compute the marginal propensity to save.

Third, information on plot sizes was gathered by both farmers' estimates or measured using the Global Positioning System (GPS). However, our inspection of the data showed significant discrepancies between the two measurements. Our concerns for the large variation between the farmers' and GPS estimates are resolved by use of the

OLS regression analysis to investigate the relationship between the GPS measurements and the farmers' estimates of the plot areas.

The GPS measurements per hectare (dependents variable) are regressed against a farmers' estimates per hectare in a linear quadratic function. We find that the farmers' estimated plot areas were marginally greater than the GPS measurements, and the bias decrease with increased plot size. Equation 3.5 illustrates the linear regressing analysis where Y is the GPS measurement per hectare, X and X^2 respectively are the farmers' plot area estimate and plot area estimate squared per hectare. We use the equation to estimate the bias adjusted plot areas.

$$Y = 0.108 + (0.74)\,X - (0.06)\,X^2 \qquad (3.5)$$

An explanation as regards to the derivation of opening cash and maize stocks, and the marginal propensities to consume staples and cash, parameters that are used in the calibration of the base models of the different types of households, is presented in chapter 5.

Chapter 4: Morbidity, labour use and rural agricultural livelihoods: A descriptive analysis of the interactions between health and agricultural labour utilisation in rural Malawi

4.1 Introduction

This chapter provides survey-based evidence on the livelihoods of rural households in the Kasungu-Lilongwe Livelihood zone in Malawi and on interactions between the consequences of ill-health and labour use in agriculture. In this analysis, we use data from the LSMS-IHS3 for Malawi. A detailed description of the data set is presented in chapter 3.

The chapter's main goals include: (1) to describe a typology of rural Malawian households depicting different livelihood strategies and resource endowments (section 4.2); (2) to describe the demographic and socio-economic characteristics of the different types of poor rural households (section 4.3); (3) to examine the utilisation and allocation of time to on-farm and off-farm activities, and highlight the demand side constraints to off-farm labour in the Malawian rural economy (section 4.4) ; and (4) to investigate the incidence of morbidity and the effects of the different dimensions of morbidity (acute and chronic illness, and body functions impairments) in terms of the productive time lost to ill-health and caring (disability days), and the monetary expenditure incurred in health care payments. Further, we determine the interactions between the consequences of ill-health and agricultural labour use (section 4.5).

The analysis presented in this chapter is important as the precursor to generating a comprehensive understanding of the linkages between health and agriculture, and consequently the differential impacts of morbidity on the livelihoods of different types of rural households in the subsequent chapters. In addition, we use the parameter estimates generated from the descriptive analysis to calibrate and validate the non-linear programming simulation models that investigate the welfare impacts of morbidity among poor farm households in chapters 5 and 6. This chapter therefore contributes to the study as follows:

(1) By using a typology of poor rural agricultural households with different resource endowments and splitting up the cropping year into shorter seasonal periods, we develop a heterogeneous and seasonal model of rural Malawian

farm households in chapter 3. Such a model enables the simulation and the determination of detailed differential households' responses to the effects of morbidity occurring at different seasonal periods, and the subsequent welfare impacts chapters 5 and 6.

(2) We use the parameter estimates on the loss of households' productive labour days due to ill-health and caring time and the health care expenditures incurred in dealing with the consequences of morbidity to create bench marks for cash and labour losses in the estimation of the base programming models in chapter 5, and the subsequent simulation models of the effects on ill-health on livelihoods in chapter 6.

4.2 Development of a typology of rural Malawian smallholder households using the cluster analysis approach

4.2.1 An overview of households' classification

The key objective of this study is to determine the welfare impacts of morbidity on different types of poor rural households with varying resource endowments and other poverty characteristics. To begin with, we recognise that the subjects of the analysis, the poor rural smallholders in Malawi, are not a homogenous group, and have differing constraints, resources and capacities to respond to opportunities and shocks. As such, we adopt a typology of rural Malawian households that classifies the households into a number of groups (clusters) that are not only meaningful, but also credible for simultaneous analysis in a single whole farm household model framework.

Development of conceptually meaningful groups of objects (or clusters) requires that the objects within a group are similar or related to one another, but different from objects in the other groups (Tan, Steinbach, and Kumar 2005). An important requirement of the typology used in this study therefore is the grouping of households that face similar opportunities and constraints, or those that have characteristics (e.g. behavioural and welfare/or economic characteristics) that indicate a consistent pattern of variation suitable for classification.

Before clustering households, a modeller must choose the variables on which the groups should be similar. For example, classification of households in previous literature in Malawi has been on the basis of landholding size (Simler 1994; S. T.

Holden 2014; Brown, Reutlinger, and Thomson 1996), on the gender of the head of household (S. T. Holden 2014), on households' economic status and livelihood strategies (e.g. Brown, Reutlinger and Thomson 1996), on agro-ecological/geographical and livelihood zones (A. Dorward 2002; A. Dorward 2012; A. Dorward et al. 2004; A. Dorward 1994; A. Dorward 2006; A. R. Dorward 1996; A. Dorward and Parton 1997), and also on a combination of key distinguishing behavioural, geographical, livelihood opportunities and resource endowments characteristics (see Dorward 2002; Dorward 2012; Dorward et al. 2004; Dorward 1994; Dorward 2006; Dorward 1996; Dorward and Parton 1997).

On his part, Simler (1994) attempted to classify farm households across all of Malawi, and concluded that landholding size was the best measure to describe the potential of households to respond to on-farm and off-farm opportunities of employment in different areas. The author proposed a system with three different classes of farms in four agroecological regions of Malawi. He described a farm with more than 1.5 hectares of land as 'emerging surplus smallholders', those with 1 to 1.5 hectares were described as "subsistence smallholders, while farm holdings of less than 1 hectare were described as "food deficit smallholders". In their analysis of the role of markets in households' food security, Brown, Reutlinger, and Thomson (1996) classified food insecure households in Malawi into three broad categories which included "smallholders", "estate workers or tenant" and the "urban poor".

A. Dorward (2002) goes further in his classification and uses cluster analysis to develop a typology of Malawian households based on a number of characteristics which include literacy and gender of the head of household, remittance income, dependency ratio, estimated stock of maize after harvest and sales, cultivated area of land per household member, asset holdings, value of loans, and income from employment, excluding casual labour.

In his analysis, Dorward (A. Dorward 2002) highlights some key aspects to consider in typology development, to make them relevant for policy analysis or examination of the impacts of external shocks. He notes that a typology should: generate a manageable number of types to include in a model; relate to variables that are of interest to the modeller (e.g. changes in availability of labour and cash resources, policy change); be linked to differences between geographical locations as regards to agroecology where the subjects are located in different localities; and relate to the broad typologies that are used by policy makers.

Similar to A. Dorward (2002), we recognise the existence of diversity among poor rural Malawian households in resource endowments and livelihood strategies, and adapt a typology of poor rural households based on a number of key observable distinguishing characteristics. A detailed explanation of the clustering procedure and the resulting clusters of poor rural households is presented in section 4.2.2.

4.2.2 Cluster analysis

The term cluster analysis incorporates a number of different algorithms and methods for grouping objects of similar kind into meaningful clusters or homogenous groups. The technique works by minimising the distance from the cluster mean of the objects within a cluster, while maximising the difference between clusters (Norusis and SPSS 2011; Tan, Steinbach, and Kumar 2005).

In his study of rural agricultural livelihoods in Malawi, A. Dorward (2002) adopted the cluster analysis approach to classify poor rural farm households. In its use however, the author cautions modellers to not expect the data to present clearly defined or discontinuous clusters of households due to the variable nature of rural households. Rather, he advises that users of the technique should aim at finding meaningful clusters of households that differ across a number of continuous variables. The modeler should therefore be careful in choosing the appropriate variables to achieve the differentiation.

In the current study, we use a typology of rural Malawian households developed by Andrew Dorward using the cluster analysis approach[1]. The technique was chosen because of its flexibility and adaptability in the development of typologies of rural agricultural households.

The typology of rural households was developed using LSMS-IHS3 data and the K-mean cluster analysis technique in the Statistical Package for the Social Sciences

[1] Andrew Dorward performed the classification of poor rural households in Malawi using the LSMS-IHS3 data for his own additional and unpublished research. In this section, I report the procedure that Andrew followed.

(SPSS). The cluster analysis approach was used to identify groups of individual poor rural households that were different in some key identifying variables.

A. Dorward (2002), Norusis and SPSS (2011) and Tan, Steinbach, and Kumar (2005) provide guidelines to the development of homogenous groups. According to the authors, the cluster analysis procedure starts with a number of cases (e.g. households) which the modeller aims to subdivide into a limited number of relatively homogenous clusters. To identify the patterns of variation across the sample, the analysis followed the following stages:

1) The identification of key variables for measuring differences and similarities between groups in the clustering procedure

In our clustering procedure, all households were geographically located in a single livelihood zone, the Kasungu-Lilongwe Livelihood zone (see MVAC and SADC FANR Vulnerability Assessment committee 2005 for livelihoods zones in Malawi), and no reference to geographical and agroecological differences is made in the classification.

The conceptual foundation of Andrew's typology was based on the variations in livelihood strategies resulting from differences in: per capita area cropped in the main rainy season (Ha); per capita area cropped in the wet lands (*dimbas*) during the dry season; per capita asset index of asset holdings such as chicken, sheep and goats, pigs, radio, bicycle and ox-cart; gender and literacy levels of the head of household (highest level of qualification); ownership of a non-farm business enterprise; per capita value of remittances and other non-farm and non-employment income; number of persons per household in regular non own-farm and non-ganyu (semi) skilled employment; value of loans per household member; distance to the nearest tarmac road and Agricultural Development and Marketing Corporation (ADMARC) facility to describe local market access; and the age dependency ratio.

Table 4.1 presents a summary of the key variables used in the classification of households. The variables were estimated directly from the LSMS-IHS3 data. Per capita asset wealth index was calculated using scores for the selected group of assets. The asset scores were adopted from A. Dorward (2002) as follows: 2 for chickens and other fowl; 9 for goats, sheep and pigs each; 7 for radio; 12 for bicycle; and 20 for oxcart.

2) Construction, standardization and weighting of the selected key variables

Where variables are measured on different scales, variables measured in large values contribute more to the distance (differences) measure used for clustering purposes than variables measured in small values. In SPSS, therefore, the variables are standardised by computing standardized scores or dividing by the standard deviation, range, mean or maximum. This results in all variables contributing more equally to the distance or similarity between cases.

In Andrew's classification, variables were measured in both a continuous and binary discrete scale. To allow the use of both continuous and binary variables in the clustering procedure and reduce the variations in estimates, the classification variables were standardised by dividing the variable measurements by the range, using a standardization procedure illustrated by Equation 4.1, and described further in A. Dorward (2002).

$$S_j \text{ (normalized)} = (X_{ik} - \min X_{jk}) / R_k \text{ (max-min)} \quad (4.1)$$

where S_j = the distance measure between cases *i* and *j* on variable *k*, and R*k* is the range of observations for variable *k*.

All classification variables were standardised to a range of 0 to 1 with the exception of binary variables which were coded 1 to 2. Implicitly, the binary variables have a higher weighting than the continuous variables as they have all the observations at both extremes of their distribution (1 and 2).

3) Decision on the clustering procedure

In SPSS, there are three data clustering procedures suited for different types of data: hierarchical cluster analysis, K-means cluster, and two-step cluster (Norusis and SPSS 2011).

Hierarchical cluster analysis is appropriate when the data set is small in size and the number of clusters is not predetermined, and hence the modeller needs to examine emerging solutions with increasing numbers of clusters. Basically, one can have as many clusters as the number of cases, and at successive runs, similar clusters are merged depending on the characteristics until the modeller finds a solution that has a reasonable number of fairly homogenous clusters (Norusis and SPSS 2011). Determination of the number of clusters that represent the data after careful examination of emerging patterns is therefore the last step.

The two-step clustering procedure is used in large data sets to make large problems tractable or where the variables for establishing the clusters are a mixture of continuous and categorical variables. In the first step, the cases or observations are assigned to pre-clusters. The pre-clusters are then clustered using the hierarchical clustering algorithm in the second step. In this procedure, the number of clusters may be specified or left to the algorithm to decide based on a preselected criterion.

K-means clustering, is used with moderately sized data sets and the number of clusters intended is predetermined. In this algorithm, K denotes the number of clusters. The algorithm iteratively estimates the cluster means and assigns each case to the cluster for which its distance to the cluster mean is the smallest. In this procedure, a case can move from cluster to cluster during the analysis until the most suitable cluster is found, and the cases are assigned to their permanent clusters. This technique was appropriate in the current analysis because of the moderate size of the sample, and because variables are presented in both continuous and categorical forms. In addition, the number of types of households was predetermined based on the limited alternative livelihood strategies and from previous literature on clustering of rural Malawian households (see A. Dorward 2002; A. Dorward 2003; A. Dorward et al. 2004).

4) Critical examination of the patterns of variation with different numbers of clusters and different variables and construction of a credible classification system

In the current classification of poor rural farm households in the Kasungu-Lilongwe Livelihood zone, Andrew identified the key variables that determine the classification to include landholding size, asset holdings, gender and education of the head of household, dependency ratio, access to credit, non-farm sources of income (such as remittances, income from non-farm business enterprises and from employment of skilled and semi-skilled labour), and market variables such as distance to tarmac road and markets.

The results of the classification were compatible with Andrew's previous attempts to classify rural households in Malawi (see A. Dorward 2002; A. Dorward 2003; A. Dorward et al. 2004). After successive runs with different number of clusters and variables, seven clusters, and which Andrew felt they were appropriate given the limited alternative livelihood strategies available in the Kasungu-Lilongwe Livelihood zone were developed.

The seven clusters of households were as follows: (1) “dimba” classified based on crop production activities in the wetlands (*dimbas*) during the dry season. *Dimbas* are areas that have residual moisture, usually in the valley bottoms, and are used for growing crops under small-scale irrigation; (2) “poor female headed” classified on the gender of the head of household; (3) “employed” classified on the number of employed skilled and semi-skilled persons in a household; (4) “non-farm enterprises” classified on the basis of ownership of a business enterprise; (6) “remittances and other income” grouped by the receipt of income from remittances and other non-farm and non-employment sources. These households received cash or in-kind transfers from sources such as relatives, social cash transfer programmes and from non-agricultural sources such as rental property; (6) “credit” classified on the value of loans; and (7) “poor male headed” whose classification was on the gender of the head of household.

The resulting classification of households presented distinct groups of poor rural households with differences in endowment of financial, physical and human capital resources.

Table 4.1: Variables used in the cluster analysis

Type of household	Main season (Ha/pp)	Dimba (Ha/pp)	Remittance (MK/pp)	Credit (MK/pp)	Skilled (pp/hh)	Education (years)	Tarmac road (Metres)	ADMARC (Metres)	Gender (1=Male 2=female)	Business (1=Yes 2=No)	Asset index	Dependency ratio	Sample
	Classification Variables												
Dimba	0.44	0.83	0.20	0.05	0.01	0.82	0.57	0.38	1.00	1.99	0.26	0.79	140
Poor female headed	0.30	0.09	0.25	0.07	0.02	0.73	0.40	0.42	1.99	1.97	0.11	0.84	171
Employed	0.35	0.09	0.18	0.04	1.00	1.17	0.33	0.40	1.02	1.94	0.21	0.71	166
Non-farm Enterprises	0.43	0.16	0.04	0.17	0.06	0.83	0.45	0.40	1.06	1.00	0.27	0.74	177
Remittances & other income	0.55	0.11	0.97	0.21	0.08	1.03	0.38	0.47	1.02	1.64	0.39	0.68	141
Credit	0.47	0.11	0.12	0.96	0.19	1.01	0.39	0.39	1.00	1.97	0.26	0.68	100
Poor male headed	0.40	0.02	0.04	0.02	0.00	0.85	0.44	0.42	1.00	1.99	0.22	0.72	553
Total	0.41	0.15	0.19	0.13	0.15	0.89	0.43	0.41	1.13	1.82	0.23	0.74	1448

Notes: Results presents the standardised estimates of the classification variables used in the cluster analysis. Variables are standardised to a range of 0 to 1, with the exception of binary variables which are coded 1 and 2. “MK” denotes Malawi Kwacha, “pp” is per person and “hh” is household.

4.3 Demographic and socio-economic characteristics of the different types of poor rural households

In this section, we provide an overview of the characteristics of the different types of households. Table 4.2 presents summary statistics of households' characteristics. The total sample comprised of 1,448 households that are unevenly distributed across the different groups of households. The "poor male headed" type of household is the largest group comprising of 38% of the sample. Households classified as "credit" due to their borrowing patterns in the year preceding the survey make only 6.9% of the sample. In rural Malawi, access to credit is constrained by missing or imperfect credit markets and a lack of collateral among poor rural households (A. Dorward 2012). In our analysis, we find that borrowing is largely from informal sources such as friends, relatives and from informal saving clubs.

The total number of persons in the sample is 7,344. Of these, adult males and females aged 15 and 64 years constitute 24.4% and 24.5% of the sample respectively. Elderly persons aged 65 years and above make up 2.5%, while children aged between 5-14 years and infants under five years of age constitute of 31.3% and 17.4% of the sample, respectively. The distribution of the sample is fairly comparable to the World Bank estimates of Malawi's age composition which comprises persons aged between 0-14 years (45%), between 15-65 years (51%), and those above the age of 65 years make up 3% of the population (World Bank 2015).

The landholding per household is approximately 1 hectare, with relatively smaller holding among the "poor female headed" households (0.7 Ha). Better to do households such as the "remittances and other income" have slightly higher land holdings (1.2 Ha), implying possible causality between landholdings and economic status. Landholdings among the "dimba", "employed", "non-farm enterprise", "credit" and "poor male headed", are fairly similar.

Generally, other than the "poor female headed", all other types of households are male headed. In Malawi, a patriarchal system largely exists and male spouses are often considered as the head of the household. The demise of a male spouse or break down of a marriage normally elevates the female spouse into the role. The head of household in the "poor female headed" is either widowed, divorced or separated from their spouses, and with an average age of 46 years, above the sample's average age of 40 years.

The literacy level of the head of the household is represented by four levels of formal education. These include; no education, primary school education, secondary school education, and university and other tertiary institutions level of education. Overall, 79% of the heads of households attained primary education, and only 20% had attained secondary level of education and above, thus implying low levels of adult literacy. The United Nations (UN) estimates that only approximately 11% and 22% of adult females and males above 25 years of age, respectively, have attained secondary education in Malawi (United Nations Development Programme (UNDP) 2015).

To examine the composition of persons within households, household members are classified on the basis of their age, gender and active engagement in a skilled primary occupation in the year before the survey. For classification based on skills, we define skilled and semi-skilled occupations as the formal salaried or commission-based employment (e.g. in the public and private sectors) and the informal and non-agricultural wage or in-kind payment-based employment to perform activities that require special training or skills (e.g. plumbing, carpentry, basketry, hair dressing, brick making and masonry among others). The definition excludes households' owned business enterprises and informal casual work, which is often agricultural and referred to as ganyu in rural Malawi.

Ganyu describes a variety of temporary informal casual off-farm work done by rural people. It includes informal engagements of varying lengths of time, which may be calculated on a piece-work or daily wage rate, and remuneration may be in cash or in-kind (such as food) (Whiteside 2000). Ganyu workers may include relatives, neighbours, or smallholders from further afield working in medium and larger estates.

In our classification of household members, seven types of persons are specified. These include: skilled adult males; unskilled adult males; skilled adult females; unskilled adult females; children; infants; and the elderly. On average, there are five persons per household.

We further calculate the size of household by adult equivalents, where each member counts as a fraction of an adult male to adjust for age and economies of scale in consumption (L. C. Smith and Subandoro 2007). To this end, we use the Organisation for Economic Co-operation and Development (OECD) scale adopted in many of the World Bank's LSMS data analysis (Haughton and Khandker 2009). Our findings show that they are four adult equivalents per household. Notably, there is a general lack of (semi) skilled adult males and females in all types of households, with the exception of the "employed" group with at least a single skilled adult male on average.

Overall, the sample's average dependency ratio is 1.2. We compute the dependency ratio by dividing the number of dependants (children, infants and the elderly) by the number of working age persons (adult males and adult females). Across the households, we find that households in the "poor female headed" group have the highest dependency ratio (1.7), and thus the working members support more dependants. In Malawi, the World Bank estimates that in 2014, the proportion of dependents per 100 working-age population was 95%. In addition, the country's dependency ratio figures indicate that the young (0-14 years) and the old (65 and above years) as a percentage of working age population were 89% and 7% respectively (World Bank 2015).

Table 4.2: Characteristics of different types of rural farm households in Malawi

	Type of Household							
Variable	Dimba	Poor female headed	Employed	Non-farm enterprise	Remittance & other income	Credit	Poor male headed	Total
Sample (n)	140	171	166	177	141	100	553	1448
Frequency (%)	9.7	11.8	11.5	12.2	9.7	6.9	38.2	100
Mean land holding (Ha/ household)	1.1	0.7	0.9	1.0	1.2	1.1	1.0	1.0
Head Characteristics								
Gender (% Male headed)	100	0	98	93	97	100	100	87
Mean age	40	46	39	37	47	38	38	40
Education Level (% within type of household)								
1. None	0	1	0	0	0	0	0	0
2. Primary	87	93	52	85	67	67	85	79
3. Secondary	13	6	40	15	31	29	15	19
4. Tertiary	0	0	8	1	1	4	0	1
Marital status (% within type of household)								
1. Monogamy	87	8	86	78	87	84	87	76
2. Polygamy	12	5	7	12	9	12	8	9
3. Separated	0	19	2	2	0.7	2	0.7	3
4. Divorced	0.7	28	1	4	0.7	2	2	5
5. Widowed	0.7	37	4	2	1	0	0.9	6
6. Never married	0.7	1	0.6	1	1	0	1	1
Household composition per household (Mean)								
Skilled adult males	0.0	0.0	0.5	0.1	0.0	0.1	0.0	0.1
Unskilled adult males	1.3	0.5	0.8	1.2	1.5	1.4	1.3	1.2
Skilled adult females	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Unskilled adult females	1.2	1.2	1.2	1.3	1.4	1.2	1.2	1.2
All adult males	1.3	0.5	1.3	1.3	1.5	1.5	1.3	1.2
All adult females	1.2	1.2	1.3	1.3	1.4	1.3	1.2	1.2
Children	2.0	1.4	1.7	1.7	1.7	1.6	1.5	1.6
Infants	1.0	0.7	0.8	1.0	0.0	0.9	0.9	0.9
Elderly	0.2	0.3	0.1	0.1	0.3	0.0	0.1	0.1
Household size (Mean)								
Persons	5.6	4.2	5.2	5.4	5.5	5.3	5.0	5.1
Adult equivalents	4.5	3.3	4.2	4.3	4.7	4.4	4.0	4.1
Dependency ratio (Mean)	1.3	1.7	1.1	1.2	1.0	1.0	1.1	1.2

Source: LSMS-IHS3 survey estimates

In Figure 4.1, we illustrate the value of physical assets, including durable assets for home use, farm implements and livestock structures, owned by households over a one-year reference period. The findings demonstrate that household in the "poor female headed" group have the least amount of assets valued at about MK 1,800 (US$ 12). Similarly, households in the "poor male headed" group are relatively poor compared to the better to do households such as the "remittances & other income" and the "employed" type of households who hold above MK 16,000 (US$ 107) in physical assets. Across the household types, the median value of assets is MK 9,400 (US$ 63), indicating that the households are relatively asset poor and thus a limited ability to use assets to mitigate against the effects of external shocks.

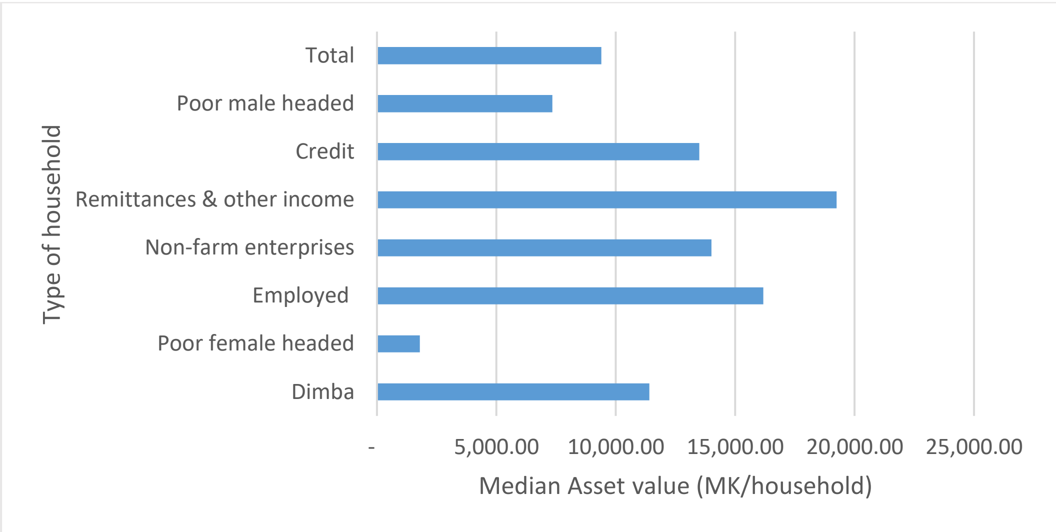

Figure 4:1 Value of physical assets holdings by the type of household

Table 4.3 examines ownership of livestock. The first row shows the proportion of households in each group of households that owned at least an animal. We find that apart from the "poor female headed" group, livestock ownership in all other groups of households is over 50%. The proportion of households owning livestock is highest among the "credit" and "remittances and other income" types of households, implying that there is a causal relationship between economic status and investment in alternative livelihood strategies such as livestock production.

Chickens are most common type of livestock across all types on households, and households kept seven birds on average. Overall, there is low level of investment in livestock among the poor rural households in Malawi, possibly related to the lack of cash to buy animals, small landholdings incapable of holding large animals and lack of pastures. As a consequence, households' ability to cope with shocks, which is often reflected both by asset portfolio and intangible social resources (Asenso-Okyere, Chiang, Thangata, and S.Andam 2011), may be diminished.

Table 4.3: Ownership of livestock

Variable	Dimba	Poor female headed	Employed	Non-farm enterprises	Remittances & other income	Credit	Poor male headed	Total
% within household types	56	40	53	59	72	73	57	57
Cattle	1	0	0	0	3	0	0	1
Sheep and goats	3	2	2	2	4	2	2	2
Chicken	9	5	8	8	9	7	7	7
Other Fowl	0	0	0	0	0	0	0	0
Pigs	1	0	0	1	1	1	1	1

Source: LSMS-IHS3 survey estimates

In Table 4.4, we summarise the consumption expenditure per adult equivalent, categorised by expenditure on staple food, non-staples and non-food items across household groups. The last column of the table shows the daily per capita total expenditure is USD. In the estimation of expenditure on food and non-food items, we use information gathered over a 7 days' recall period in the LSMS-IHS3 data. Data on some non-food items was gathered over a one month to twelve months' recall period. Food from own production or gifts is valued at the local purchase price.

Across the household groups, the findings show little variations on households' per capita consumption of staples (cereals, legumes, and root and tuber crops). They are however considerable variations on spending non-staple and non-food items with the poorer households, the "dimba", "poor female headed" and "poor male headed" spending less than MK 40 (US$ 0.3) per person per day on non-staple foods and less than MK 16 (US$ 0.1) on non-food items.

In each type of household, the total daily per capita consumption expenditure is below the international poverty line of US$ 1.25 per person per day. Moreover, the poorer groups of households' consumption level is below the Malawi national poverty line which defines poor households as those with an annual per capita consumption below

MK 37,002 (approximately US$ 0.66 per person per day) (National Statistical Office (NSO) 2012a).

The poorer household groups, the "dimba", "poor female headed" and "poor male headed" households constitute 60% of the sample, and as our results show, their level of consumption is below the minimum level deemed adequate for Malawi.

Table 4.4: Per capita daily consumption expenditure on food and non-food items across household types

Type of household	Per capita daily consumption expenditure (MK/person/day))				
	Staples	Non-staple food	Non-food items	Total expenditure	Total expenditure (US$)
Dimba	28.46	37.26	13.96	79.68	0.53
Poor female headed	37.67	32.67	12.5	82.85	0.55
Employed	37.61	58.81	26.77	123.19	0.82
Non-farm enterprises	40.82	62.99	23.62	127.43	0.85
Remittances & other income	37.06	59.78	25.05	121.9	0.81
Credit	36.17	47.51	25.59	109.27	0.73
Poor male headed	32.42	38.47	15.63	86.52	0.58
Sample	35.71	44.91	18.13	98.76	0.66

Source: LSM-IHS3 survey estimates

Our analysis further explores the share of the total annual households' expenditure that is used on health care. A key objective of this study is to determine the welfare impacts of ill health, and as such, we use the LSMS-IHS3 data to determine households' spending on health care. We find that while over 60% of the households' total annual expenditure is spent on food and beverages, spending on health care is only 2% or less of the total annual expenditure across all groups of households. The low level of spending on health care is not entirely unexpected. First, health care in Malawi is government funded and provided free at the point of delivery, but there are also private health care facilities (M. L. Wilson et al. 2012).

Second, distance to the nearest health care facility is relatively high in rural Malawi. On average, our analysis of the LSMS-IHS3 data shows that the distance from the community dwellings to the nearest village health clinic (referred to as *chipatalala* in local dialect) is 8.5 Km. Distance to higher level medical facility with a qualified doctor is 22.5 Km away. Village level health facilities are usually without a qualified medical doctor and are staffed with a medical assistant, nurse and a midwife. For more serious conditions, patients are referred to a higher level medical facility. Patients therefore cover long distances and since there are to transport subsidies, transport costs are likely to be large due to the poor road infrastructure, and may constitute a barrier to care seeking in all but very severe cases.

Third, previous literature has found a causal relationship between poverty and access to health care, with evidence that people in poor countries have reduced access to health services compared with developed countries, and within countries, the poorer have less access to health services (D. H. Peters et al. 2008), shorter life expectancy and greater risk of disease (Wilkinson and Marmot 2003).

Inequalities in seeking or accessing health care are therefore influenced by socioeconomic status, which may in turn lead to poorer health outcomes and reduced ability to work. As Wagstaff (2002) notes, the linkage between poverty and health can be described as cyclic, where poverty leads to ill-health and ill-health exacerbates poverty.

In our analysis, we therefore conclude that the low spending on health care is not only as a result of the free government health care, but also because the poor are less likely to seek or purchase health services, unless the illness is severe or they have cash in hand to meet the out-of-pocket payments for medical and non-medical expenses such as transportation costs.

In Table 4.5, we summarise the average area cropped with the major crops in the Kasungu-Lilongwe Plain (KAS) Livelihood zone using the LSMS-IHS3 data. The crops which are also incorporated in the programming models of farm households in the subsequent chapters include local and improved varieties of maize, tobacco (burley tobacco), groundnuts, soybeans, cassava, beans and sweet potatoes. For the estimation of the average area cropped, the summaries include only crops cultivated in pure stand fields due to unreliability of information on area cropped in mixed stand fields. Data was collected for the past complete main cropping season. Depending on the date a household was interviewed, the main rainy season under consideration is either 2008/2009 or 2009/2010.

In the Kasungu-Lilongwe Plain, the primary food crop is maize while tobacco is the major cash crop (MVAC and SADC FANR Vulnerability Assessment committee

2005). Tobacco, sweet potatoes, groundnuts and soybeans are largely monocropped, while maize is often intercropped with either beans or cassava.

The findings show that across the household types, nearly equal amount of land is allocated to local and hybrid maize varieties in the main cropping season, and all the sample observations produced maize, either hybrid maize (50%), local maize (54%) or both. Access to improved maize varieties through the farm inputs subsidy program that is targeted towards the poorest and the most vulnerable, would be a probable cause for the adoption of hybrid maize. There is also little variation in the mean area under maize production across household types.

Tobacco and groundnuts are the other two important crops produced by 43% and 45% of the sample, respectively. As expected, the "poor female headed" and "poor male headed" groups, who are often cash constrained allocate the least amount of land to tobacco which is both labour and capital intensive. There is however little variation across the household groups in the amount of land allocated to groundnuts. Beans and sweet potatoes appear to be minor crops produced by less than 4% of the sample each.

Table 4.5: Average amount of land cultivate under monocropped systems

Type of household	local maize		Hybrid maize		Tobacco		Groundnuts		Soybeans		Beans		Sweet potatoes	
	count	mean	count	mean	count	mean	count	mean	count	mean	count	mean	count	mean
Dimba	75	0.52	83	0.52	77	0.42	73	0.34	15	0.37	0		10	0.28
Poor female head	106	0.45	64	0.40	33	0.34	75	0.29	24	0.33	3	0.23	5	0.22
Employed	68	0.51	115	0.42	41	0.40	74	0.30	18	0.37	2	0.23	6	0.21
Non-farm enterprise	85	0.48	118	0.50	73	0.43	91	0.33	22	0.35	2	0.33	7	0.61
Remittance	71	0.57	87	0.59	69	0.49	70	0.34	23	0.39	5	0.31	5	0.31
Borrowers	57	0.50	54	0.50	65	0.46	49	0.29	12	0.28	3	0.21	4	0.31
Poor male head	337	0.48	272	0.50	261	0.39	229	0.31	86	0.34	11	0.31	25	0.25
Total	799	0.49	793	0.49	619	0.42	661	0.31	200	0.35	26	0.28	62	0.30

Source: LSMS-IHS3 survey estimates

4.4. Households' time utilisation and allocation to on-farm and off-farm activities

4.4.1 Construction of time utilization variables and data

In this section, we examine the sample households' patterns of allocation of available time from a micro-economic perspective, making use of LSMS-IHS3 data gathered over a one-week recall period. The findings are presented either as mean or medium estimates. The choice between the mean or the median depends on the quality of data for the variable in question. In summaries where we have concerns of outlying measurement that are likely to distort the data symmetry, we use the median measurement.

The activities under consideration in the analysis include domestic chores, on-farm and off-farm activities. Data gathered on domestic chores include collection of water and firewood, while own farm agricultural activities include both crop and livestock production activities. Off-farm activities include non-farm undertakings such as small business enterprises, employment in a wage, salary, commission or in-kind payment non-agricultural work, and employment in the informal casual ganyu wage labour market.

In Malawi, a large proportion of the population resides in the rural areas and is predominantly dependent on agriculture. However, poor agricultural productivity in small landholdings with depleted soils means that many households are unable to provide an adequate livelihood. Consequently, poverty is both widespread and deep. To close the gap between own production and consumption, households participate in casual off-farm employment, often referred to as ganyu.

In the analysis of time utilisation patterns in this section we begin by calculating the households' seasonal labour supply estimates for the amount of time actively engaged in domestic chores, on-farm and off-farm activities using the information gathered over a 7-days recall period. We do this by aggregating all household members' time allocation to the different activities over seven days, and then extrapolate the aggregated time (hours) over the entire length of the seasonal period that a household was interviewed.

Second, we estimated the households' total labour resources per seasonal period. In this computation, infants are considered non-productive, and children's time is capped at 3 hours per day. The elderly persons are assumed to be moderately active and their daily supply of labour is capped at 4 hours. Adult males and females supply of labour is capped at 7 hours per day.

Third, we examine the inter-household groups and inter-seasonal variation in the proportion of time allocated to on-farm and off-farm opportunities. Section 4.4.2 presents the findings and discussion of the analysis.

4.4.2 Households' time utilisation patterns: results and discussion

Figure 4.2 depicts the share of total households' available time that is allocated to different farm and off-farm activities in each seasonal period. We make the following inferences from the findings. First, as one would expect in rural Malawi, agriculture is dominant and its labour share estimates are highest across all seasonal periods. Allocation of time to own-farm agricultural activities is highest in the peak seasonal periods (November to January), with households allocating 29% of their time to agriculture. During the latter, households would be more inclined to work on their own farms. Allocation of time agriculture steadily declines towards the end of the cropping year as production activities become less labour intensive.

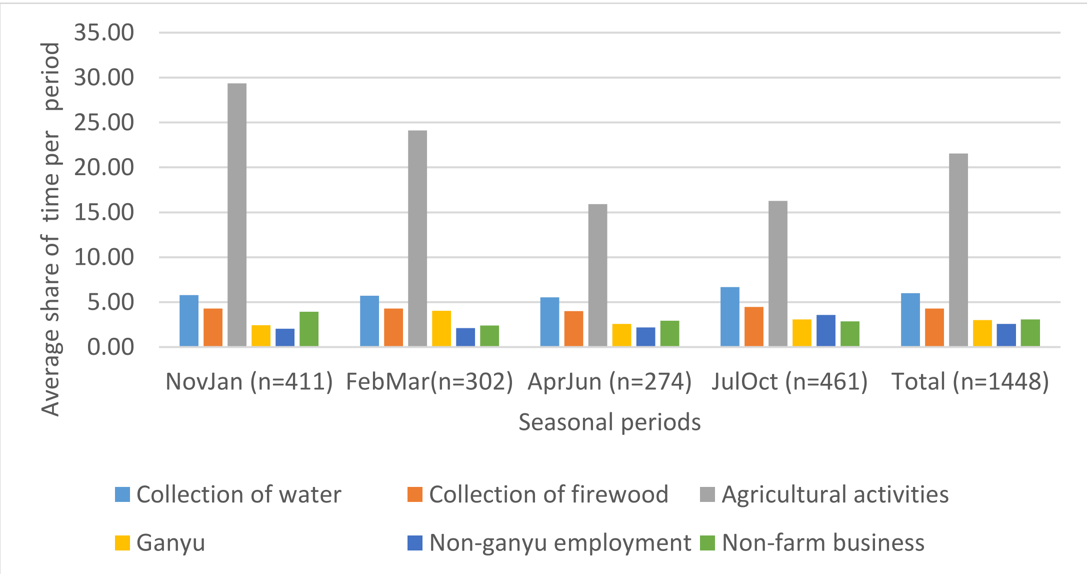

Figure 4:2 Average share of time allocated per seasonal period to different on-farm and off-farm activities

Although the February to March seasonal period is largely off-peak in Malawi and with reduced demand for farm labour, some activities such as late weeding, early harvesting of legumes and green maize and staking of tobacco are often performed. Utilisation of time in agriculture is therefore considerably high particularly for tobacco farmers who cure and bail tobacco for sale at the auction market in April.

Second, allocation of time to domestic activities such as collection of water and firewood is comparatively similar across all seasonal periods. Largely, households used collected firewood as the main source of cooking fuel. Over 85% of the sampled observations collected firewood mainly from unfarmed areas in the community and farmer owned wood lots. On average, households took up to 38 minutes (one way) to their main source of cooking fuel. Water for domestic use is mainly sourced from boreholes as reported by 62% of the observations, and the average time taken, one way, to the main source of water is 14 minutes.

Third, on average, 3% of the total available labour resource in a household was hired out to the informal ganyu labour market. Across the seasonal periods, we observe a marginally higher allocation of households' time to ganyu labour over the February to March seasonal period (4%). In Malawi, the period between February-March is characterised by: low labour demand as the crops are in the growing stages; low ganyu wage rate due to decreased demand for casual farm labour; low food supply as households run out of food stocks; and high food prices resulting from reduced supply of food commodities in the output market. Consequently, the poor and more vulnerable households are more likely to hire out their labour to any available off-farm opportunities irrespective of the low wage rates, in order to meet their immediate consumption needs.

Fourth, on average, only 3% of households' total time is allocated to off-farm opportunities in the ganyu and non-ganyu labour markets each. This may indicate that there are limited opportunities for off-farm employment in rural Malawi, where the economy is mainly agricultural driven and non-agricultural service or industrial sectors are largely non-existent. In addition, our findings on the proportion of households' time allocated to agricultural activities shows that about a third or less of the time available per seasonal period is utilised in agricultural and off-farm opportunities. As a result, households have an abundance of labour due to underemployment on-farm or in the rural off-farm economy.

Due to unavailability of data, our calculation of time utilisation within households does not include time spent on domestic chores such as cooking, child care, and travelling time to own-farm or off-fam activities.

Figure 4.3 illustrates the average share of time allocated to agricultural and off-farm employment across the different types of households. We find that with the exception of the "employed" and the "non-farm enterprises" groups, all other groups of households allocate the largest share of time to agriculture, the primary occupation. For the "employed "and "non-farm enterprises" groups, there is competition for available time for allocation between on-farm and off-farm opportunities such as employment and business enterprises, respectively.

The results in Figure 4.3 further show the "poor female headed" group had the highest allocation of time to the informal ganyu labour (4%) per seasonal period. These households are the poorest as illustrated by their low land and asset holdings. Consequently, they engage in off-farm casual work to meet their immediate consumption needs.

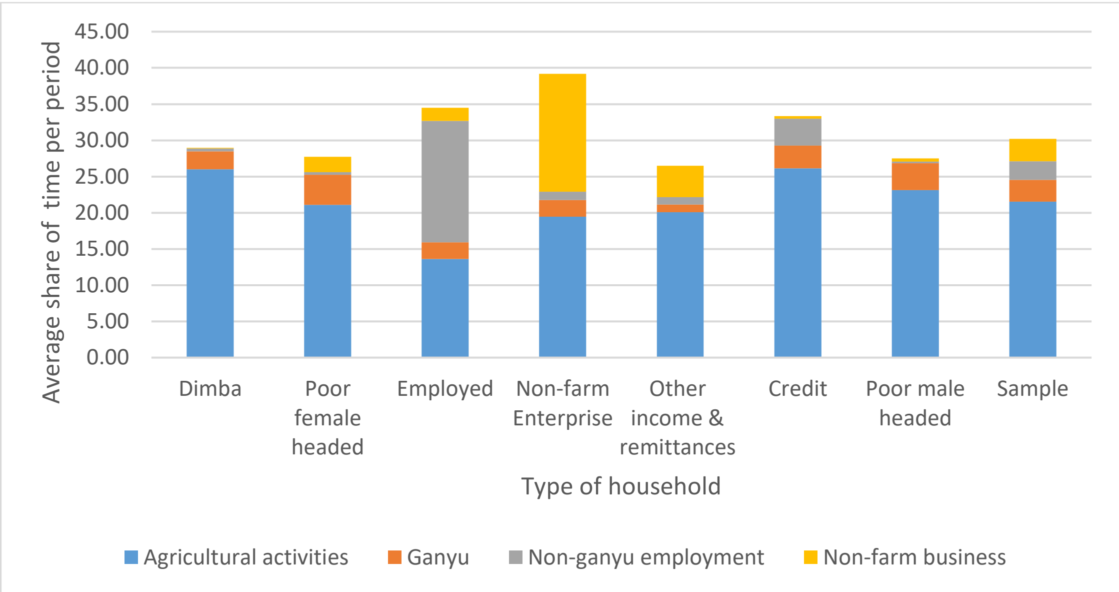

Figure 4:3 Average share of time allocated to agricultural and off-farm activities by type of household

In Figure 4.4, we show the proportion of households that participated in ganyu work in the seven days preceding the interview, within each group of households. We find that nearly a quarter of all household within the "poor female headed", "credit" and “poor male headed” groups participated in ganyu work. As earlier findings show, the “poor female headed” households are multiply deprived with the least land and asset holdings, lowest literacy and highest age dependency ratio (see Table 4.2). Consequently, they are more likely to do ganyu work as a livelihood strategy. Similarly, the “poor male headed” group are also asset poor and with larger family sizes of approximately 5 persons on average. They largely rely on agricultural production for their livelihoods and probably unable to meet their food and cash requirements from agriculture alone.

Despite their ability to access credit, the “credit” type of household also engages in ganyu work, implying the need to finance expenditures and repayment of credit plus interest by hiring out labour.

On the contrary, the better off households with alternative livelihood strategies such as the “remittances and other income”, “non-farm enterprises” and the “employed” have the lowest participation in the ganyu labour market.

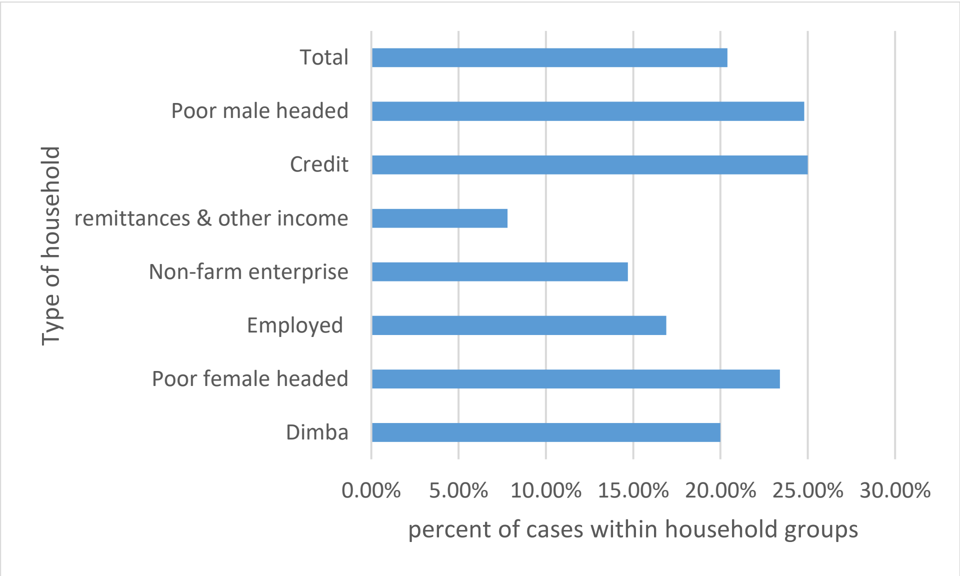

Figure 4:4 The proportion of observations that engaged in ganyu work in the seven days preceding the survey, across types of households

4.5 Health status and rural agricultural livelihoods

4.5.1 Validation of the LSMS-IHS3 data on morbidity

In the gathering of data on the multiple dimensions of morbidity (chronic and acute morbidity, physical disability and functional or activity limitations) in the LSMS-IHS3 data, questions on health status were predominantly self-reported, mainly by a primary respondent, and constructed to have yes or no answer, or a variety of choices.

For acute morbidity, questions were framed as a binary choice question, to establish which member of a household had been ill in the two weeks preceding the survey. A positive response to this questions led to succeeding multiple choice questions on the specific type of illnesses or injury (up to two illnesses were recorded), type of diagnosis (e.g. diagnosis by self or other non-medical personnel or by a medical professional) and actions taken to treat the illness (e.g. no treatment due to lack of money or for non-severe morbidity, treatment using home remedies or medication already in stock, treatment at a government funded or in a private health facility, purchase of medication from a pharmacy or local grocery, and treatment by traditional and faith healers).

In addition, questions on the number of days a person was unable to perform normal duties due to ill-health over a two weeks' period and the associated care days over a similar recall period were recorded at the household member level.

Information on health care expenditure was recorded at member level, and covered the four weeks preceding the interview. Data were collected on costs incurred on consultations fees, medical tests, prescribed medication, in-patient fees, preventative health care, prenatal care and expenditure on non-prescription medicines. Additional information on medical and non-medical costs incurred through overnight stays at a hospital were was also collected over a 12-months recall period.

For chronic morbidity, data was gathered over a 12-months recall period, and included questions chronic illnesses and on body functions impairments such as sight, hearing, mobility, cognition and speech. Only persons aged five and above were enumerated for body function impairments.

As we earlier indicated, all information on morbidity in the LSMS-IHS3 data was self-reported. In larger surveys such as the LSMS-IHS3, high costs and the difficulties often associated with assessing or gathering data on the health of a population using clinical diagnosis often lead researchers to search for indicators of health status that are easy to collect and in a cost-effective way. Kuhn, Rahman, and Menken (2006) argue that measuring health is complex and requires resources such as time, skill, finances, training and logistics. Thus, quick and low-cost measures of assessing the burden of disease such as the use of self- reported indicators of health status are often favoured in many developing countries. However, determining the validity of the self-reported health measurements is important before making inferences from such reports.

In this study, we are cognisant of the fact that responses to questions on self-reported health status could either understate or overstate the extent of health problems. The responses to the health status questions in the LSMS-IHS3 were largely based on self-diagnosis, by respondents who may have had little or no knowledge about acute and chronic morbidity conditions. As a result, their responses may affect the validity of the health status reports, not only because of incorrect diagnosis, but also because of recall bias.

Because of the potential shortcomings of the subjective data on health status, we begin our analysis of the occurrence of morbidity and the interaction between health and agricultural livelihoods by providing an ex-post examination of the survey data on morbidity. Our validation particularly focuses on acute morbidity since additional information on who diagnosed the illness, sources of treatment and loss of productive days due to illness and care was recorded.

Our main goal is to cross-check and carefully examine the interrelationships or the logical consistency between the indicators of acute morbidity.

Specifically, we cross check the occurrence of acute illness and the specific types of illness against; (1) the treatment options sought; (2) the type of diagnosis; (3) loss of productive time; and (4) person groups. The validation aims at identifying plausible interrelationships between variables, and exclude concerns regarding the quality of data.

We begin our data checking process by examining the occurrence of disease within the sample and a summary of the distribution of the 12 commonly occurring acute and chronic illness is presented in Table 4.6. The percentages reported are within the cases affected by each type of morbidity.

Out of the total number persons surveyed in the LSMS-IHS3 data in the Kasungu-Lilongwe Livelihood zone (n=7,344), 19% had positive responses to self-reported acute morbidity in the two weeks preceding the survey. For chronic conditions, 4% of the enumerated persons has a chronic illness, and 8.5% of persons over the age of five years (n=6068) had a body function impairment, in the 12-months preceding the survey. On average, those with chronic illnesses had suffered from them for up to 8 years.

Table 4.6: Samples' distribution of acute and chronic morbidity

Chronic illness type	Number of cases	Percent of Cases	Acute illness type	Number of cases	Percent of Cases
Asthma	53	19.3	Malaria/fever	655	46.3
Epilepsy	47	17.1	Stomach ache	126	8.9
Arthritis/Rheumatism	29	10.5	Flu & cold	114	8.1
HIV/AIDS	25	9.1	Lower respiratory (Chest, lungs)	110	7.8
Stomach disorder	19	6.9	Upper respiratory (sinuses)	81	5.7
High blood pressure	19	6.9	Diarrhoea	57	4.0
Chronic malaria/fever	11	4.0	Headache	50	3.5
Pneumonia	11	4.0	Measles	41	2.9
Mental illness	10	3.6	Skin problems	32	2.3
Tuberculosis	9	3.3	Backache	26	1.8
Sores that don't heal	8	2.9	Wound	24	1.7
Bilharzia/Schost	7	2.5	Dental problems	23	1.6
Heart problems	7	2.5	Sore throat	20	1.4

Source: Calculated from LSMS-IHS3 survey data

We find that out of the total number of persons with a chronic condition in the past year, asthma, epilepsy, arthritis/Rheumatism, HIV /AIDS, stomach disorders and high blood pressure are the top six chronic conditions affecting communities in rural Malawi.

For acute illness, approximately 46% of the total number of persons reporting a short-term illness in the two weeks prior to the survey had malaria or fever, which is endemic in Malawi (Ministry of Health 2011). In the interpretation of our findings, we do take caution because in Malawi, presumptive malaria diagnosis is often used especially in the rural areas lacking laboratory facilities (Lowe, Chirombo, and Tompkins 2013), and hence over-diagnosis of malaria cases can be expected.

For example, in the Malawi malaria indicator survey of 2014, differences in malaria prevalence among children under the age of five years were observed between different diagnostic tests for malaria parasite, the rapid diagnostic test (RDT) and blood smears by microscopy. By using RDT, 37% of children under five years were found to be positive of malaria, while microscopy revealed a lower prevalence rate of 33% (National Malaria Control Program (NMCP) [Malawi] and ICF International 2014), indicating possibility of misdiagnosis of the disease.

Irrespective of the possibility of over reporting, our samples' malaria prevalence rate is slightly above the Malawi's ministry of Health estimated prevalence rate of 43% (Ministry of Health 2011). However, the findings are indicative of the high prevalence of malaria and the implications of the disease on rural agricultural livelihoods. A detailed analysis of malaria prevalence and morbidity effects on rural agricultural livelihoods follows in section 4.5.2.

An examination of the sources of treatment for the self-reported acute morbidity indicates that over half (57%) of the patients sought treatment from a free government funded health facility and nearly a quarter (23%) purchased medicine from the local groceries and pharmacies. Approximately 9% sought treatment from private and church mission health facilities and 6% did not need treatment as the illness was not considered serious. Only 1% of acutely ill persons could not get treatment due to lack of finances, and another 1% sought remedies from traditional or faith healers. The low proportions of persons failing to seek treatment however could be subject to response bias as respondents may not openly admit their inability to seek health care.

Our findings reveal the importance of government facilities in providing free health care to the rural poor as indicated by the high rate of attendance to a government health facility. In Malawi, an Essential Health Package (EHP) is free and government funded (Government of Malawi 2011). Health care is provided at health centres at the local level, regional/rural hospitals one level up, and district hospitals at the highest level. The conditions treatable under the Essential Health Package include: vaccine for preventable diseases; acute respiratory infections; malaria; tuberculosis; sexually transmitted infections including HIV/AIDS; diarrhoeal diseases; schistosomiasis; malnutrition; ear, nose and skin infections; perinatal conditions; and common injuries.

In the cross examination of the relationship between acute morbidity and diagnosis, we observe that 65% of the cases of acute illness were initially diagnosed by non-medical personnel, largely self-diagnosis or by other members of the household, and to a lesser extent by traditional healers. As already indicated, non-medical diagnosis of self-reported poor health may sometimes result in overstated or understated health reports. However, as already noted earlier, over 60% of the reported cases were treated either in a government or private health facility, implying a possible confirmation of the diagnosis by a qualified medical professional.

In Tables A1, A2, A3 and A4 in Appendix A, we demonstrate the relationship between the commonly occurring acute illnesses and the type of treatment sought, type of diagnosis, type of persons infected and loss of productive time due to morbidity, respectively. For the purposes of this examination, we only consider the main acute illness reported, treatment and diagnosis, for persons with more than one type of acute condition.

Table A1 shows that consistent to the expectation that poor households are more likely to seek health care from free health facilities, we find that across the common types of acute illnesses, patients mostly sought treatment from a government health facility for all types of acute morbidity. In Table A2, we find that with the exception of measles, diagnosis of the 12 ranked acute illnesses was initially diagnosed by a non-medical professional, but as earlier noted, there is possible confirmation of the diagnosis on seeking treatment from a health facility.

Table A3 summarises the concentration of the common acute illnesses across different types of persons. We find that generally, incidences of malaria and fever, diarrhoea, flu and colds, and respiratory problems, are highest among children and infants under ten years of age. Our findings on malaria corroborate the World Malaria Report of 2013 findings of higher incidences of malaria in younger age groups (World Health Organisation (WHO) 2013).

In Table A4, we cross examine the inter-relationship between the loss of productive days due to illness among the more productive adult males and females, the type of acute illness and treatment options sought. We find that of the total number of adult males and females who had malaria/fever in the two weeks preceding the interview, 47% sought treatment from a government facility, and lost on average 6 days of productive time. Approximately 36% bought medicine from local groceries and pharmacies and lost on average 4 days, while 8% sought treatment from a private or church mission facility and lost up to 8 days on average. Similarly, half of the adult males and females with stomach and lower respiratory problems were treated at a government health facility and lost up to 5 days of productive work to illness.

Due to the small number of cases across treatment options and type of illness, we cannot make sound conclusions on the variations in the loss of productive time in all other forms of acute morbidity. However, we find that on overall, adult males and females sought treatment from government health facilities, and in the case of malaria, those who sought treatment from a private health facility appear to have the highest loss of productive time. The higher loss of time could be possibly as a result of more severe illness and thereby seeking treatment from facilities that are perceived to be of higher quality.

In the next section, we explore the occurrence of disease, distribution of morbidity across seasonal periods and person types, and expenditure on health care among poor Malawian households.

4.5.2 A descriptive assessment of occurrence and economic burden of morbidity on poor rural households

Like much of the SSA, Malawi faces a growing burden of disease as evidenced by high level of child and adulthood mortality rates, and according to the WHO, the country's epidemiological profile is characterised by: (a) a high prevalence of communicable diseases such as malaria, HIV/AIDs, tuberculosis and other tropical diseases; (b) high incidence of maternal and child health problems; (c) an increasing burden of non-communicable diseases; and (d) resurgence of neglected tropical diseases such as schistosomiasis, lymphatic filariasis, onchocerciasis, human African trypanosomiasis, trachoma, leprosy and soil transmitted helminths (World Health Organisation (WHO) 2009b; World Health Organisation 2014).

We begin this section by highlighting some of the major diseases in Malawi that pose the highest health challenges. These include malaria, HIV/AIDS, tuberculosis and non-communicable diseases.

Worldwide, malaria remains one of the greatest health and development challenge. The disease is endemic in a number of countries but the greatest load of mortality and morbidity due to malaria is borne by the world's poorest economies, most of them in sub-Saharan Africa (SSA).

According to the World Malaria Report 2015, 88% of the cases of malaria occurred in the African region, but globally, incidences of malaria were estimated to have decreased by 37% between 2000 and 2015 (World Health Organisation (WHO) 2015c). Further, the report notes that although malaria deaths are on the decline globally, 90% of the deaths occurred in Africa (World Health Organisation (WHO) 2015c).

Although malaria is no longer a leading cause of death among children in SSA (World Health Organisation (WHO) 2015c), it is still particularly dangerous for children under the age of five years, who have not yet developed partial immunity from the disease, and for pregnant women and their unborn children.

The WHO attributes the reduction in malaria incidence and mortality to the tremendous expansion in the financing and coverage of malaria control programmes that supply medicine, bed nets and information on malaria control (World Health Organisation (WHO) 2013; World Health Organisation (WHO) 2015c).

In Malawi, malaria which is transmitted by the bite of an infected mosquito (*Plasmodium falciparum)*, and causes fever and flu-like symptoms is endemic in more than 95% of the country and is a leading cause of morbidity and mortality in children under five years of age and pregnant women (Government of Malawi 2011; National Malaria Control Program (NMCP) [Malawi] 2005).

In 2014, the government estimated a malaria prevalence of 33% (National Malaria Control Program (NMCP) [Malawi] and ICF International 2014), and according to the World Health Organisation, Malawi has a high malaria transmission rate with over one case per 1000 people in the population (World Health Organisation (WHO) 2015c). The transmission of the disease is perennial and with substantial seasonal variation (Mathanga et al. 2012).

Owing to the high malaria incidence in Malawi, the government embarked on different interventions such as vector control through indoor residual spraying and insecticide-treated nets in a bid to reduce the spread of the disease (Mathanga et al. 2012; Okiro et al. 2013). Mass distribution of free treated bed nets was primarily focused on pregnant women and children under the age of five, who are the high-risk groups in malaria infection.

In addition, the Malawi's Ministry of Health in collaboration with development partners developed the National Malaria Strategic Plan 2011-2016 (NMSP 2011-2016) aimed at decreasing the burden of malaria to a reduced level of public health significance in the country (National Malaria Control Program (NMCP) [Malawi] and ICF International 2014). The strategic plan specifies improved diagnosis, appropriate treatment, integrated vector management, supply chain management, behaviour change, communication and advocacy, and a robust monitoring and surveillance system as key to achieving the control and reduced burden of Malaria (Ministry of Health 2011).

In addition to malaria, high prevalence rates of HIV/AIDs and tuberculosis which is often associated with HIV/AIDS, are major public health problems in Malawi. According to the 2010 Malawi Demographic and Health Survey (DHS), the national adult (aged 15-49 years) HIV/AIDS prevalence was estimated at approximately 11% of the country's population. The prevalence rate was higher among women than men. Overall, 13% of the women and 8% of men were HIV-positive (National Statistical Office (NSO) and ICF Macro 2011). In 2014, the WHO estimated a mortality rate of 42% resulting from HIV/AIDs and TB combined in Malawi (World Health Organisation 2016). However, on a worldwide basis, the 2015 WHO report on TB notes that TB mortality has fallen by 27% since the onset of the millennium development goals in 1990 (World Health Organisation (WHO) 2015a).

Noncommunicable diseases (NCD's) such as hypertension, diabetes, cancers and cardiovascular diseases are also on the increase in Malawi, and the WHO estimates that NCDs account for 28% of total deaths in Malawi (World Health Organisation (WHO) 2014). Maternal mortality in Malawi is also among the highest in Africa due to obstetric complications, delays in seeking health care, poor referral systems to better equipped health facilities, lack of drugs and equipment and reduced staff capacity (World Health Organisation 2014).

Following the preceding overview of the disease burden in Malawi, we examine the common types of morbidity reported in the LSMS-IHS3 data and their occurrence across the different types of households, persons and seasonal periods. As we noted earlier, information of households' acute and chronic morbidity was gathered over varying recall periods, depending on the nature of morbidity.

Further, we explore the consequences of morbidity through loss of productive time and cash losses where health care is paid for or in coping with the consequences of ill-health.

Figure 4.5 illustrates the concentration of acute and chronic morbidity, and body function impairments across different types of person within a household. As we noted earlier, 19% of the sampled persons are reported to have been ill in the two weeks before the interview. The occurrence of acute morbidity is highest among the infants and the elderly persons. Approximately 35% and 30% of all infants and the elderly in the sample, respectively, are reported to have suffered from an acute illness in the two weeks prior to the survey.

The concentration of acute illness within these categories of person points out to high vulnerability to illness probably resulting from age and decreased or underdeveloped (in infants) immunity to tropical diseases such as malaria, diarrhoea, flu and colds, and upper and lower respiratory problems. As a consequence, productive time of the other healthy members of the household may be diverted to taking care of the sick infants and elderly persons, and hence reducing labour available for on-farm and off-farm activities.

For chronic conditions and body function impairments, we observe that they are largely concentrated among the elderly, possibly because they are more likely to suffer from age related chronic and body function impairments.

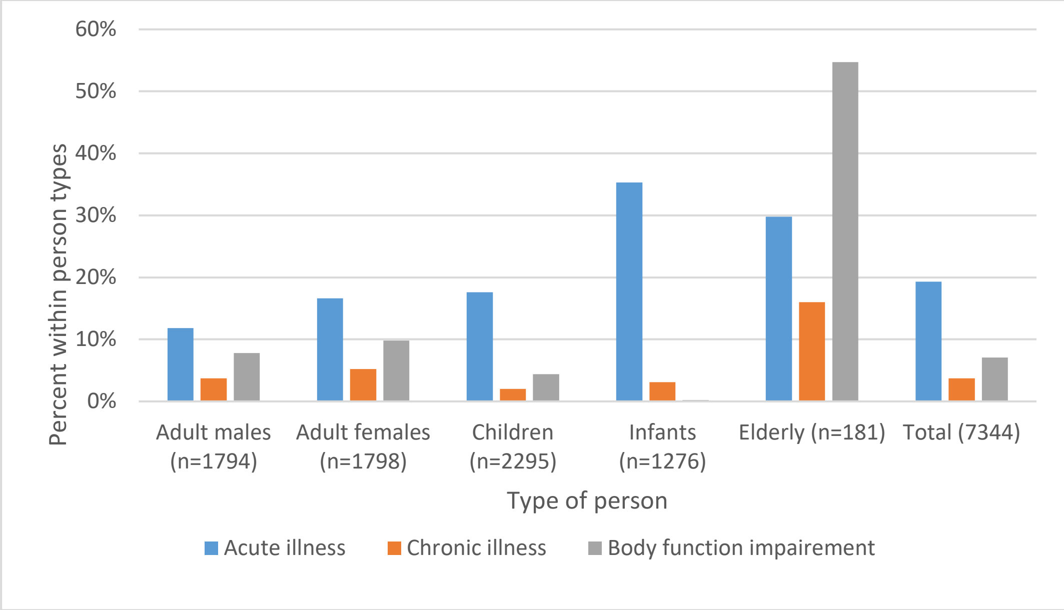

Figure 4:5 Concentration of acute and chronic illness, and body function impairments across different types of persons

In Figure 4.6, 4.7 and 4.8 respectively, we explore the concentration of the common acute and chronic illnesses, and body function impairments across the different groups of persons.

On account of magnitude of the proportion of cases with acute illness within each type of person group, Figure 4.6 shows that malaria/fever was the most commonly reported of the cases of acute infections. Notably, of the total cases of acute infections reported among the children and infants in the two weeks prior to the survey, over half of them in each group were as a result of malaria/fever.

As we noted earlier, malaria prevalence in Malawi is highest among children and it is a leading cause of morbidity among children under the age five (Government of Malawi 2011; National Malaria Control Program (NMCP) [Malawi] 2005). More recently, the 2014 Malaria Indicator Survey for Malawi report found that 30% of children under the age of five years were reported to have had fever, often associated with malaria, during the two weeks preceding the survey. Further, the prevalence of fever was highest among children aged 6-11 months, followed by those aged 12-35 months (National Malaria Control Program (NMCP) [Malawi] and ICF International 2014).

Within the adult males and females' groups, approximately 37% of reported acute illnesses were as result of malaria/fever for each group, and 26% within the elderly persons.

The concentration of all other acute ailments is comparatively spread out across the different types of persons, with the exception of diarrhoea, which is more common among infants. In Malawi, acute diarrhoea mainly occurs in children under 5 years of age, and in 2010, the number of episodes of acute diarrhoea among infants was over 13 million per year (Ministry of Health 2011). Backaches and skin problems are observed to largely occur among the elderly, possibly as a result of age related complications.

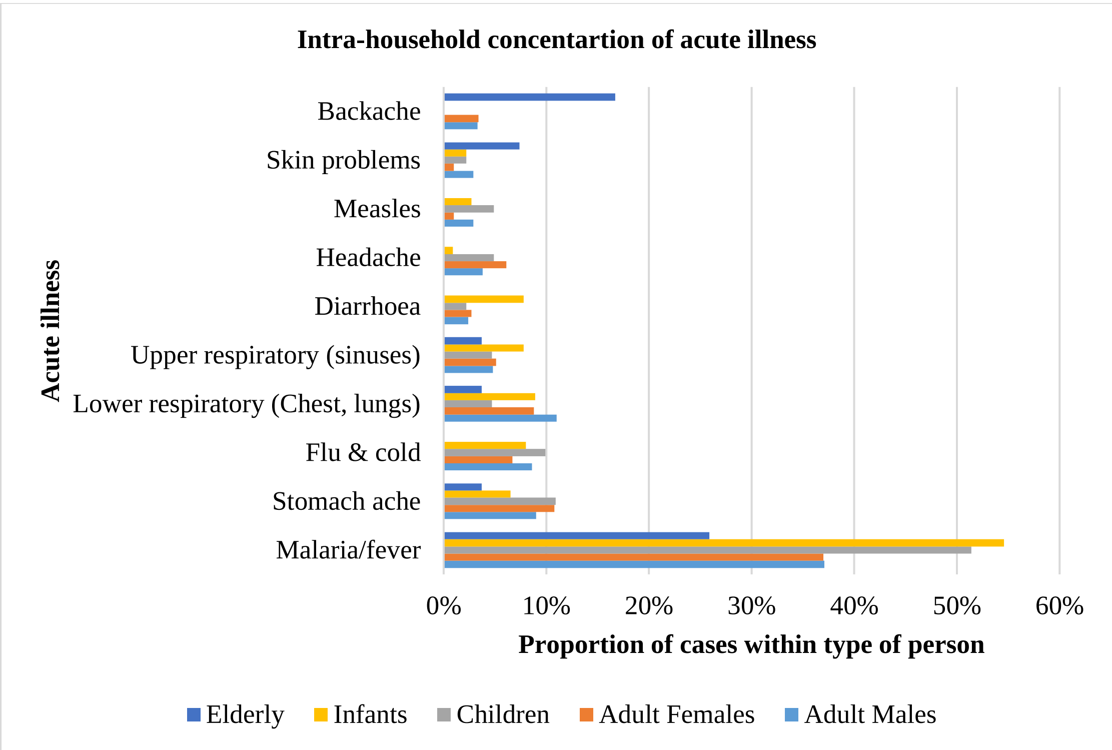

Figure 4:6 Concentration of acute illnesses by type of person

Figure 4.7 illustrates the patterns of concentration of chronic conditions across different groups of household members. Due to the low number of chronic conditions within each type of person groups, our findings are based on magnitudes only.

Generally, we find that asthmatic and epileptic conditions largely occurred among children and infants, while arthritis/rheumatism and stomach disorders were more common among the elderly. Cases of high blood pressure are highest among adult females. However, only a small number of adult females (n=15) reported to have suffered from high blood pressure.

Similar to our expectation, cases of HIV/AIDS were largely reported among adult males and females, and to some extent, among the elderly. An estimated 11% and 15% of all the cases of chronic conditions among adult men and women respectively, are HIV/AIDS related. Our estimates are slightly higher in comparison with the findings in the 2010 Malawi Demographic and Health Survey (DHS) report, where the HIV/AIDS prevalence rate was 13% among the adult women and 8% among adult men (National Statistical Office (NSO) and ICF Macro 2011). However, similar to the DHS, we find higher HIV/AIDS prevalence rate among adult women than men.

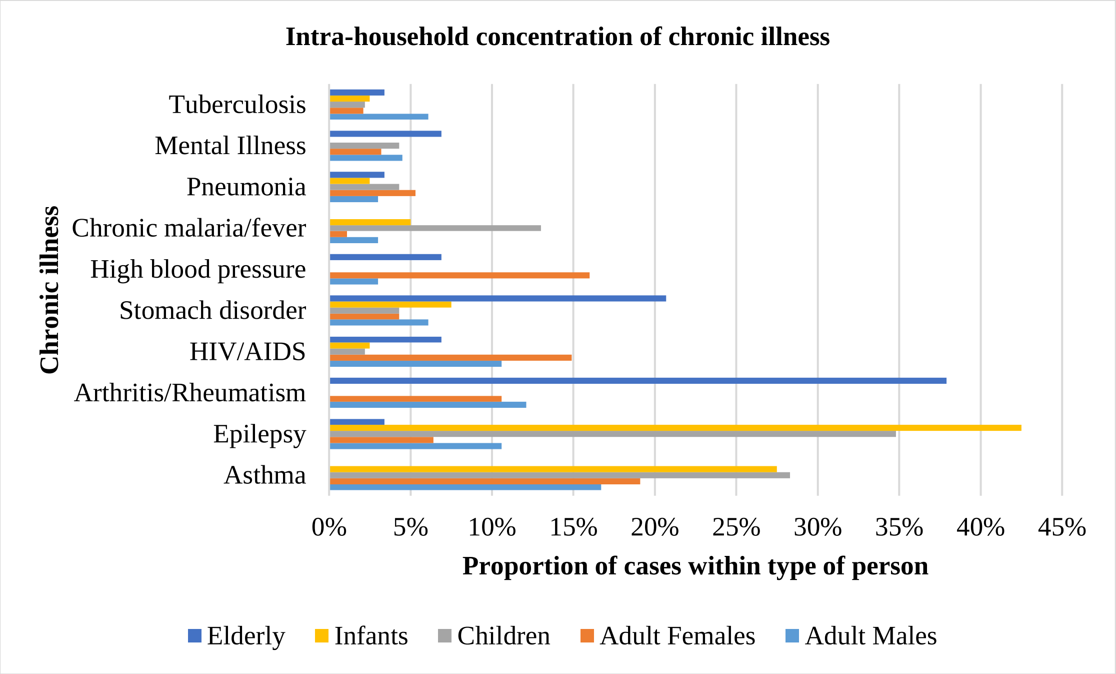

Figure 4:7 Concentration of chronic illnesses by type of person

In Figure 4.8, we examine the concentration of different forms of body function impairments across different groups of persons. Six types of impairments are investigated in this analysis. These include difficulties seeing even when wearing prescription glasses, difficulties hearing even with a hearing aid, difficulties walking or climbing steps, difficulties in remembering or concentrating, difficulties in self-care (such as washing all over, dressing and feeding), and difficulties in communication using the usual or common language.

In the current analysis, 9% of the total number of sampled persons (n=6068), which excludes the infants who were not enumerated for body function impairments, had at least one form of disability or body function impairment (some of the persons enumerated had more than one form of body function impairments).

Of the persons with a form of disability, 52% and 31% were due to visual and hearing difficulties respectively. A quarter of the disabilities (25%) were due to mobility and 13% were as a result of cognition difficulties. Difficulties in self-care and speech were the least reported forms of disability constituting of 5% of the cases of disability each.

Our findings however significantly differ from previously documented estimates. The Malawi Ministry of Health estimates that the prevalence rate of disability in Malawi is about 4.2%, with physical disability accounting for 48%. About 23% and 16% of disabilities are due to visual and hearing difficulties, respectively. Intellectual and emotional disabilities constitute 11% of the disabilities, while 13% are due to speech or communication difficulties. About 1% of the disabled cases is due to old age (Ministry of Health 2011).

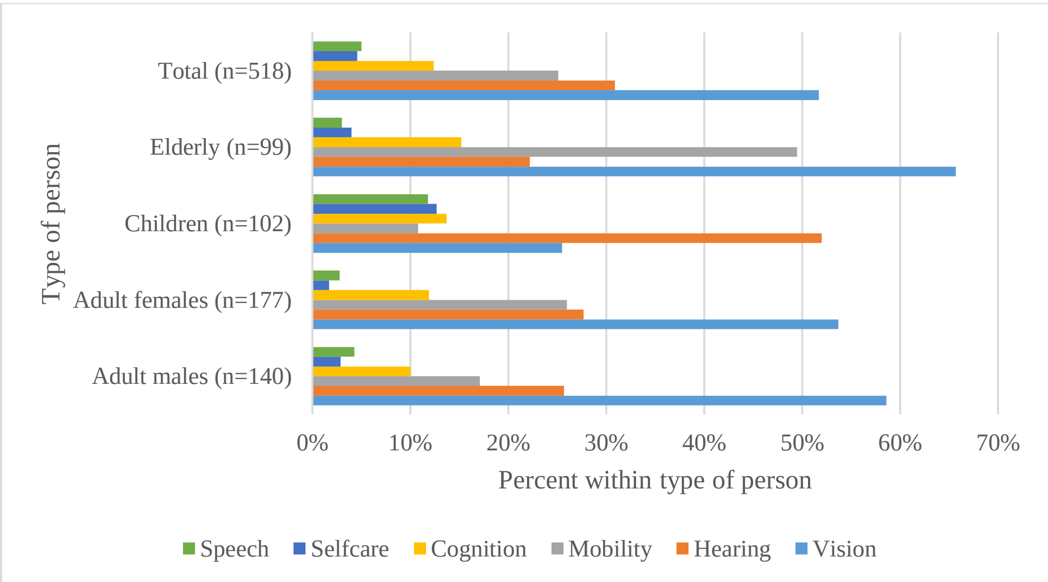

Figure 4:8 Concentration of specific forms of body function impairments by type of person

As Figure 4.8 illustrates, across the type of person groups, visual difficulties are the most common forms of body function impairments, while hearing difficulties are concentrated among children. Among the adults, 66% of the elderly, 59% of the adult males and 54% of the adult females had visual difficulties. The results are of significance as they portray the extent of visual problems in rural Malawi, probably as a result of inadequate nutrition and Vitamin A deficiencies. Between 1995-2005, approximately 6% of the population was estimated to suffer from night blindness (World Health Organisation (WHO) 2009a).

Also notable is the high concentration of hearing difficulties among the children, which is likely to impact on their quality of life, development and attainment of education (Filmer 2008). Finally, our findings show that mobility difficulties were largely among the elderly, indicating a possibility of causality between age and mobility difficulties.

In Table 4.7, we summarise the findings of the examination of the concentration of acute and chronic conditions, body function impairments, birth of a child and mortality across different types of poor rural households. For acute and chronic illnesses, all sampled individuals are included. The analysis of body function impairments excludes infants, while the analysis of child birth includes all females between the ages of 12 and 49 years, and who had a birth in the 24 months preceding the survey. Data on mortality within a household was gathered over a 24-months recall period. The reported proportions are within each type of household.

Table 4.7: Occurrence of health related shocks across household types

	Percent within each type of household group				
Type of Household	Acute Illness (n=7,344 persons)	Chronic illness (n=7,344 persons)	Body function impairments (n=6,068 persons)	Child birth (1,835 persons)	Mortality (1448 households)
Dimba	17	4	8	27	2
Poor female headed	25	7	15	21	10
Employed	20	4	6	28	5
Non-farm Enterprise	19	3	8	26	5
Remittances & other income	20	4	10	17	4
Credit	21	4	6	28	6
Poor male headed	18	3	8	33	3
Total	19	4	9	27	5

Source: LSMS-IHS3 Survey data estimates

We find that across the types of households, there is little variation in the occurrence of acute illness with the exception of the "poor female headed" type of household, where nearly a quarter of all the persons in this category reported an acute illness in the two weeks prior to the survey. Similarly, the occurrences of chronic illnesses and disabilities or body function impairments are highest in the “poor female headed” household type.

Households in the “remittance and other income” and “poor female headed” groups had the lowest cases of child birth in the 2 years prior to the survey. Generally, these households comprise of older persons with an average of 0.3 elderly persons per household and are headed by an older person, with an average age of at least 46 years (see Table 4.2). As such, they are likely to have lower birth rates resulting from the relatively aged household members.

An examination of the specific forms of body function impairments reported by households is illustrated in Figure 4.9. The findings reveal that visual problems are the most common forms of body function impairments across all types households. For all forms of body function impairments, their concentration is highest in the “poor female headed” type of household. The findings provide further evidence on the vulnerability of the poor female headed households to the welfare impacts of morbidity.

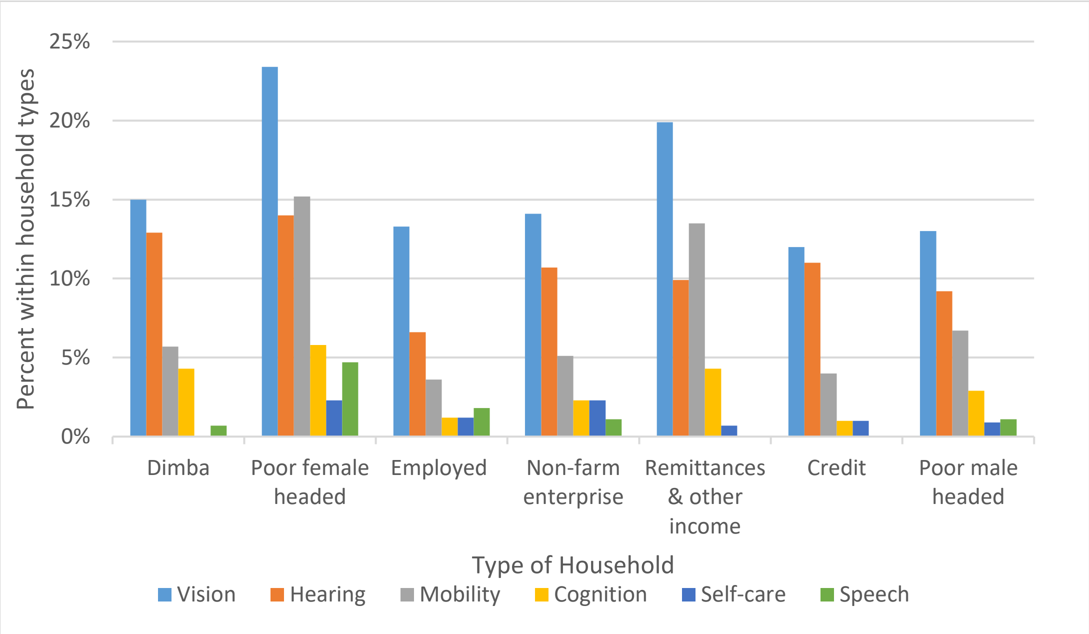

Figure 4:9 Concentration of body function impairments across household groups

In Figure 4.10 we show the seasonality in the occurrence of the self-reported short-term illnesses or injuries among the different person types. The reported estimates are calculated over the number of persons that had an acute illness in the two weeks before the interview in each seasonal period and across person types.

The results show that among children and infants, occurrence of acute illness has an increasing trend through the pre-harvest seasonal periods, reaching its peak in the February to March seasonal period. The pre-harvest periods, November-January and February-March, are characterised by high rainfall, humidity and also favourable temperatures for various disease pathogens, hence the observed high level of disease occurrence.

In contrast, adult females and males portray an unexpected trend with the occurrence of acute illness decreasing towards the February-March seasonal period. The peak seasonal period, November to January, which has the highest demand for labour has the highest occurrence of ill health among adult males and females, and thus likely to cause seasonal labour and cash constraints for farm activities. For the elderly, the occurrence of illness is relatively evenly spread across the cropping year, implying the likelihood of perennial sickness.

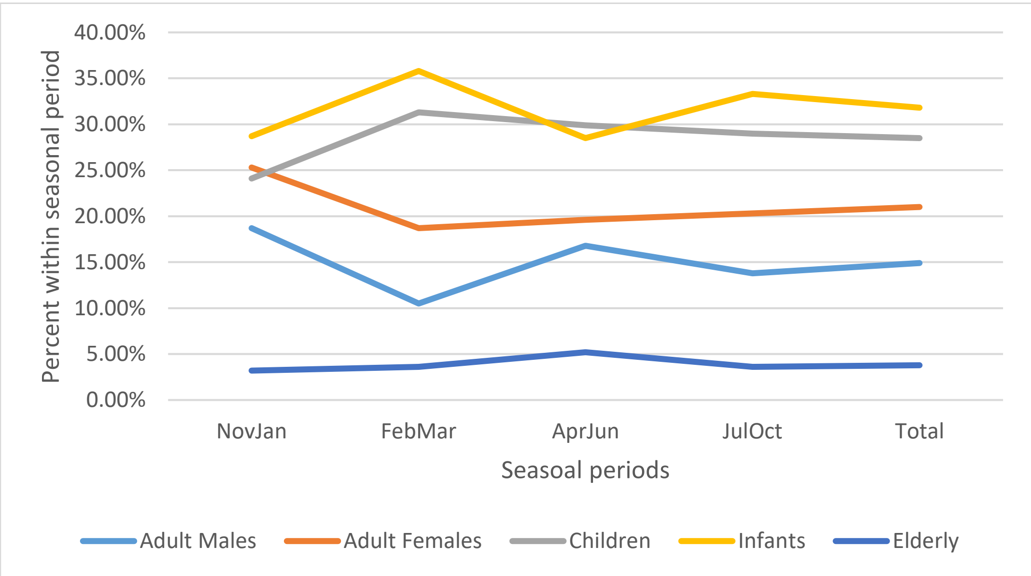

Figure 4:10 Occurrence of acute illness across person types by seasonal periods

In Figure 4.11, we present the seasonal distribution of the commonly reported types of acute illnesses. As we already determined earlier, malaria is the most common of the tropical diseases reported in Malawi. Our findings provide further evidence on the significance of malaria in the area of study.

From the findings, we observe that while the occurrence of other types of acute illnesses is relatively low and nearly equally spread across the seasonal periods, there is a distinct seasonal variation in the occurrence of malaria. The occurrence of malaria sharply increases from the onset of the cropping season up to the harvest period, April to June, before declining sharply towards the drier months in July to October.

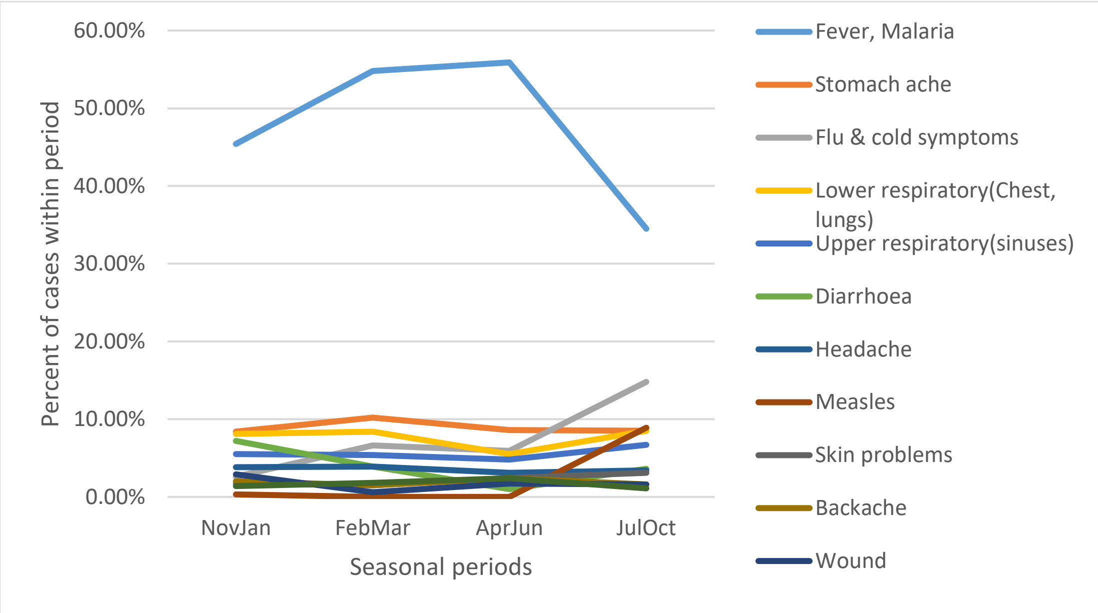

Figure 4:11 Seasonal distribution of acute illness

Our findings confirm that the transmission of the malaria parasite is dependent on climatic factors, and collaborate previous findings (Mathanga et al. 2012; National Malaria Control Program (NMCP) [Malawi] and ICF International 2012; Cox et al. 1999).

Cox et al. (1999) note that temperature and rainfall determine the development of *Anopheles* mosquitoes, the intermediate host in the transmission of malaria. Humidity affects the survival rate of mosquitoes or the longevity of adult vectors, while elevation defines the ecology of malaria transmission through temperature. Other diverse environmental exposures that modulate patterns of malaria risk, particularly in rural areas, include land cover, agriculture, soil moisture, topography, human and vector population densities, and construction of human dwellings (Stresman 2010).

In Malawi, vector abundance follows seasonal rainfall patterns, and an increase in temperature raises the parasite's reproductive rate, thereby influencing the prevalence rate of malaria in the population (National Statistical Office (NSO) and ICF Macro 2011). The transmission patterns of the disease show substantial seasonal variation, determined largely by high temperatures and the annual rains that normally begin from November-December and last through March-April in most parts of the country (Mathanga et al. 2012; National Malaria Control Program (NMCP) [Malawi] and ICF International 2012).

Kazembe et al. (2006) and National Statistical Office (NSO) and ICF Macro (2011) find that the transmission and risk of malaria is highest along hotter, wetter and more humid low-lying regions (Lakeshore, Shire River valley and Central plain areas), and lowest in the highland areas of Rumphi, Mzimba, Chitipa and the Kirk range. However, Kazembe et al. (2006) further argues that in Malawi, topography is the main factor that defines the differences in malaria risk because climatic variables change little over the limited range of latitude.

The increasing occurrence of malaria in the November-January period has implications on the farm households' supply of labour. Although the prevalence of malaria is highest among children and infants, there are still considerable cases of malaria among the economically active age groups.

As the findings in Figure 4.11 demonstrate, the highest cases of malaria coincide with the peak cropping seasons, when demand for family labour for own farm activities and cash expenditure for farm investment is highest. Consequently, morbidity among household members is likely to affect supply of on-farm labour and the final harvest outcomes through cash and labour losses. In households where the loss of labour occurs within the short window of peak cropping activities such as planting, and cannot be substituted with family and hired in labour, the production losses are likely to be more severe.

Finally, the findings in Figure 4.11 show that cases of flu and cold, which mostly affected children and infant, were highest over the dry winter season, July to October.

Interestingly, nearly all the reported cases of measles occurred in the July to October, although the cases are too few for firm conclusions.

In the following analysis, we examine the economic burden of morbidity through the health care expenditure and the loss of productive labour days due to ill-health and caring for the sick persons within the household. Finally, we determine the interaction between acute morbidity and agricultural labour use.

Table 4.8 details the average monthly value of out-of-pocket payments for health care across the different types of households and across seasonal periods. In the LSMS-IHS3 data, information on health care expenses was gathered over a one-month recall period and includes the cost of consultation, prescribed medication, non-prescribed medication such as painkillers and malaria tablets, and preventative health care such as pre-natal visits and vaccinations. Data on non-medical costs such as transport was not recorded.

Table 4.8: Average monthly value of out-of-pocket expenditure on health care across different types of households and seasonal periods

Type of household	Nov-Jan		Feb-Mar		Apr-Jun		Jul-Oct		Total	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Dimba	254	44.25	75	16.00	142	64.89	307	36.5	778	42.23
Poor female headed	157	31.56	160	62.57	132	39.62	260	46.0	709	45.35
Employed	180	30.50	160	70.56	224	94.11	292	58.9	856	64.33
Non-farm enterprises	264	62.41	166	77.74	218	50.64	299	61.2	947	62.01
Remittances & other income	248	52.42	151	58.84	154	72.14	228	79.6	781	65.48
Credit	156	45.22	141	45.82	104	37.64	133	47.3	534	44.41
Poor male headed	736	34.99	678	47.96	433	74.04	892	70.4	2739	55.91
Total	1995	42.09	1531	54.39	1407	66.56	2411	60.5	7344	55.39

Source: LSMS-IHS3 survey estimates

We find that on average, a household spent approximately MK 55 per month (approximately US$ 0.4) on health care, which is less than 1% of the total expenditure on food and non-food items per month. However, as we noted earlier, our findings show high dependency on the government funded free health facilities, thus the low spending. As shown in Table A1, over half of the people with an acute illness in the two weeks prior to the survey sought treatment from a government funded health facility and nearly a quarter purchased medicine from the local groceries and pharmacies.

As expected, the economically better off types of households, which include the “employed”, “non-farm enterprises” and “remittances and other income”, spent above MK 60 per month on average. Across the household types, there are random variations on health care spending across the four seasonal periods, and we do not find a consistent seasonal pattern of spending. On overall however, households appear to spend more on health care in the April to June and July to October seasonal periods, when they are more likely to have income from crop sales

In Table 4.9, we present a summary of the six top responses to health shocks reported by the sample households. The responses are ranked according to the number of cases. Data oh health shocks and the corresponding responses is gathered over a 12-months recall period in the LSMS-IHS3. In the interview, households were prompted to answer questions on three types of health shocks including; serious morbidity among household members; birth in the household; and death of a household member.

Of the total number of sample households, 19% had experienced at least one health related health shocks. Across the different types of health shocks, 15% of the total sample households had a serious illness among household members, 2% had a birth within the household, and 2.5% experienced death of a household member.

Results in Table 4.9 show that use of savings to cope with the effects of health shocks was the most common coping strategy adopted by households, especially the effects of morbidity. For birth and mortality, we find that more households had no coping strategy, while others relied on the unconditional help of relatives and friends. A negligible number of households sought credit, employment and disposal of assets to cope with the consequences of health shocks. As our earlier findings illustrated in Figure 4.1 show, households have limited assets holdings thus increasing their vulnerability to health shocks.

Table 4.9: Households responses to the effects of health shocks

Response to health shock	Type of health shock						Total	
	Morbidity		Birth		Mortality			
	Count	% within shock	Count	% within shock	Count	% within shock	Count	% within shock
Relied on own-savings	102	48.30	4	16.00	7	19.40	113	41.50
Did nothing	48	22.70	13	52.00	17	47.20	78	28.70
Received unconditional help from relatives/friends	18	8.50	5	20.00	9	25.00	32	11.80
Obtained credit	10	4.70	1	4.00	2	5.60	13	4.80
Adult household members who were previously not working had to find work	9	4.30	0	0.00	0	0.00	9	3.30
Sold durable assets	6	2.80	1	4.00	0	0.00	7	2.60

Source: LSMS-IHS3 survey estimates

Table 4.10 shows the differences in the average loss of productive days due to illness and being cared for in the two weeks preceding the interview, across seasonal periods and household types. This summary excludes all infants and children, as they are assumed to outside the economically productive age bracket.

Across the household types, we observe marginally higher losses in productive time in the "remittances and other income" type of household. The higher losses of productive time due to the effects of morbidity are possibly associated with the higher number of elderly persons and older age of the head of the household in this type of household (see Table 4.2).

Across the seasonal periods, we don't observe considerable variation in the average number of disability days overall. However, as illustrated in Figure 4.10, the adult females and males, and the elderly, who are the more productive types of persons, had a relatively even pattern in the occurrence of acute illness across all seasonal periods. Consequently, their loss of productive time due to illness would be expected to follow a similar trend.

Table 4.10: Average loss of productive days (disability days) due to ill-health and care time

Type of household	Nov-Jan		Feb-Mar		Apr-Jun		Jul-Oct		Total	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Dimba	14	5.4	1	7.0	9	4.7	12	8.0	36	6.1
Poor female headed	12	6.3	16	4.3	14	6.8	20	9.1	62	6.8
Employed	17	4.5	10	10.9	14	7.2	16	5.7	57	6.6
Non-farm enterprises	19	5.2	9	12.2	11	6.4	15	4.1	54	6.3
Remittances & other income	19	9.6	11	1.9	14	13.9	19	7.2	63	8.5
Credit	10	8.1	8	6.0	7	5.6	7	7.7	32	6.9
Poor male headed	52	6.0	38	6.4	28	3.1	46	6.5	164	5.7
Total	143	6.3	93	6.5	97	6.5	135	6.8	468	6.5

Source: LSMS-IHS3 survey estimates

In Figure 4.12, we compare the average days spent on agricultural activities by healthy adults (adult males and females and the elderly) against that of adults with an acute illness and the associated loss of productive days due to the effects of ill health. The estimations are averaged over a two weeks' recall period, and a full day of agricultural activities is capped at 7 hours.

The results indicate that across all seasonal periods, healthy adults spent more time on agricultural activities than their sick counterparts. In the peak production seasons, November to January and February to March, healthy adults spent twice as much time on agricultural activities compared to the sick persons. For poor households, supply of family labour to agricultural production is key to their food security and farm income, and morbidity during peak agricultural periods can cause reductions in the final harvest outcomes.

As Chambers (1982) argues, loss of productive time during peak agricultural periods due to the effects of morbidity leads to loss of agricultural production and income, and sickness is the most liable to push people into more severe poverty.

Notably, across the seasonal period, the average time lost to illness over a two weeks' period is higher than the time allocated to agricultural activities by the sick adults.

However, due to small landholdings and the short window of time for performing agricultural activities over a seasonal period, only part of the households' labour resource is engaged in farm activities. As a result, labour losses due to health shocks are more likely to affect agricultural production activities if they occur during the short window of peak agricultural activities, thus causing demand on the limited cash resources or labour constraints where surplus labour is absent.

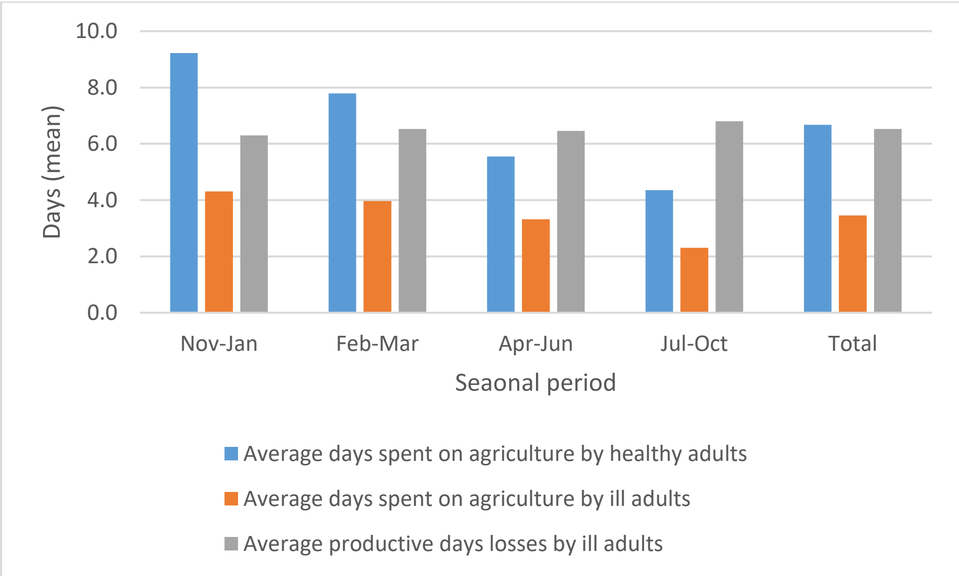

Figure 4:12 Comparison between the average loss of productive days to ill-health and care and the time spent on agricultural production by ill and health adults

Chapter 5: Calibration and validation of the base models

5.1 Introduction

This chapter presents a detailed description of the procedure followed in the calibration of the set of non-linear programming base models of farm household types in rural Malawi. Critically, the chapter highlights the difficulties in getting the programming models to find feasible solutions in optimization problems for severely cash constrained, land scarce and unskilled labour abundant rural farm households.

We begin the chapter in section 5.2 with an explanation of the base models' calibration procedure and estimation of the models' parameters. In section 5.3, we discuss the validation of the models' design and of the results. Section 5.4 reports on the base models results and a discussion of the outcomes, and section 5.5 highlights the limitations of adopting a programming model of farm households as a methodological tool in the analysis of the impacts of external shocks on rural livelihood systems, and in policy analysis.

5.2 Calibration of the base models

5.2.1 Overview of the base models' calibration procedure

As already discussed in chapter 3, our formulation of a set of base programming models for farm household types, which are fairly consistent with the characteristics and behaviour of rural farm households in Malawi, follows the approach described in Dorward's earlier modelling activities in rural Malawi, and his insights into their livelihood strategies (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006). A key advantage of the author's model formulation is the integration into the model of the seasonality of rainfed agricultural production, multiple cropping and off-farm activities and heterogeneous farm households. Moreover, Dorward's formulation makes considerations for strategic policy options, such as the subsidised farm inputs programme, that are relevant to the Malawian agricultural sector.

Our modelling activities of the rural livelihood systems in Malawi are also guided by information gathered through the review of a wide body of literature on Malawian smallholder agriculture and livelihood strategies, and also an in-depth assessment of the dynamic mathematical programming methods suitable for modelling such systems. A detailed review of literature and the methodological approaches is presented in chapters 2 and 3, respectively.

The set of the base non-linear programming models have been calibrated to a typology of rural farm households in the Kasungu-Lilongwe Livelihood Zone in the Central Region of Malawi, using the median (mean estimates have been used for land area) estimates for the parameter coefficients, and which are computed directly from the LSMS-IHS3 data gathered between March 2010 and March 2011 in Malawi. A discussion of the households clustering procedure is presented in chapter 4.

All expenditure estimates are reported at 2010/11 price levels. However, we recognise that there have been substantial changes in prices post 2011 resulting from the devaluation of the Malawian Kwacha through a government fiscal policy. Consequently, future application of the model would be required to account for such changes and adjust coefficient estimates for inflation.

Where information key to model calibration was missing, patchy or unreliable in our primary LSMS-IHS3 data set, we adapted coefficient estimates and cropping enterprises from the previous modelling activities of Andrew Dorward, figures that were calculated and verified by the author (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006). In addition, we gathered data from secondary sources to calibrate the models and to verify the validity of estimates calculated from the primary data set. An extensive discussion of the procedure followed in the estimation of base models parameter coefficient values follows later in this chapter, and a summary of parameter coefficients and their corresponding sources of data is presented in Table A5 (Appendix A).

As discussed in chapter 3, the farm household models' structure incorporated various components relevant to the livelihoods of rural farm households. As such, the formulation of the model readily maps into a whole farm mathematical programming framework, and hence the model is written in the General Algebraic Modelling System (GAMS) code (Brooke et al. 1988).

The creation of the GAMS entities[2] involved the declarations (assignment of names or labels) and definitions (assignment of specific values) of all parameters (input-output coefficients), decision variables and equations, and writing solve statements (commands to run a model) in a main input file. The main input file design establishes the structure of the model, and then call up all data for parameters whose specific values are not assigned in the main inputs file. The main inputs file also calls up a solve routine and a reporting routine. The model outputs are then transferred from the reporting routine and captured in a simplified form in Excel spreadsheets for the final reporting.

The livelihood models are developed under deterministic conditions, with the assumption of perfect foresight in expected yield and prices and hence with no uncertainties in the seasonal supply of capital and labour resources, even when simulating ill health scenarios. As discussed below, this may lead to a degree of underestimation of the impacts of ill health.

In addition, the findings of our descriptive analysis in chapter 4 indicate that farm households in rural Malawi often suffer from bouts of illness, particularly recurring malaria and upper respiratory infections. Malawi also faces a significant HIV/AIDS pandemic with nearly 11% of the adult population affected by the disease (National Statistical Office (NSO) and ICF Macro 2011). Consequently, ill health to a certain extent is implicit in the base model, and the subsequent simulation models therefore examine the effects of additional health shocks.

The base models are used as the point of reference for the simulation models that explore household-level impacts of health shocks on rural agricultural livelihoods under stochastic variation of the household labour and capital resources, both at the first period of the farm production cycle and in subsequent seasonal periods. Specifically, we simulate the households' welfare effects of loss of unskilled family labour and cash resources due to malaria and HIV/AIDS.

[2] Original model syntaxes were written in GAMS code by Andrew Dorward. I have largely used the models as developed by Andrew, but have made detailed modifications (for example changing some of the models' restrictions as explained in section 5.2.3 below) to suit my particular requirements.

Losses in cash due to malaria are estimated as the median and mean cost of treatment for malaria in a private health facility. For the HIV/AIDS simulation scenario, we estimate the costs incurred to cover incidental expenses for households with a HIV/AIDS patient.

Generally, our analysis of the sources of health care in the LSMS-IHS3 data shows that poor rural households primarily seek health care from government health facilities that provide free treatment. As such, our malaria simulations investigate the potential welfare impacts in the absence of the government policy on free health care in public health facilities in Malawi. In the HIV/AIDS scenario, free public provision of anti-retroviral therapy is assumed and the simulations examine the impact on livelihoods of the out-of-pocket expenses incurred by households with HIV/AIDS patients along with the impacts of labour loss. A description of the simulation scenarios and a comprehensive analysis of the effects of ill health in rural livelihoods is presented in chapter 6.

5.2.2 Calibration of the base model: general reflections

In the development and calibration of a mathematical programming model, there are potential pitfalls which may affect the application of the model, and which the analyst is expected to be cognizant of. For example, some of the constraints and parameter estimates used in the model may be too limiting and may lead to solutions that are infeasible. In other instances, improper specification of the constraints may potentially cause optimal solutions that are unbounded or multiple possible solutions.

An unbound optimal solution means that the constraints that are set in the model are not efficient in limiting the optimal solution, and therefore the feasible region of the model extends to infinity. For example, if the landholding and supply of labour constraints are not effective in limiting the model coefficients to the available households' resource endowment, the model would generate unrealistic optimal solutions that bear no similarity to real farm situations. The potential problem is overcome by carefully checking the formulation and specification of all constraints, in regards to the inequality signs, numerical errors and ensuring they are restricted to the actuals calculated from the data. This can be time-consuming.

A solution is referred to as infeasible if the constraints that are set by the analyst are too limiting and have left no feasible region for the model to find a feasible solution.

The resolution to an infeasible solution is to identify the infeasible set of constraints, and then re-formulate the model. However, B. A. McCarl and Spreen (2011) advise that a modeller must first check for any misspecifications, such as the direction of inequality signs and numerical errors in the set of constraints and parameters causing the infeasibility.

Initially, we attempted to run the set of base models for each household type, whose parameters were calibrated using the median actuals estimated from the LSMS-IHS3 data and from the other sources of data where information was unavailable in the primary data set. With the sole exception of the relatively better off "employed" type of household, the models could not generate a feasible solution in all other household types.

This initial inability of the models to find feasible solutions, given that the models' parameter estimates that are used in the calibration of the model are fairly consistent with reality, reflects on the unrelenting struggle for survival of the poor, or the extreme difficulties they face in their ability to fulfil their basic food and cash consumption needs. Further, it provides an insight into the actual standards of living that the households' meagre resources can provide in order to survive. In 2010, the government estimated that a quarter of the Malawi's population lived in extreme poverty (National Statistical Office (NSO) 2012a; United Nations Development Programme (UNDP) 2015).

After carefully identifying the causes of infeasibility, we fixed the models by making specific adjustments to the models' parameter estimates with the aim of relaxing some of the resource constraints that were deemed to be too limiting. In addition, restrictions on certain activities, for example hiring out of labour to the informal ganyu labour markets and arbitrage in maize marketing, were put in place in order to reflect behaviour that is consistent with the households under investigation.

5.2.3 Calibration of the base model: detailed explanations

As a starting point to the process of model calibration, we begin by highlighting the assumptions in the specification of the objective function, and then follow with a detailed description of the procedure followed in the estimation of specific parameter coefficients, which have been used to calibrate the base livelihood models for the different types of households modelled.

Our models are formulated as optimization problems, whose objective function is to maximise utility in the consumption of cash, food (estimated in caloric quantities), leisure and savings. The specification of the objective function is based on the arguments in earlier theoretical work of T. W. Schultz (1983) and Duflo (2006). In his seminal work on transforming traditional agriculture, T. W. Schultz (1983) explains the behaviour of farmers engaged in traditional agricultural production and conceptualises that the "poor but efficient" farmers are rational decision makers. Given the difficult circumstances that they face in terms of severely constrained resources, they do their best to maximise production out of their fields and no productive factors, for example human capital, remain unemployed.

In her study titled "poor but rational", Duflo (2006) followed on Schultz's theoretical work, and found that the poor are perfectly rational, and poverty affected decision making by affecting the constraints and changing the decision-making process itself. As such, our specification of a utility maximisation optimization problem references to a poor but rational decision maker, who aims to maximise utility from the consumption of cash (for purchase of non-food and non-staple foods) and calories first, before leisure and savings, given their constrained cash resources and asset endowment.

In the specification of the objective function for each type of household, the minimum cash requirement per seasonal period is estimated directly from the LSMS-IHS3 data using information on consumption expenditure of non-staple foods and non-food items. Non-staple foods include food items that households do not ordinarily produce or food consumed away from home, such as in restaurants. For minimum caloric consumption requirement per seasonal period, we adopt international standards recommendations for daily calorie intake by age, sex and level of activity (Institute of Medicine 2002; Food and Agriculture Organisation (FAO), World Health Organisation (WHO), and United Nations University (UNU) 2001). Family labour which is not utilised in on-farm and off-farm activities is assumed to be leisure time. The marginal propensities to consume cash and calories (from staples) are calculated using LSMS-IHS3 data on cash (expenditure on non-food and non-staple items) and staples consumption expenditure by a linear regression analysis by ordinary squares. Staples food consumption is incorporated in the model as caloric consumption since staples contribute the largest share of households' caloric intake (Ecker and Qaim 2011).

The specification of the model constraints incorporates an initial endowment of pre-seasonal stocks of cash and maize grain that each type of household carried over from the previous harvest. This is used for pre-harvest consumption needs, including for investment in agricultural inputs during the peak cropping seasonal periods. In the model, as in reality, it may be inadequate to cover all these requirements.

To ensure that the households' welfare status at the end of the cropping year is at least as good as it started with, the closing stock of maize grain and the minimum closing stock of cash are equated to their pre-seasonal stocks. The equality requirement implies that all the income that is generated by households and all food produced within the single year production cycle is either consumed or kept to meet the closing stocks requirements that are carried forward to the next cropping year. Savings and borrowing (except in the "credit" type of household) are not allowed for in the model as the households under consideration are severely cash constrained and are also faced with thin or missing credit markets in rural Malawi.

In his formulation of a set of non-linear programming models of rural farm households in Malawi, A. Dorward (2003) states that maintaining the equality between the opening and closing stocks of cash and grain ensures that the programming model does not generate artificial windfall gains by portfolio changes, such as a household replacing their stocks of maize with cash (see chapter 3 on the structural model formulation). In reality however, severely cash constrained households may choose to satisfy current consumption needs at the expense of farm investment and future consumption. Thus, equating opening stocks of cash and grain to the closing stocks does not allow households to adopt such coping strategies.

We discuss the estimation procedure of the model coefficients and the restrictions put in place in turn.

1) Pre-seasonal stock of cash

In the LSMS-IHS3 data, information on the pre-seasonal stocks of cash is unavailable. It was therefore necessary to develop logical estimates of "carry over" cash amounts from the previous season to proxy the opening cash requirements for the new season.

We therefore use the consumption expenditure data in the LSMS-IHS3 to estimate the monthly households' expenditure on all food and non-food items.

Initially, we assumed that the opening stock of cash was equivalent to the total monthly expenditure, and that the estimated pre-seasonal cash resources could be used to relax the cash constraints at the beginning of the cropping season. On running the model, the results revealed that the pre-seasonal cash allocation, equivalent to one month of households' expenditure, was too limiting, across all groups of households, with the exception of the "employed" type of household. We therefore ran the model with increasing amounts of pre-seasonal stocks of cash, and at doubling the initial amounts of pre-seasonal cash stocks, a feasible solution was found for all groups of households.

Although arbitrarily computed, our estimation of pre-seasonal stocks of cash is consistent with Stuart Rutherford's arguments on money management among poor people and the pivotal role of savings in the lives of the poor (Rutherford and Arora 2009). In the book titled *"The Poor and their Money"*, the authors attempt to contribute to the improvement of micro-financing through several studies of how poor people make use of informal saving channels, such as the rotating savings and credit associations (ROSCAs), to accumulate small savings into lump sum amounts. Our estimation of the pre-seasonal stocks of cash is therefore in line with Rutherford's argument that poor households do make small savings and use them in lump sum to meet needs that require larger amounts in critical periods, such as at the start of the cropping season where they are significant expenditures on agricultural inputs.

Although savings are not specifically modelled in our current formulation, we do account for cash stocks carried over from the previous year's season, and also from one period to another within the single cropping year.

2) Pre-seasonal stock of grain

Another short-coming of the LSMS-IHS3 data was the lack of specific information on the pre-seasonal stocks of maize grain for consumption in the pre-harvest periods of the 2010/2011 cropping year. We therefore estimated the cropping year's opening stock of maize grain per household from information on the quantity of maize grain that each household had in storage at the time of the interview, and we adopted the following procedure.

First, we began by selecting all households that were interviewed over the post-harvest months (1st July 2011 to 30th November 2011). For each household, we computed their total stock of maize grain in Kilograms. Second, for each type of household group, we computed the median daily quantity of maize consumed per adult equivalent. Since there was little variation in consumption levels across the household types, we used a common daily consumption per adult equivalent of 0.4456 kg across all household groups. We then multiplied the median per capita daily value of maize grain consumption by the number of adult equivalents per household, and the total number of days between the date of interview and the 30th day of November to estimate the quantity of maize grain consumed by a household within that period.

Finally, we deducted the total grain consumed from the date of interview to the end of November from the stock of grain retained by the household at the time of interview. Sale of maize grain was largely non-existent, so we overlooked the small quantities of the maize grain that were sold. The balance in the quantity of maize grain for each household group is the best estimate of the pre-seasonal stock of maize.

3) Minimum cash requirements

Initially, we calibrated the households' minimum cash requirements using the median estimates of households' expenditure on non-staples and non-food items per seasonal period. In the LSMS-IHS3 data, households' food consumption of more than 100 food items was surveyed on a 7 days' recall period. The reports of the food items consumed were differentiated according to their sources such as from own production, market purchases, and food gifts. Expenditures on non-food items were also recorded on a recall period ranging from one to twelve months. In the computation of the seasonal households' consumption of cash coefficients, we excluded the consumption expenditure on key staples as their consumption is captured in terms of caloric quantities.

After an initial attempt to run the models whose cash consumption requirements were calibrated on the actual median cash consumption estimates, the results were infeasible. Specifically, for the poorer households' groups, the "dimba", "poor female headed", and "poor male headed", the required cash consumption expenditure, particularly in the pre-harvest periods, was high relative to the pre-seasonal stocks of cash and income earned over the pre-harvest periods.

To relax the cash constraint, we first equated the minimum cash consumption requirements to the estimated median actuals for the poorest household group, the "poor female headed" (see Table 5.1 for models' parameter coefficients estimates). By using the "poor female headed" group's cash consumption expenditure to bench mark the minimum level of cash consumption requirements, we allow the poorer households to find a feasible solution. At the same time, the better off households maximise utility through consumption of cash above the minimum level of cash consumption. In his modelling activities, Dorward also equates the minimum cash requirements as equal to the cash consumption of the poorest group of households, the "poor female headed" households (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006).

Second and as earlier noted, the models' results showed severe cash constraints especially in the pre-harvest periods, November to January and February to March, for the "dimba", "poor female headed" and "poor male headed" groups. Thus the households could not meet the minimum level of cash and food consumption. Consequently, we dropped the pre-harvest periods minimum cash consumption requirement by 20% in the "poor female headed" group, and by 10% in the "dimba" and the "poor male headed" group each.

In addition, when running the models, a further drop of up to 15% in the level of cash consumption (across all four of the seasonal periods) is permitted where a household is unable to meet the minimum level of cash consumption in one or more of these periods, and therefore cannot find a feasible solution. The downward adjustment is meant to steer the model towards logical and feasible solutions for the ultra-poor groups of households.

4) Minimum caloric consumption requirements

Initially, we calibrated the households' minimum consumption requirements based on the international standard recommendations and requirements for individual daily calorie intake as suggested by Food and Agriculture Organisation (FAO), World Health Organisation (WHO), and United Nations University (UNU) (2001) and Institute of Medicine (2002). From these we estimated household's caloric consumption per seasonal period, based on a person's age, sex and level of physical activity. Specific calorie requirements that differ from the international norms, and those that reflect variance in local consumption patterns and physiological requirements are not available for Malawi, as far as we are aware.

However, attempts to solve the models showed that the internationally recommended caloric requirements were too high, and more so for the poorest types of households, who could not meet the caloric needs. We therefore adjusted the internationally recommended caloric quantities and set the minimum per capita daily caloric requirements as follows. For adult males and females, we assume an active life style with a minimum daily calorific requirement of 2300 and 2100, respectively. On the contrary, the elderly persons and children are perceived to be moderately active and with a daily intake of up to 2000 calories, while the sedentary infants are allocated 1200 calories per day.

In the setting of the minimum level of caloric intake, we recognise that in poor food insecure households, where poverty and food insecurity reinforce one another and periods of severe food deficits occur frequently, calorie deficiency is probable. Consequently, our model allows a downward adjustment of the caloric intake by up to 15%, for all groups of households that cannot meet the minimum set caloric requirements in any of the four seasonal periods.

In this study, the estimated minimum caloric requirements approach is adopted due to the difficulties in calculating the calorie composition from the food consumption quantities reports in the LSMS-IHS3 data set. In the gathering of data on households' food consumption, traditional or non-standard units of measurements were used. The use of these non-standard units of measurements and their associated conversion factors presented a challenge as conversion factors of some product-unit combinations were missing. In addition, previous attempts to use the conversion factors presented in the LSMS-IHS3 data deemed them implausible and therefore unreliable (Pauw, Beck, and Mussa 2014; Verduzco-Gallo, Ecker, and Pauw 2014).

We were unable to obtain the new conversion factors used by Verduzco-Gallo, Ecker, and Pauw (2014). However, on the basis of these conversion factors, the authors find evidence that between 2004/05 and 2010/11, calorie deficiency declined across all regions of Malawi, but with decreasing dietary diversity and mineral and vitamin deficiencies among the rural poor. In the Central region of Malawi, the authors estimated a daily per capita calorie consumption of 2,258, averaged across all household members, while the national average was 2,305. This suggests that our minimum calorie consumption requirements of 2300 per day for an adult male and less for other members of a household are reasonable.

5) Marginal propensities to consume cash, calorie, leisure and savings

The estimation of the Linear Expenditure System (LES) objective function requires the computation of the marginal propensities to consume calories (from staples), cash and leisure and to save in each seasonal period to allow for seasonal differences in the consumption expenditure. We estimate the marginal propensities to consume calories and cash using information on the consumption expenditure on staples and on non-staple and non-food items in the LSMS-IHS3 data. However, due to the lack of information on households' savings and time spent on leisure in our primary set, we assume that the marginal propensities to consume leisure and to save are nil.

For each household group, the annual marginal propensities to consume staples are computed in a linear regression analysis, where the seasonal per capita expenditure on staples is the dependent variable, and the total annual per capita expenditure on all food and non-food items is the independent variable.

Similarly, marginal propensity to consume cash is estimated with the seasonal per capita cash consumption as the dependent variable and the annual per capita cash consumption as the independent variable. The resulting marginal propensities (MPCs') are converted to seasonal propensities to accommodate for the differences in the length of the seasonal periods.

6) Crop budgets, price and technical coefficients

In the current study, twenty-nine cropping activities, that are undertaken either on monocropped or intercropped plots, and with varying seasonal demands for labour and purchased inputs are modelled. These cropping activities include: fourteen local maize technologies with differences in planting densities and labour requirements; four hybrid maize technologies differentiated by the intensity of fertilizer and labour requirements; six groundnut technologies of either monocropped or intercropped fields and with varying input requirements; intercropped beans; intercropped pigeon peas; monocropped and intercropped cassava; monocropped sweet potatoes; monocropped soybeans; and three technologies of monocropped burley tobacco with varying input and labour requirements. Tables A6 and A7 (Appendix A) respectively report the crop budgets for the hybrid maize and local maize technologies, while Table

A8 presents crop budgets for burley tobacco, cassava, groundnuts, beans, soybeans, pigeon peas and sweet potato cropping activities.

Information on the cropping activities and technical coefficients such as seasonal labour requirements, plant density, number of weedings, seed rate, fertilizer rate and other inputs requirements are adapted from the previous modelling activities of Andrew Dorward (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006). The yield of cassava is however adjusted upward by 25%, as (Southern Africa Root Crops Research Network and International Institute of Tropical Agriculture (IITA) 2007) suggests that the original figure was too low.

Inputs and output prices are estimated directly from the LSMS-IHS3, and verified using data from the government's official market price statistics and from various market reports (Government of Malawi 2013; Famine Early Warning Systems Network (FEWSNET) 2010; Food and Agriculture Organisation (FAO) 2016). Our comparison between the farm gate output prices estimated from the LSMS-IHS3 data and local market prices data gathered from the secondary sources indicate that the farm gate prices of crop commodities are approximately 65% of the local market prices. Such a price "wedge" between farm-gate and local markets purchase prices is however not unexpected as households interact with imperfect markets characterised by uncertainties in the price of food and inputs. In the crop budgets, therefore, we used the local market prices adjusted for these transaction costs.

The difference between the farm gate and local market prices shows that rural farmers do not benefit from the full price of their output, often resulting from the poor market infrastructure and high transaction costs (A. Dorward 2003). The author further notes that an increase in farm gate prices would be expected to improve the livelihoods of poor rural farmers, provided they can increase production in response to the higher produce price, and market prices do not fall in response to the increase in the supply of produce.

In our models' formulation, we allow for the fact that both hybrid maize seed and basal Nitrogen fertilizer can be acquired either at a subsidised price through the farm inputs subsidy program or at the full commercial price. The upper bound for subsidised input acquisition was set at two 50 kg bags of Nitrogen fertilizer at 91% discount level, and 5 kg of hybrid maize at 95% discount level.

In Malawi, the input subsidy program is one of the government's pro-poor policy interventions that are meant to promote more rapid economic growth and food security, and often targeted towards the poorest and the most vulnerable households. A brief description of the Malawi farm inputs subsidy program is presented in chapter 2 of this study.

Finally, following negligible levels of land market transactions in the LSMS-IHS3 data, our model assumes the absence of a land market, with no buying or renting in of land for additional production activities. Similarly, input credit is only accessible by the "credit" type of household and tied to the amount of land under tobacco production, at a 20% rate of interest.

7) Off-farm employment and wages

A critical issue for the livelihoods of the poor in rural Malawi is the ability to hire labour in the casual labour market, known as ganyu labour. Kerr (2005) examined the relationship between ganyu and food security in Northern Malawi. The author used the livelihoods framework and argued that in Malawi, ganyu was both a livelihood strategy and a measure of vulnerability. Similarly, Whiteside (2000) suggested that in Malawi, ganyu was a rational choice made by poor households to cope with acute food shortages, typically between December to February. In their analysis of resource allocation by poor smallholder farmers in SSA, Barrett et al. (2001) find that meagre endowments of productive assets such as land and livestock often forced poorer household to sell labour, sometime for low wages in the unskilled casual labour market.

In the calibration of the models, the hourly wage rates for ganyu labour per seasonal period are adapted from A. Dorward (2012). However, we find that the author's estimates of a more than 50% drop in ganyu wages in the February to March seasonal period, compared to the November to January wage rate, is too high. In addition, the lower wage rate in the February-March seasonal period is contrary to farmers reports during a personal field visit in the Kasungu District in Central Malawi. Typically, ganyu wage rate in February-March seasonal period is lower due to the low demand for labour, and is estimated to drop by approximately 35% from peak season's, November to January, wage rate.

Additionally, differences in the returns to off-farm employment opportunities such as ganyu (unskilled labour), and skilled and semi-skilled labour are modelled using different seasonal wage rates. We assume that skilled and semi-skilled persons hire out their labour at a rate higher than the ganyu wage rate. Following on A. Dorward (2012), the wage rate for skilled and semi-skilled labour per seasonal period is arbitrarily set at three times the corresponding seasonal ganyu rate.

A key related issue is the amount of labour that households are able to hire out as ganyu labour. If no restrictions were imposed on households' supply of unskilled labour to the informal ganyu labour market, across all household groups, the models predicted high levels of labour supply to ganyu – much higher than in reality, thus overlooking the very real labour demand constraints in rural Malawi. Furthermore, this allocation of large portions of households' time to ganyu resulted in high income to households from ganyu, thus overshadowing the severe cash constraints than households face in reality.

In the analysis of the impacts of HIV/AIDS related mortality and morbidity on poor rural agricultural livelihoods using a farm household model approach as in the current study, the simulations of A. Dorward, Mwale, and Tuseo (2006) treated all non-farm activities as hired out of labour, and thus allowed much greater hiring out of labour than is in reality. As such, households earned higher income from such employment. With less severe morbidity, households were able to weather such shocks due to the income from ganyu labour. However, as the severity of health shocks increased, their findings show reductions in the amount of labour offered to the unskilled farm labour market, and thus income losses.

As a result of the limitations of models with unrestricted supply of ganyu labour, we considered integrating into the model structure an unskilled labour demand function to interact with the aggregated labour supply offers of the seven household types. Towards this end, we enlisted the help of an experienced household modeller, but a combination of the complexity of the models and some logistical challenges meant that the exercise would not be feasible within the time available to complete this study.

As an alternative, I made a one-week residential visit in rural Malawi in March of 2016, within the February-March seasonal period, which is an off-peak, food deficit and high food prices period. The objective was to understand the livelihoods of poor people in the Kasungu-Lilongwe Livelihood zone during the off-peak but food deficit period. Specifically, the survey aimed to observe and understand time utilisation in poor farming households, and the process through which ganyu labour and wages were mediated between workers and employers. An explanation of the survey methods and data is presented in chapter 3.

Observations of the villagers' utilisation of time revealed that other than staking tobacco leaves to dry, there were no other major cropping activities at the time of the visit, and most of the villagers were mostly idle after performing domestic chores such as collecting water, fuel and cooking. Notably, some adult men spent long hours, sometimes an entire day, gathered around local liquor brewing sites, while others were engaged in off-farm activities such as thatching houses with grass or operating motor bikes for paid transport in and out of the village. Adult women who were members of local savings clubs met at least once per week for up to four hours.

The reports of the casual farm labourers and employers of ganyu workers revealed the following key points. First, while ganyu was key to their livelihoods, opportunities for work were limited due to the few number of villagers who hired in casual farm labourers. In fact, all the respondents reported working a maximum of 15 days during the peak agricultural months, and in a village of approximately 200 households, less than 10% hired-in casual ganyu labourers.

Ganyu labour was predominantly demanded by farmers who had relatively large pieces of land (over 10 Ha) or by owners of large and medium scale tobacco estates. Larger tobacco estates were however few and sparsely located, and as such, there were limited employment opportunities in them, and those who sought employment from them often travelled long distances to the estates.

The findings reveal the ganyu labour demand constrictions in rural Malawi, and hence that poor households face serious liquidity constraints due to the lack of opportunities to convert available labour into income.

Second, due to the limited demand for ganyu labour but with high supply of labourers, reports of the respondents suggested that ganyu work was mediated on kinship, trust and social capital. Among the respondents who employed ganyu labourers, all of them indicated that they often hired their kin in order to reinforce family ties, or hired in the people that regularly worked for them and had developed trust and confidence in their ability to work without supervision.

In addition, the farmers were embedded in social networks and to maintain such relationships, they would often hire people they regularly interact with, such as friends and neighbours. Similarly, those seeking ganyu work indicated that they often preferred to work for people within their social networks, as working for strangers was occasionally exploitative. The findings therefore show that in rural Malawi, the casual labour market is a not a pure demand and supply market clearing system, and that the amount of time hired out to ganyu is regulated by social relations in a context of structural over supply.

Third, many of the respondents who sought employment in the ganyu labour market were compensated either by cash or in kind, largely with maize, and their engagement in ganyu was primarily to meet their food consumption needs, and occasionally to cater for emergencies. The high reliance on ganyu for income to purchase food points to food shortages, where many households run out of food several months before the next harvest, and therefore employ coping mechanisms such as ganyu for food provision.

As a result of these observations, we decided that a quantitative restriction on the amount of labour hired out by each household type was justifiable. Specifically, the amount of family time allowed to be hired out to the informal ganyu labour market for unskilled labour is restricted to 10% of the total supply of household labour per seasonal period, for all household groups with the exception of the "poor female headed" group. This restriction is above the calculated levels of hired out ganyu labour from the LSMS-IHS3. As shown in chapter 4, using information gathered over a 7-days recall period, we find that ganyu labour accounted for only 3% of the total time supplied by active household members per seasonal period. Therefore, a 10% restriction is arguably quite generous. However, it is a much tighter restriction than was used in previous work by Dorward (A. Dorward 2011; A. Dorward 2006; A. Dorward 1999; A. R. Dorward 1996; A. Dorward 2003). We believe it reflects the realities of limited labour demand in rural Malawi.

For the “poor female headed” type of household, supply of labour to the informal ganyu labour market is marginally higher compared to all other households. We find that their labour allocation to ganyu averages 4.2% across the year, and 6% during February-March. Similar findings were reported by Kerr (2005) who found that in Northern Malawi, women in female headed households relied more on ganyu than those in married households. However, in order to assist this household type to meet its consumption requirements during the lean season, the amount of labour hired out to ganyu in the pre-harvest periods is capped at 15% of the total household’s supply of labour.

8) Dimba cropping activities, business profits, and remittances and other income adjustments

A limitation of the model formulation is the failure to incorporate a second cropping season for the “dimba” household group. The clustering of this group is based on their agricultural production activities in the wetlands (referred locally in Malawi as *dimbas)* during the dry months. To incorporate dimba cropping activities in the model, the “dimba” households are allocated an additional pre-seasonal stock of maize grain, estimated at 200kg per household from the LSMS-IHS3 data. They are however required that their closing stock of maize grain equal to the opening stock of grain less the grain from the dimba season’s harvest.

For the “non-farm enterprises” household category, and whose classification is based on their engagements in non-farm business enterprises, the annual business profits were calculated as median actuals from the LSMS-IHS3 data, and then evenly distributed across the seasonal periods. Annually, the net earnings from non-farm enterprises were estimated to be MK 24, 000. The estimated business profits may however overestimate or underestimate the actual income. In the gathering of information on business profits in the LSMS-IHS3, respondents were asked for business profits from the last month the enterprise was in operation. We extrapolated the information over the total number of months the business was operational over the 12 months preceding the interview in our calculations.

A critical examination of the “remittances and other income” group revealed that their actual level of cash consumption expenditure per seasonal period was inconsistent with their income stream either from employment in the informal ganyu labour market or from other sources of income such as remittances by relatives residing outside of the household, gifts, pensions, savings and investments. In addition, this household group had the highest value of physical and livestock assets (see chapter 4), and were self-sufficient in grain consumption over the pre-harvest periods due to the high opening stock of grain (see Table 5.1). To a greater extent, the household characteristics point to a better off type of household relative to the poorer household groups. A probable explanation therefore to the low earnings of remittances and income from other sources could be as a result of under reporting of income, and particularly of remittances.

To relax the pre-seasonal cash constraints, we made two adjustments to the income streams received by this group. First, we doubled the income from remittances, gifts, pensions, savings and investments to MK 2,000 per month per household, to match the income from business profits estimated in the "non-farm enterprises" type of household and to narrow down the bias caused by potentially underreported income.

Second, to relax the requirement for the closing stock of cash to be equal to the opening stock, we reduced the pre-seasonal stock of cash by making the assumption that part of it was received by a household as remittances in-kind, and is equivalent to the 2011 commercial price of two 50 kg bags of Nitrogen fertilizer and one 50kg bag of a top-dressing fertilizer. As such, we transferred from the pre-seasonal stock of cash MK 15,650 to the November to January resource of remittances. In Malawi, fertilizer is primarily imported through the neighbouring countries ports (Tanzania and Mozambique), and hence fertilizer prices are generally high. For example, during the 2012-2013 cropping year, the domestic price of a 50 kg bag was estimated at MK 14,000-16, 000 (US $42.42 – US$ 48.48) (International Fertilizer and Development Center (IFDC) 2013).

9) Restrictions to arbitrage in maize marketing

An attempt to find a solution to the set of base models after the relaxation of the pre-harvest periods' cash constraints presented feasible solutions, but with simultaneous buying and selling of maize to replace the maize stocks with cash.

Contrary to our findings in the initial data analysis where poor households are largely net buyers of maize (see chapter 4), the model's predictive solution allowed for arbitrage in maize marketing, with households taking advantage of the higher maize prices in the February to March seasonal period, and therefore replacing stocks of maize with cash.

Consequently, we set up restrictions to inhibit the speculative buying and selling of maize grain across the seasonal periods. Selling of maize from own harvest is, of course, accommodated in the model framework.

After all the adjustments to the relevant set of constraints and verification that all the assumptions hold, we developed a set of base models that generated feasible solutions that are fairly consistent with the livelihood activities largely observed among poor Malawian rural farm households. The results of the base models are reported in section 5.4.

Table 5.1 summarises the models median parameter coefficient estimates calculated from the LSMS-IHS3 survey data, and have been used in the calibration of the base models. The description of the validation procedure for the base model is presented in section 5.3.

Table 5.1: Parameter coefficients used for calibration of the household models and estimated from the LSMS-IHS3 data set

Parameter Description	Types of households							
	Dimba	Poor female headed	Employed	Non-farm enterprises	Remittances & other income	Credit	Poor male headed	Sample
Landholding (Ha/HH)	1.05	0.65	0.72	0.82	1.07	1.01	0.84	0.82
Pre-seasonal stocks								
Cash (MK/HH)	24,008	16,389	33,379	35,317	27,869	30,308	22,940	26,452
Maize (Kg/HH)	334	6	171	331	641	368	252	218
Minimum per capita cash expenditure per day (MK)	45.17	45.17	45.17	45.17	45.17	45.17	45.17	45.17
Minimum per capita cash expenditure per day ($)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Minimum per capita daily calorific requirements	2021	1994	2038	2019	2069	2048	2024	2029
Remittances and other income per year (MK/HH	0	0	0	0	39,650	0	0	0
Non-farm enterprise income per year (MK/HH)	0	0	0	24,000		0	0	0
Credit per year (MK/HH)	0	0	0	0	0	10,000	0	0
Marginal propensity to consume staples								
November - January	0.013	0.015	0.014	0.012	0.011	0.013	0.017	0.013
February - March	0.007	0.011	0.004	0.005	0.005	0.007	0.025	0.021
April-June	0.019	0.019	0.013	0.013	0.011	0.013	0.019	0.016
July-October	0.021	0.030	0.021	0.017	0.016	0.033	0.011	0.017
Marginal propensity to consume cash								
November - January	0.051	0.048	0.049	0.051	0.052	0.051	0.046	0.050
February - March	0.020	0.017	0.023	0.022	0.022	0.020	0.002	0.006
April-June	0.041	0.044	0.049	0.050	0.052	0.049	0.044	0.047
July-October	0.091	0.082	0.091	0.095	0.097	0.079	0.102	0.096
Marginal propensity to consume leisure	0	0	0	0	0	0	0	0
Marginal propensity to save	0	0	0	0	0	0	0	0

Source: Author estimations

Notes: "HH" means household and "MK" is Malawi Kwacha (150 MK= US$ 1 in 2010/2011).

5.3 Validation of the base farm household models

An important part of the process of developing a programming model is its validation to ensure that it is suitable for both the predictive and prescriptive purposes. In this section, we present in detail the procedures followed in the validation of the set of non-linear programming models of farm households to ensure their consistency in mimicking the expected behaviour of poor rural Malawian households.

B. McCarl and Apland (1986) note that while the process of model validation is tedious and time consuming, it is a critical aspect in model development as it often leads to improvement of the programming model. It is also valuable in providing the analyst with insights into the behaviour of the model, and therefore informing in the interpretation of the model results. Ordinarily, the validation procedures require the skills and knowledge of the modeller of the context and the subjects for a valid portrayal in the formulation of the model and in the model output (B. McCarl and Apland 1986).

In literature, validation procedures and criteria vary but with a common goal of testing how the model serves the intended purpose and validly represents the system modelled. On one hand, B. A. McCarl and Spreen (2011) identify two validation approaches, "validation by construct" and "validation by results". Validation by construct checks that the formulation of the model was proper, while validation by results refer to procedures involved in checking that the model outputs are valid by systematically comparing them against real world observations.

Ignizio (1982) on the other hand identified a four criteria for model validation: the logical consistency in the formulation of the model; reliability of the data used in modelling; logical consistencies of the model in its responses to simple stimuli; and correspondence of model results with the reality of the subjects under investigation.

On his part, A. Dorward (2003) finds that the comprehensiveness or scope of a model in describing the effects of all key variables that affect the system or the scenario being modelled is key to testing the validity of the model. The author however cautions that in modelling rural farm households, the inherent variability of peasant livelihoods systems demands care in making firm quantitative predictions or recommending prescriptions about change. He concludes that the validity of a model is primarily in its ability to correctly illustrate the interrelationships or interactions within the livelihood systems.

In our formulation and development of a set of base non-linear programming farm household models, we make considerations of both the validation of the model structure and of the results, and apply the following integrated criteria.

First, the logical consistency in the construction of the model, which is anchored on its formulation and its implementation is validated by first checking the correctness in: the declaration of sets, data and variables; in the specification of the objective function; the assignment of values to the input-output coefficients; the declaration and specification of equations; and the inclusion of the solution statements. The validation procedure involves the use of checking procedures within the GAMS compiler. This is an iterative process that involves repeated examination and modification of the GAMS instructions and logic, by examining the model outputs for errors and model's internal consistency.

In addition, we ensure that all the data used in the model are specified and estimated using scientific estimation tools, and the constraints imposed to restrict the model to realistic solutions are effective. The model design/structure and data are set up to represent the real observation and actual data, to ensure that the model results replicate a real world outcome and the results are not contradictory to the reality and to the well-established theory (B. A. McCarl and Spreen 2011).

Of importance in our modelling procedure is the intentional reduction of the number of constraints and adjustments made to steer the model towards results that are that are fairly consistent with the real world observations. Where applicable, constraints are set within the actuals computed in the primary data set. However, flexibility is allowed in some of the constraints that hinder the generation of a feasible solution. All the specific model adjustments were outlined in section 5.2.3.

Second, reliability of data is often a key concern in quantitative analytical work. Even with good survey data, sampling and non-sampling errors may occur as well as omission of information on important variables. In our model formulation, data on some key variables, such as the pre-seasonal stocks of cash and maize grain was omitted in the primary survey data, and as such, logical estimates of these variables have been used. Regression techniques were used to estimate land area (as explained in chapter 3) and the marginal propensities to consume cash and staples. An elaborate explanation of the estimation of parameters whose data was missing or scanty in the primary data set was explained earlier in section 5.2.3. Furthermore, in the calibration of the base model, we performed sensitivity analysis around the variables of interest to observe their effects on the stability of the model.

Third, the scope of the model is ensured through the fairly complete coverage of the livelihood aspects of the subjects under investigation. In his formulation of farm households models for different types of rural Malawian households, A. Dorward (2003) stated that while the models may not have exhausted all aspects of rural farm households' livelihoods, they covered the major farm household activities and processes, and the omissions were taken into account in the interpretation of the results.

Similarly, our modelling approach attempts to cover the major on-farm and off-farm activities that poor rural households in Malawi engage to meet their consumption needs, and the processes in the acquisition of farm inputs and utilisation of family labour. In addition, aspects of seasonality and the resulting labour and capital constraints, transfer of resources across and within periods, heterogeneity of households, receipt of subsidised fertilizer and hybrid maize are integrated in the model design. Clear omissions in the model formulation such as the exclusion of dry season cropping activities for the "dimba" household group were corrected for, as described in section 5.2.3 above.

Fourth, the logical consistency of the models' responses to simple stimuli is investigated by sensitivity analysis, a test of the model stability and internal consistency that is used to explore the magnitude and direction of change of the results when model coefficient estimates are varied. By itself, sensitivity analysis does not evaluate how accurately a model simulates what occurs in reality, but it is a partial validation test that reveals how well the model tracks changes in the parameter estimates and the corresponding adjustments in the system. For example, a substantial increase in the wage rate of skilled labour is expected to result in higher employment of skilled persons' labour and improved welfare for households with skilled labour.

Finally, the correspondence of model outputs with observed reality involved careful examination of the models' results and comparing them to information in key literature sources of smallholder livelihoods, agriculture and rural economies (Chapoto and Jayne 2005; Ricker-Gilbert and Jayne 2012; Denning et al. 2009; Chibwana, Fisher, and Shively 2012; S. T. Holden 2014; Chirwa and Dorward 2013; A. Dorward 2012; A. Dorward 1999; A. Dorward 2006; A. Dorward 2003), results of the descriptive analysis of the LSMS-IHS3 presented in chapter 4 and insights from personal visits to smallholder farmers in rural Malawi. In addition to the validation of the models' results, we enhance the models' creditability by clearly describing the model structure (chapter 3) and procedure followed in the estimation of the models' parameter coefficients, to enable the readers and users to understand the model.

In section 5.4, we present the results from the estimation of a set of base farm household models for the 2010/2011 cropping season. A discussion on how consistent the results are to the reality of rural Malawian households, and where they fall short of mirroring the reality, follows.

5.4 Results of the base farm household models and discussion of findings

The key purpose of the deterministic models in this study is to provide quantitative information about the farm households considered, and then use them as the base in the simulation of the effects of varying levels of severity of morbidity from malaria and HIV/AIDS. As earlier mentioned, the results of the base model assume certainty, and hence production risks and other external shocks are assumed to be absent.

For the base models to be useful for this purpose, they require the confidence of the modeller and the user that proper procedure was followed in their development, and that the models results are validated. As such, careful examination of how well the models predict farm household behaviour is critical, and where the predicted results deviate from the reality, a plausible explanation should be made.

In this section, we present the results of the base models, and discuss the aspects of the farmers' behaviour that they predict. The results of the models are predictive and not prescriptive, and they are intended to show the best farm plans for utility maximisation, given the constrained set of cash, human and physical capital resources, and also the constraints in the products, inputs and labour markets. The predicted crop choices are expected to be broadly comparable to the cropping patterns that emerge in the LSMS-IHS3 data. However, in the models' predicted feasible farm plans, the estimated area under each cropping activity, the level of input use and labour allocation to farm activities are not expected to match the actual estimated from the LSMS-IHS3 data.

Specifically, we present the models' results of the predicted cropping enterprises combinations, investment in variable farm inputs (includes seed, fertilizer, chemicals and other variable inputs, excluding labour costs) and allocation of family labour to own-farm production activities. In addition, we present the predicted household's income which includes the value of farm produce sold and that which is consumed at home from own production, and also income generated from off-farm employment of (semi) skilled labour and of unskilled labour in the ganyu labour market. Finally, we will show the results of the welfare indicators, as estimated by the per capita daily consumption of cash and calories.

Table 5.2 reports on the models' predictions of cropping activities, allocation of family labour to on-farm production activities, and input use for each type of household. Generally, the models' predictions of households' crop choices are broadly comparable to the cropping patterns observed in the LSMS-IHS3 data. With the exception of groundnuts, all other major crops in the study area such as local maize, hybrid maize, tobacco and soybeans enter the model. Cassava production also enters into the models' predicted cropping patterns but it is primarily intercropped with local varieties of maize.

Together with minor crops such as beans, sweet potatoes and pigeon peas, groundnuts fail to enter into the farm plans because the models' prediction of the best farm plan that maximises utility is on the basis of the cropping activities that have the highest return to capital and to land. The results are however not unexpected as other than groundnuts, our analysis of the cropping patterns in the LSMS-IHS3 data shows that none of the sampled households produced pigeon peas, and 4% produced beans and sweet potatoes each. For the major crops, 54% and 50 % produced local and hybrid maize respectively, 47% had groundnuts, 43% grew tobacco and approximately 12% had cassava. The proportion of the total area of land under each cropping activity across the different types of households, and calculated from the LSMS-IHS3 data is summarised in Table 5.3.

Table 5.2: Base models' cropping patterns and input use

Type of household	Local maize & Cassava	Hybrid maize	Tobacco	Soybean	% farm labour	Total Inputs (MK/hh)
Dimba	0.53 (49%)	0.25 (23%)	0.10 (9%)	0.21 (20%)	36	4,131.03
Poor female headed	0.33 (46%)	0.25 (35%)	0.02 (2%)	0.12 (17%)	33	1,334.65
Employed	0.06 (7%)	0.25 (29%)	0.40 (46%)	0.16 (18%)	38	26,745.95
Non-farm Enterprises	0.27 (26%)	0.25 (24%)	0.31 (30%)	0.20 (20%)	43	21,171.43
Remittances & other income	0.57 (46%)	0.25 (20%)	0.24 (20%)	0.17 (14%)	40	16,732.17
Credit	0.32 (29%)	0.25 (23%)	0.38 (35%)	0.15 (14%)	42	28,852.25
Poor male headed	0.69 (70%)	0.25 (26%)	0.05 (5%)	0 (0)	32	3,689.74
Weighted average (ha	0.47	0.25	0.16	0.10		

Notes: Results are presented for the seven types of households. Area under each cropping activity is estimated in hectares. The area as a proportion of the total land holding is in parenthesis. "HH" means household and "MK" is Malawi Kwacha (150MK=$1 in 2010/2011).

Table 5.3: Proportion of the total area cropped for each cropping activities across the different types of households (%)

Type of household	Cropping activities							
	Local maize	Hybrid maize	Tobacco	Groundnut	Soybeans	Beans	Sweet potatoes	Others
Dimba	26.17	28.26	21.17	16.33	3.76	0.39	1.86	2.06
Poor female headed	40.28	21.10	9.16	17.96	6.72	1.60	0.89	2.29
Employed	25.15	35.45	11.79	16.17	4.84	1.20	0.89	4.51
Non-farm Enterprises	22.75	32.53	17.36	16.60	4.30	0.62	2.36	3.48
Remittances & other income	23.60	30.18	19.77	13.82	5.25	1.54	0.89	4.95
Credit	26.08	24.70	27.14	12.82	3.11	1.05	1.13	3.97
Poor male headed	30.40	25.60	19.08	13.30	5.60	0.88	1.16	3.98

Source: Author estimations

A comparison between the findings in Tables 5.2 and 5.3 indicates that for most of the household types, the models predict larger allocations of land to local maize production than it is in reality. However, higher concentration of local maize across the household types is as expected, and as we already noted, minor crops such as beans and sweet potatoes that are produced in small quantities by the sampled households do not enter into the models' predictions and are thus replaced by local maize and cassava intercrops. In addition, due to low labour and capital requirements, local maize is preferred to other crops as it provides more edible and cheaper calories per unit area.

Further, we note that the models' prediction of hybrid maize production is nearly identical to the reality as presented in Table 5.3. In both the models predictions in Table 5.2 and the estimates from LSMS-IHS3 in Table 5.3, production of hybrid maize is largely driven by the availability of the highly subsidised hybrid maize seed and fertilizer through the farm input subsidy program (FISP). For instance, the models' predictions of hybrid maize production is limited to the maximum amount of subsidised hybrid maize seed (5 kg) that is provided to farmers through the farm inputs subsidy program.

The technical explanation to the model limiting hybrid maize production to the maximum available seed is that hybrid maize is one of a limited number of crops that require capital inputs in the November-January period. However, capital is scarce and returns to capital for monocropped hybrid maize are low compared to tobacco production. As a result, households are generally predicted to acquire all their hybrid maize seed and the required fertilizer for its production through the subsidy programme. They also pick local maize intercrops for food and income, and produce small portions of tobacco and soybeans to generate additional farm income.

Since 2005/2006 cropping year, the government of Malawi embarked on a comprehensive fertilizer and seed subsidy programme, where targeted poor rural households received coupons for purchase of subsidized fertilizer and hybrid maize seed, to boost agricultural production and to enhance food security in the country (Chirwa and Dorward 2013; Denning et al. 2009; A. Dorward and Chirwa 2011). In reality, farmers who received the subsidised inputs adopted the high yielding hybrid maize, irrespective of the expected return to capital (Denning et al. 2009). In our models' predictions however, fixed price expectations are assumed and therefore hybrid maize with low return to capital compared to other crop alternatives is strictly restricted to the available subsidised hybrid maize and fertilizer across all the household groups.

The results in Table 5.2 show a clear relationship between the pre-seasonal stocks of cash, crop choices, input use and allocation of labour to on-farm activities. Economically better off households in the "non-farm enterprises" and the "employed" groups, and who are characterised by income from business profits and skilled employment respectively, and with relatively large amounts of the pre-seasonal stocks of cash, are predicted to opt for the input intensive tobacco production. Production of tobacco is also high among the "credit" type of household, and who despite being asset poor, they have access to inputs for tobacco production on credit. There is also considerable production of tobacco among the "remittances and other income" group who receive income in remittances and from other non-farm and non-employment sources of income.

On the contrary, the poorer households, the "poor female headed", "poor male headed", and "dimba" opt for less input intensive cropping activities, and are therefore predicted to allocate most of their land to the production of local maize intercropped with cassava. These groups of households are severely cash and land constrained, are more likely to be risk averse, and are therefore less likely to put large portions of their available land under the capital intensive tobacco production. Moreover, their severe cash constraints require them to hire out unskilled labour to the ganyu labour market to meet their immediate consumption needs. However, since the model restricts hiring out of labour to between 10% and 15% of the total labour resource, sale of labour is unlikely to affect their own-farm labour supply.

The heterogeneity between farmers in their crop choices suggests that the difference in capital endowment, for both consumption and agricultural investment, is key to the differentiation between household types.

Across all households' types, there is a strong concentration of local maize, which is predominantly intercropped with cassava. In the models, cassava is preferred because it is a perennial crop that is harvested later in the post-harvest period, July to October, and is therefore an important source of cash after the harvest period of all the other crops.

Soybean production is also predicted across six of the seven types of households, but in relatively smaller portions of land compared to intercropped local maize and cassava. The results suggest that regardless of the high return to capital and land, soybeans are preferred to groundnuts because they have lower labour input requirements and have no capital requirements.

The models' predictions effectively describe cropping activities that are consistent with the norm in rural Malawi, where maize is the dominant staple and accounts for more than two-thirds of caloric intake (Ecker and Qaim 2011), approximately 97% of households produce maize (Chirwa and Dorward 2013), and local maize varieties are preferred by farm households due to their favourable processing and consumption characteristics, that include good taste, storability, and flour-to-grain ratio (Lunduka, Fisher, and Snapp 2012).

We now consider the models' predicted patterns of use of family labour on cropping activities summarised in Table 5.2. The utilisation of labour on own-farm shows little variation across the household groups. Endowment in labour resources is dependent of households' size and composition, and utilisation of labour is dependent on crop choices. The "poor female headed" has the smallest land holding (0.72 ha), and coupled with its crop choices that include very low levels of tobacco production, their labour use is expected to be relatively low.

Further, our results reveal abundance in the supply of labour as less than half of the available labour resource is utilised on-farm, and due to the labour demand constrictions in Malawi (see chapter 4), off-farm opportunities are limited. For the majority of the poor households with low land-to-labour ratio, and who are lacking in skills, a significant amount of their labour resource is underemployed as there are limited opportunities for remunerative uses of labour.

Notably, our models' predictions of labour use on own-farm production activities are higher than the actual labour use estimated from the LSMS-IHS3 data over a seven days' recall period. The LSMS-IHS3 data estimates indicate that on average, 24.5% of households' time was spent on agricultural activities, with more time (32%) utilised in the peak November to January seasonal period (See chapter 4 for detailed analysis of labour utilisation).

In Tables 5.4 and 5.5, we present the daily per capita earnings and consumption expenditure estimates predicted in the base models and those calculated using the LSMS-IHS3 data, respectively.

Table 5.4: Base models' prediction of per capita daily expenditure and earnings

Type of household	Per capita daily income ($)	Per capita daily cash consumption ($)	Per capita daily calorie consumption ($)	Per capita daily expenditure on farm inputs ($)	Per capita daily total expenditure ($)	Downward adjustment of cash & caloric consumption at base (%)
Dimba	0.40	0.28	0.07	0.02	0.37	5
Poor female headed	0.33	0.25	0.07	0.01	0.33	10
Employed	0.97	0.67	0.16	0.12	0.95	0
Non-farm Enterprises	0.71	0.47	0.11	0.09	0.68	0
Remittances & other income	0.70	0.46	0.11	0.07	0.64	0
Credit	0.64	0.38	0.11	0.12	0.61	0
Poor male headed	0.39	0.28	0.07	0.02	0.37	10

Notes: Result are presented for the seven types of households. The last column shows downward adjustment in the base level of consumption of cash and calories for households that cannot find a feasible solution at base. Adjustment of consumption is at 5% intervals.

Table 5.5: Per capita daily expenditure and earnings calculated from the LSMS-IHS3 data set

Type of household	Per capita daily income ($)			Per capita daily expenditure ($)		
	Mean	Median	Std. Deviation	Mean	Median	Std. Deviation
Dimba	0.75	0.32	2.29	0.72	0.59	0.49
Poor female headed	0.45	0.23	1.66	0.76	0.56	0.58
Employed	1.27	0.68	2.53	1.08	0.89	0.84
Non-farm Enterprises	0.93	0.42	2.22	1.07	0.91	0.68
Remittances & other income	1.06	0.53	5.24	1.17	0.96	0.92
Credit	0.80	0.43	1.48	1.02	0.76	0.81
Poor male headed	0.44	0.26	1.11	0.84	0.64	1.09
Total	0.71	0.34	2.35	0.92	0.71	0.89

Notes: Income includes sale of crops, value of food consumed from own production, earnings from employment, remittances, business enterprises and all other income sources

Across all household groups, the model estimates that the daily per capita earnings and total consumption expenditure is less than US$ 1 a day[3]. With the exception of the "employed" type of household, the predicted consumption levels are below the consumption levels calculated from the LSMS-IHS3 in Table 5.5. The models' low predictions of consumption expenditure in comparison to the LSMS-IHS3 estimates are likely to arise from the downward adjustments in cash and caloric requirements allowed in the models in order to find feasible solutions.

In addition, errors often associated with the gathering of consumption data, such as in the estimation of the value of good consumed or from recall bias, may lead to the differences in the estimated consumption expenditures in the LSMS-IHS3 data, resulting in an overestimation. However, the conventional view is that in large household surveys, consumption data is often more reliable than income, especially in countries where income is highly seasonal, and people tend to forget due to long recall periods (Deaton 2003).

Interestingly, the findings in Table 5.5 show that the calculated income and expenditure from the LSMS-IHS3 data is systemically different. Across all household types, consumption expenditure is nearly twice as much the income estimates on the median coefficients, thus revealing inconsistencies between income and consumption data gathered in the LSMS-IHS3 survey.

On one hand, information on income maybe underreported, and thus the calculated income is lower than consumption expenditure estimates. On the other, both data and income and consumption expenditure may be inaccurate due to issues arising from misreporting and recall bias among others.

The lower daily per capita consumption estimates predicted by the base models can also be compared with official poverty estimates, most of which are also based on the LSMS-IHS3 data. According to the 2010/11 Malawi's national poverty line, 50.7% of the population were poor and 25% were ultra-poor (National Statistical Office (NSO) 2012a). The Malawi national poverty line defined poor households as those with an annual per capita consumption below MK 37,002 (approximately $0.66 per person per day), and those whose annual per capita consumption is less than MK

[3] In 2010/2011 150 Malawi Kwacha were approximately equivalent to US$ 1.

22,957 (approximately $0.42 per person per day) are considered ultra-poor (National Statistical Office (NSO) 2012a).

In our analysis, the poorest groups of households, and who constitute 59.7% of the sample, the "dimba", the "poor female headed" and the "poor male headed", all fall within the ultra-poor category.

This discrepancy between our models' prediction and the Malawi's government poverty level estimates is likely to be as a result of underreported income or possible errors in the consumption expenditure data in the LSMS-IHS3 survey data. As we noted in Table 5.5, the calculated income is lower than the consumption expenditure, indicating that the LSMS-IHS3 income and consumption data is incompatible. Another explanation for the high levels of poverty in our models predictions arises from the restriction in the models that closing cash and maize stocks must equal their opening stocks. This means that, over the course of the year, consumption expenditure equals income. Thus, if income is too low, consumption will also be low.

The main forms of income for the model households come from agricultural production, where we believe both yield and price information to be reliable, and from ganyu wage income, where our ceiling of 10% (and 15% among the "poor female headed" households in the pre-harvest periods) of total available labour supply is higher than actual ganyu levels reported within LSMS-IHS3. We also include income from employment in the skilled and semi-skilled labour markets with relatively higher wages. However, if either the incidence or value of other income streams is under reported within LSMS-IHS3 (e.g. remittances and income from business enterprises), this will cause the incomes of our household types to be too low.

In our analysis, we are confident that the model formulation captures all the income streams available to the different types of households. With the exception of income from business enterprises and from remittances where the values we adopt from the LSMS-IHS3 may be understated, all other sources of income which include income from crop sales and from employment in the informal ganyu and the formal labour market is calculated within the model.

Similarly, consumption of cash and calories based on the available income is computed within the model formulation. Our model prediction of income and consumption expenditure is therefore nearly equal (see Table 5.4). Income is however slightly above consumption resulting from the use of pre-harvest maize prices only to value consumption of own produced maize. In addition, maize carried forward from the previous season and consumed by households is also valued.

5.5 Limitations in the use of the mathematical programming model of farm households as a tool for external shocks and policy analysis

The key strengths of using a set of mathematical programming models of farm households in the current study is in their ability to incorporate into a single model framework the economic analysis of decision making in an agricultural production system, consisting of heterogeneous households and a combination of multiple on-farm and off-farm activities that use constrained resources such as labour, land, variable inputs, knowledge and capital resources over time (seasonal periods) to produce goods which are either consumed by the household members or marketed. However, there are a few limitations in our modelling approach.

First, our model formulation does not consider non-embedded risk analysis, such as stochasticity of prices and yields, or the effects of climate variability on farm level production and welfare.

Second, modelling multiple periods, activities and household groups, and the specification of constraints and opportunities for the different activities and across seasonal periods makes challenging demands in the model formulation and in the requirements for data on the various technical coefficients (for example the input and output relationships or yield for the various activities modelled, seasonal labour and input requirements per unit area, plant density and number of weeding operations), price coefficients (for both inputs and outputs across seasonal periods) and scale coefficients (for example interest rate, price mark-up and mark-downs, landholding, assets, calorific requirements, and pre-seasonal stocks of cash and grain stocks). Despite the high demand for data, a key advantage of using a programming model however is in its flexibility in the use of a wide variety of existing data sources where data in particular variables is patchy or unavailable in the primary data.

Third, four seasonal periods of between two and four months are specified in the model. However, some peak cropping activities such as planting and weeding are implemented within very short time frames, and therefore the estimated resource availability, such as family labour, over long seasonal periods may understate the effects of short-term losses of labour due to ill health on households' production choices.

Similar modelling approaches with short seasonal periods that accommodate for the length of key production activities may therefore produce different results. However, as already noted in chapter 3, model formulations with very short seasonal periods produce large matrixes and for each seasonal period, data on activities, input requirements and price coefficients is required, thus making them improbable in the current analysis due to the high demand for data.

Fourth, the unit of analysis in our modelling approach is the farm household. As such, our analysis does now allow for the differentiation of the welfare impacts of health shocks that affect different types of individuals within a household. For example, Yamano and Jayne (2004) found that in Kenya, households that suffered the death of a male head of household had significantly higher losses in the value of net agricultural output. In addition, the authors found that death of the head of household or spouse resulted in the inability of such households to replace the labour lost through mortality, but labour lost through the death of other adult members could be replaced by new entrants into the household, thus steadying the supply of family labour to agriculture.

Fifth, our model formulation does not explicitly model issues of aggregation and market interactions between the different types of households, either in the local informal rural, sectoral and national economies. Although such aggregation and interactions would provide insights into the behaviour of households within the wider context of a national rural economy or in the smallholder sector, and should be compatible with macro or national and sectoral estimates of resource use and production, such modelling procedures would require large data sets. The lack of reliable sources of data and information on many aspects of agricultural farm livelihoods and the trade-offs between the time required for developing a more sophisticated and complex CGE model for groups of rural farm households makes the exercise impractical, and is well outside the scope of our objectives in the current analysis. Such attempts however have been made in previous literature (see J. E. Taylor 2012; Filipski and Taylor 2012).

Finally, the process of validating the models formulation and outcomes is not only time consuming, but also fundamentally subjective. The choice of the validity tests, the criteria for passing those tests and the choice of model output to test is often at the discretion of the modeller. In addition, the models' outcomes are sensitive to changes in coefficient estimates, and relatively small changes can result in different outcomes. Consequently, programming models are often context specific and may not be directly applied in different contexts without further tests for validity as parameter estimates and specification of constraints and equations change. Nonetheless, B. A. McCarl and Spreen (2011) note that the effort to validate a model is in itself important as it reveals the strengths and weakness of a model in mirroring the system being modelled.

Chapter 6: Simulation models of the welfare effects of morbidity: results and discussion of findings

6.1 Introduction

This chapter presents the findings from the estimation of a set of non-linear programming simulation models that investigate the effects of morbidity on the welfare of poor rural farm households. In general, simulation models are tools designed to answer the "what if" question about the specific circumstances or policy options under investigation. They therefore effectively describe and predict the behaviour of the subjects (e.g. households) and their responses to the effects of external shocks.

In this analysis, we use simulation models to predict the welfare impacts of two types of health shocks among poor rural Malawian households. The shocks operate through losses in the amount of unskilled family labour and cash resources available to a household, via changes in cropping patterns, and the effects are estimated in terms of lost consumption.

In Malawi, health care services are government funded and free through district hospitals at the highest level, and local health centres and village health posts at the lower levels (M. L. Wilson et al. 2012). A parallel private health system also exists, together with shops and pharmacies that sell prescribed medication or over-the-counter.

In the descriptive analysis of the sources of health care in chapter 4 of this study, we find that poor households predominantly seek treatment from the free government health facilities. The findings show the importance of the free health facilities in meeting the health care needs of poor households, who would otherwise have to meet the cost of treatment, or risk deteriorating into more severe morbidity. But what would be the cost implication if treatment was not provided free? What would be the welfare implications of out-of-pocket payments by households that are already severely cash constrained and facing regular bouts of ill health?

A recent magazine article by Sightsavers, an international non-governmental organisation (NGO) that works in developing countries to treat and prevent avoidable blindness, pointed out a case in rural Malawi where beneficiaries of the free eye treatment could not meet the cost of transport to the treatment facility, estimated at US$ 2 per person per trip (Sightsavers 2016). The author's experience reveals the severity of poverty, where cash constraints would prevent access to potentially life changing treatment.

In this analysis, we consider three simulation scenarios. The first and second scenarios simulate the welfare effects of malaria in a situation where treatment for the disease is paid for from out-of-pocket payments in a private health care facility. The direct impacts of the different intensities of malaria are simulated by reducing the cash resources available to a household in the first seasonal period of the cropping year by up to MK 739.36 (approximately US$ 5), and unskilled labour is reduced by up to 30.6 hours.

In the third scenario, we simulate the welfare effects of HIV/AIDS using the monthly calculated cost of medication, laboratory tests and consultation fees of households with a patient infected by HIV/AIDS. Due to data limitations in the LSMS-IHS3, the estimated cost incurred by households with a HIV/AIDS patient are modest estimates of incidental expenses incurred by such households, and does not include the cost of accessing anti-retroviral therapy (ART). HIV/AIDS is a rarer but serious chronic conditions and the cost of care, such as the anti-retroviral therapy is provided free in Malawi.

In the case of HIV/AIDS, we simulate seasonal cash losses of up to MK 874.44 (US$ 5.8), and labour losses equivalent 50% of the time supplied by an adult male per seasonal period. In their study on the labour market and wage impacts of HIV/AIDS in rural Malawi, A. Dorward, Mwale, and Tuseo (2006) use a similar approach where the direct impacts of different intensities of morbidity due to HIV/AIDS are simulated by varying proportionate loss of skilled and unskilled family labour and increasing expenditure on treatment. The HIV/AIDS simulation scenario is different from the two malaria simulations in a number of ways. First, we simulate larger labour losses across the four seasonal periods of the cropping year. Second, although the cash losses are moderate, they occur across all the seasonal periods. Third, larger losses in labour result in losses in income from ganyu and thus reinforcing the cash constraints.

The findings of our analysis show that relatively small reductions of seasonal cash stocks have an impact on consumption expenditure. Further, the results of the simulation models provide insights into the differential production and consumption responses of the different types of households in reaction to the impacts of malaria and HIV/AIDS. A detailed insight into the findings is discussed in the subsequent sections.

The chapter is organised in the following order. Section 6.2 specifies the simulation scenarios investigated in this study. For each household group, the results of the simulation models for the effects of malaria and HIV/AIDS, and their impacts on cropping patterns, input use and consumptions expenditure are presented in section 6.3. The findings of the analysis are summarised in section 6.4.

6.2 Specification of the simulation scenarios

In this analysis, three simulation scenarios are considered with increasing levels of severity of morbidity to assess the differential production and consumption responses to ill health of the seven household types, and the welfare impacts of acute and chronic morbidity on poor rural farm households.

The first and second scenarios aim at investigating the welfare effects of varying but modest levels of acute ill health among poor rural farm households. To this end, we simulate the direct effects of different intensities of malaria by varying the supply of unskilled labour and cash resources to illustrate the effects of increasing severity of morbidity during the critical decision making first stage of the cropping season. In the third scenario, we simulate loses of unskilled labour and cash resources throughout the four seasons of the production cycle resulting from the effects of HIV/AIDS and the associated infections.

As earlier explained in chapter 5, this study investigates farmers' planned or strategic responses to the effects of ill health. Therefore, the first and second simulation scenarios consider labour and cash losses in the first period of the production year, November to January, only. In this analysis, the first seasonal period is considered the most critical as all farm investments, production and resource allocation decisions are made at this stage, and thus modelled as such. As a result, stochastic variations in labour and cash resources due to health shocks that occur after the first period would have no effect on the crop choices and resource allocation decisions that were already made in the first period. However, such shocks would have an effect on labour availability and consumption decisions in the subsequent periods.

In the third scenario, we investigate the effects of chronic diseases on the welfare of poor rural farm households. In this scenario, we simulate the impacts of the loss of productive unskilled labour and cash due to the effects of HIV/AIDS and the co-associated illnesses, such as pneumonia and tuberculosis, over the entire annual production cycle. In this scenario, we recognise that HIV/AIDS and the co-associated illnesses are chronic conditions whose impacts are likely to persist over long periods of time.

In the first two simulation scenarios, we chose to investigate the direct impacts of malaria on households' welfare due to the importance of the disease in the study area. In Malawi, malaria is endemic in more than 95% of the country and with a prevalence rate of 43% (Government of Malawi 2011; National Malaria Control Program (NMCP) [Malawi] 2005).

Although our analysis of the LSMS-IHS3 data shows high concentration of malaria among the lower age brackets that include children and infants (see chapter 4), its effects through the loss of productive time in recovery, caring for the sick and the cash implication where treatment is paid for cannot be understated. In the analysis of disease incidence using the LSMS-IHS3 data, the results show that of the total enumerated persons, 19% had an acute illness in the two weeks preceding the survey, and of the total persons with acute illness, 46% had malaria. A detailed analysis of malaria incidence and spread across age categories and seasonal periods is presented in chapter 4, and a review of the pathways through which malaria and HIV/AIDS interacts with agriculture is presented in chapter 2.

In the third scenario, we are cognisant of the direct and indirect impacts of HIV/AIDS on rural agricultural households. These arise through the reduction of human capital and cash resources as a result of morbidity and mortality of the HIV/AIDS infected persons. Globally, there has been significant progress against the HIV/AIDS pandemic due to the scaling up of the provision of ART through public funded health programmes. Malawi, a country with a HIV/AIDS prevalence rate of about 11% among adults aged between 15-49 years (National Statistical Office (NSO) and ICF Macro 2011) is no different. In 2004, Malawi started implementing a government funded free ART programme (Government of Malawi 2015).

Due to the provision of free ART care, recent studies that have attempted to estimate the cost of ART care have done so by estimating the costs at the health facilities level. For example, Tagar et al. (2014) investigated the facility-level cost of ART in a random sample of facilities in Malawi, Ethiopia, Rwanda, South Africa and Zambia. The authors estimated that in Malawi, the average annual cost of treating a patient is US$ 137. The estimated cost included medications, laboratory services, direct and indirect personnel, patient support, equipment and administrative services. Evidently, without the government support of free health care, such costs would be too large if passed on to poor households.

Despite the free provision of ART care services, HIV/AIDS patients may also face other costs. These may include transport to the health facility, foregone income in time spent visiting the health facilities and purchase of medications from private facilities or local pharmacies to treat opportunistic infections. However, with the exception of Pinto et al. (2013), there is a lack of recent studies that estimated the time and transport costs associated with the care for HIV/AIDS patients in Malawi.

Pinto et al. (2013) conducted a cross-sectional survey on patient characteristics and costs associated with accessing HIV/AIDS care among patients who received centralised care (CC) in a tertiary referral hospital and those who received decentralised care (DC) in five rural health centres in Zomba District, in Southern Malawi. The authors found that over 40% of HIV/AIDS patients spent between one and two hours on one-way travel to the health facility, and a waiting time at the health facility of up to seven hours on average was estimated.

Further, the authors estimated that for HIV/AIDS patients, the time and travel costs of seeking health care per visit was US$ 2.55 in CC and US$ 1.48 in DC, on average. The findings of Pinto et al. (2013) show that even in a system of free health care, patients still incurred costs in accessing health care, particularly travel related and the foregone income, and such costs are likely to be significant for poor households.

In Malawi, malaria and HIV/AIDS are some of the major health challenges, and therefore points us to the choice of our simulation scenarios. In addition, irrespective of the substantial reports of ill health among the enumerated persons in the LSMS-IHS3 data, our analysis of health care spending shows that on average a household spent approximately MK 55 (US$ 0.37) per household per month on health care (see chapter 4). The low level of health care spending originates from the presence of government funded free health care. But what if households had to pay for treatment of malaria privately?

To determine the welfare impacts of losses of unskilled labour due to the effects of malaria in the first and second simulation scenarios, we used the LSMS-IHS3 data to calculate the mean and median number of productive hours lost due to malaria infection and/or the associated care, in the two weeks preceding the interview. For this calculation, we selected all observations (n=84) interviewed in the first seasonal period, November of 2010 to January 2011, and who reported malaria infection in the two weeks preceding the interview. Labour losses were estimated for productive household members who provided unskilled labour. These included adult males and females, the elderly and children above the age of ten years. Children aged ten years and below are considered as non-productive members of a household and so their days of incapacitation are not considered.

Next, to estimate the cash losses due to malaria, we selected all observations that reported malaria infection in the two weeks preceding the interview, and sought treatment in a private health facility. Due to the small number of observations that sought treatment from a private health facility in the first seasonal period, we consider observations from across the four seasonal period (n=55). For these observations, we calculated both the mean and median value of out-of-pocket spending per household for the month in question (In the LSMS-IHS3 data, cash expenses on health care were recorded on a monthly basis whereas questions on health problems and their consequences for labour used a two-week recall period).

For the simulation of the third scenario, data on labour losses and the cost of treating HIV/AIDS and its associated conditions are unavailable in the primary LSMS-IHS3 data set. As such, we simulated labour losses by assuming a 50% loss of an unskilled adult male's productive time for each of the four seasonal periods through the year. For cash losses, we calculated the mean monthly spending on health care for all persons who reported HIV/AIDS and the co-associated infections in the twelve months preceding the survey, irrespective of the provider of treatment (private or government funded free health care facility). The cost estimated for HIV/AIDS care are conservative estimates that only include payments for prescription and non-prescription medicines, laboratory tests and medical consultations. Costs associated with ART care and transport to the health facilities are disregarded.

In as far as income foregone is accessing health care for HIV/AIDS is concerned, such losses in income are captured in models' formulation as loss in productive on-farm and off-farm labour and thus loss in crop income and that from ganyu. There can however in a context where labour is underemployed, loss of unskilled labour from one family member can generally be substituted by unskilled labour from another family member.

Table 6.1 summarises the information on labour and cash losses used in the simulations. In section 6.3, we present the results of the simulation models.

Table 6.1: Labour and cash losses for models' simulations

Simulation scenario	Number of observations within LSMS-IHS3	Cash and unskilled labour losses	
Effects of malaria (median estimates, November to January)	84	Labour (hours/household)	16.00
	55	Cash (MK/household)	400.00
Effects of malaria (mean estimates, November to January)	84	Labour	30.60
	55	Cash	739.36
Chronic effects of HIV/AIDS	36	Loss of adult male's labour by 50% per seasonal period (working hours)	
		November-January	247.50
		February-March	165.00
		April-June	264.00
		July-October	308.00
		Cash losses per seasonal period (MK/household)	
		November-January	655.83
		February-March	437.22
		April-June	655.83
		July-October	874.44

6.3 Welfare impacts of malaria and HIV/AIDS on poor rural agricultural households

6.3.1 Impacts on cropping patterns, input use and utilisation of family labour across the different types of households

In this part of our analysis, we present the results of the simulation models, which describe and predict the behaviour of households in their production and consumption responses to the increasing losses of unskilled family labour and cash resources as the effects of ill health increase with the severity of morbidity.

The simulation models for the different types of farm households are designed such that all decisions on investment in farm inputs (e.g. seed, fertilizer chemicals and structures), crop choices and allocation of the labour and land resources are made at the beginning of the first period of the production cycle, November to January. There are therefore no farm investments in the subsequent periods, other than utilisation of labour in the following growing, harvest and post-harvest periods. Consequently, in the economic analysis of a whole farm system in a production cycle with multiple periods, the first period is the most critical because key production and resource allocations decisions are made.

In the implementation of the dynamic ill health simulation problems in the current chapter, risk is treated as the loss of unskilled family labour and cash resources due to the effects of ill health during the critical decision making stage, the November to January seasonal period. This allows us to capture the effects of ill health on the decision making process. In our analysis, there is no attempt to simulate the effects of health shocks occurring after the first period of the cropping year, and the resulting sequential responses to embedded risk, such as reallocation of resources to minimise the impact of health shocks. In addition, we do not investigate non-embedded risk analysis arising from stochasticity of prices and yields, or due to climate variability.

The major emphasis of our study therefore is on planned or strategic approaches to shocks, and the adjustments made by farmers to their farm plans to minimise the effects of health shocks. These shocks are assumed to be known by the decision maker prior to the allocation of resources to production activities, and the expected losses in labour and capital are taken into consideration in the decision making process. Therefore, decisions on crop choices, intensity of production (including levels of purchased input use), and hiring out of family labour to the off-farm employment market are made subject to the available cash and labour resources. The assumption however could potentially underestimate the full impacts of health shocks faced by farm households. In reality, farmers have no perfect knowledge of impeding events and they respond to them as they unfold.

In the labour surplus but severely cash constrained types of households that this study investigates, effects of ill health, such as the loss of cash resources, are likely to be significant in the first period as they may affect farm investment and crop choices. On the contrary, effects of labour losses are likely to be less significant due to the abundance of labour within households.

In the first and second simulation models, we investigate the welfare impacts of cash and labour losses due to the effects of malaria in the first period of the production cycle. In the third scenario, we simulate the effects of HIV/AIDS, with cash and labour losses throughout the production cycle due to the chronic nature of the infection.

Our analysis of a whole farm optimization problem using a mathematical programming approach generates the best farm plan for each type of household, and one that guarantees attainment of the minimum level of consumption, and maximisation of utility through consumption of cash, calories and leisure time, given a set of constrained resources.

Table 6.2 presents the models' estimates of the level of cropping activities and investment in inputs as predicted by the three simulation models for the different types of households. For each type of household, the first row of the table shows the base case scenario (reported in chapter 5), while the subsequent rows report on the cropping activities and levels of input use that are predicted under the different simulation scenarios.

In the third scenario where we simulate cash and unskilled labour losses across all seasonal periods due to the impacts of HIV/AIDS, a feasible solution is not reached for the "poor female headed" type of household. An infeasible solution means that under the existing set of resource constraints, households in the poorest group, the "poor female headed", are not able to meet their basic consumption needs and therefore cannot function under the severely cash scarce conditions.

Table 6.2: Differential production responses to the effects of malaria and HIV/AIDS (and its associated infections) by household type

Type of household	Simulation scenario	Local maize & Cassava	Hybrid maize	Tobacco	Soybean	Pure Cassava	Total Inputs (MK/hh)
Dimba	Base	0.53 (49)	0.25 (23)	0.10 (9)	0.21 (20)	0.0	4,131.03
	Malaria 1*	0.54 (49)	0.25 (23)	0.10 (9)	0.20 (18)	0.0	4,305.93
	Malaria 2*	0.53 (49)	0.25 (23)	0.09 (9)	0.21 (20)	0.0	4,019.99
	HIV**	0.49 (45)	0.25 (23)	0.10 (9)	0.25 (23)	0.01 (1)	3,999.69
Poor female headed	Base	0.33 (46)	0.25 (35)	0.02 (2)	0.12 (17)	0.00	1,334.65
	Malaria 1	0.32 (45)	0.25 (35)	0.01 (1)	0.14 (19)	0.00	1,000.41
	Malaria 2*	0.34 (47)	0.25 (35)	0.01 (2)	0.12 (17)	0.00	1,123.73
Employed	Base	0.06 (7)	0.25 (29)	0.40 (46)	0.16 (18)	0.00	26,745.95
	Malaria 1	0.06 (7)	0.25 (29)	0.40 (46)	0.16 (18)	0.00	26,635.62
	Malaria 2	0.24 (28)	0.25 (29)	0.28 (32)	0.09 (11)	0.00	18,872.95
	HIV	0.13 (15)	0.28 (32)	0.36 (42)	0.04 (5)	0.06 (7)	24,616.25
Non-farm Enterprises	Base	0.27 (26)	0.25 (24)	0.31 (30)	0.20 (20)	0.00	21,171.43
	Malaria 1	0.30 (29)	0.25 (24)	0.30 (29)	0.18 (17)	0.00	20,590.12
	Malaria 2	0.40 (39)	0.25 (24)	0.28 (27)	0.10 (10)	0.00	19,204.98
	HIV	0.42 (40)	0.25 (24)	0.29 (28)	0.08 (7)	0.00	19,768.60
Remittances & other income	Base	0.57 (46)	0.25 (20)	0.24 (20)	0.17 (14)	0.00	16,732.17
	Malaria 1	0.58 (47)	0.25 (20)	0.24 (19)	0.16 (13)	0.00	16,441.49
	Malaria 2	0.60 (49)	0.25 (20)	0.23 (19)	0.15 (12)	0.00	16,107.11
	HIV	0.56 (46)	0.25 (20)	0.23 (19)	0.19 (15)	0.00	15,731.11
Credit	Base	0.32 (29)	0.25 (23)	0.38 (35)	0.15 (14)	0.00	28,852.25
	Malaria 1	0.34 (31)	0.25 (23)	0.37 (34)	0.13 (12)	0.00	28,204.88
	Malaria 2	0.37 (34)	0.25 (23)	0.36 (33)	0.12 (11)	0.00	27,549.92
	HIV	0.42 (38)	0.25 (23)	0.35 (32)	0.08 (7)	0.00	26,501.79
Poor male headed	Base	0.69 (70)	0.25 (26)	0.05 (5)	0 (0)	0.00	3,689.74
	Malaria 1	0.70 (71)	0.25 (26)	0.04 (4)	0 (0)	0.00	3,315.21
	Malaria 2	0.69 (70)	0.25 (26)	0.04 (4)	0 (0)	0.00	2,997.04
	HIV*	0.64 (66)	0.25 (26)	0.06 (7)	0.02 (2)	0.00	2,981.27

Notes: Results are presented for the seven types of households with varying severity of morbidity. “Base” is activity level and input use under base scenario, “Malaria 1” and “Malaria 2” are simulation for the effects of malaria using median and mean estimates of unskilled labour and cash resources, respectively. “HIV” represents labour and cash losses due to the effects of HIV/AIDS and associated infections. Area under each crop is estimated in hectares and the area as a proportion of the total land holding is in parenthesis. “hh” means household and “MK” is Malawi Kwacha (150 MK=US$ 1 in 2010/2011).

* and ** indicates 5% and 10% downward adjustment of cash and caloric consumption from the base level, respectively

As we already noted in the preceding chapters, the “poor female headed” type of household is multiply deprived, with the smallest landholding, low literacy levels, least amount of pre-seasonal stocks of maize and cash, high dependency ratio, and with the lowest value of livestock and physical assets. Consequently, as the cash constraints become tighter, the models are more likely to become infeasible. For this type of household, adoption of coping strategies such as seeking assistance from their social network, receipt of food aid and cash based interventions may be necessary to avoid destitution.

Perhaps not surprisingly, the results of the cropping patterns predicted in the simulation models are similar to those of the base scenario discussed in chapter 5, with little variation in the crop choices as the severity of morbidity increases. Across all simulation scenarios, our findings in Table 6.2 show that irrespective of the increasing effects of morbidity, production is concentrated to local maize intercropped with cassava in all household types with the exception of the “employed” type. In Malawi, maize is a key staple.

As our findings reveal, there are three basic dynamics in production responses to the effects of morbidity by the household groups. First, because of the reduction in the available stocks of cash due to ill health, households can afford fewer inputs and thus contract the area under production of the input intensive tobacco. Second, by reducing production of tobacco, and which has high return to capital and land, some of the poorer households are unable to meet their future income targets and thus they cut back on their current consumption expenditure. Third, for the “dimba” type of household, cash losses due to the less severe malaria prompts the households to sacrifice current consumption and thus increase input investment marginally in order to generate more future income from tobacco production.

The findings in Table 6.2 show that in the “remittances and other income”, “credit” and “poor male headed” types of households, there is a general decline in the level of investment in farm inputs and hence the area under tobacco production with increasing severity of morbidity. The “remittances and other income” and “credit” types of households steadily reduce investments in inputs but with no adjustment in the level of cash and caloric consumption.

For households in the "poor male headed" group however, the more severe effects of HIV/AIDS cause then to not only cut back on input investment, but also reduce their consumption expenditure by up to 5% from the base level, thus leaving the households worse off. In addition, "poor male headed" households shift to production of tobacco that is less input intensive.

Despite reducing the level of input investment, production of tobacco in the "credit" type of household remains relatively stable and is over 30% of the landholding irrespective of the increasing effects of ill health. Tobacco production among the credit borrowing households is driven by their access to inputs on credit, and the results demonstrate the importance of credit in cushioning farmers against shocks.

In the "poor female headed" type of household, we find a decline in input investment as a result of the effects of malaria. However, in the more severe malaria scenario (Malaria 2), households cut back on input investment by a lower magnitude, but they also adjust their consumption expenditure downward by up to 5%. Such a response shows that poor households that are not able to meet their capital requirements make sacrifices on current consumption as a coping strategy. As the effects of morbidity become severe from HIV/AIDS infection, there are much bigger losses in cash and unskilled labour across the four seasonal periods. Loss of income from ganyu is also higher (see Table A9, Appendix A). These cause more severe cash constraints and the poorest household type, the "poor female headed" has an infeasible solution.

For the "dimba" type of household, we find that in the less severe malaria scenario (Malaria 1), there is a marginal increase in the level of input investment for tobacco production. The increase is however accompanied by a 5% decline from the base level of cash and caloric consumption. Such as response indicates that as a result of the health shock, households in the "dimba" group sacrifice their current consumption instead of inputs. To meet their consumption requirements for the rest of the cropping year, they need to increase their tobacco production to increase their future income, but with lower level of current cash and caloric consumption.

Generally, we find that severely cash constrained households such as those in the "dimba, "poor female headed" and "poor male headed" groups have low input investment even at the base level and thus have relatively small portion of their land (less than 10% of total landholding) under tobacco production. As a result, their adjustment of the area under tobacco production is marginal and most of their production remains concentrated in local maize intercropped with cassava.

In addition, due to the total depletion of available cash resources particularly in the first seasonal period, a downward adjustment of between 5% and 15% in their level of cash and caloric consumption is necessary for the models to find feasible solutions in both the base and simulation scenarios. Among these poorer household types, we also find that the magnitude of change in the value of the farm inputs from the base scenario is not considerably different from the simulated cash losses in the first period of the production cycle, meaning that such changes are particularly in response to the cash losses from ill health rather than labour losses.

In the “non-farm enterprises” type of household, our findings show a decrease in input investment and in the amount of land under tobacco production due to ill health. Notably, households in this group respond to the more severe effects of HIV/AIDS by reducing the level of input investment by a smaller magnitude compared to their level of input adjustment in the more severe malaria (see Table A9). Such a response is triggered by larger losses in labour and thus ganyu income in the HIV/AIDS scenario.

Similar to the “non-farm enterprises” group, households in the “employed” group are predicted to decrease their production of tobacco and input investment. However, in the HIV/AIDS scenario, the “employed” household group produces more tobacco than in the severe malaria scenario (Malaria 2) to compensate for the income losses resulting from loss of unskilled family labour that is hired out to the ganyu labour market. At the same time, households in this groups also increase production of hybrid maize and pure cassava enters the models to boost income.

Surprisingly and contrary to expectation, we note that in the severe malaria scenario, there is a local tipping point in the model prediction, with large downward adjustment in the level of input investment and thus area under tobacco production. We deem such a change implausible and do not infer any conclusion from the severe malaria scenario for the “employed” household group.

Overall, we find that the economically better off household groups, the “employed”, “non-farm enterprises”, “remittances and other income” and “credit” have a steady production of tobacco in relatively large portions of their land irrespective of the increasing effects of morbidity. Their production of an input intensive crop such as tobacco is financed from income generated from their alternative livelihood strategies.

The results of our analysis show that with the exception of the severe malaria simulation scenario for the "employed" type of household, the predicted crop choices and adjustments in the level of input investment for the rest of the simulation scenarios are plausible, and households generally respond to the increasing effects of ill health by reducing investment of inputs and the area under tobacco.

Production is also concentrated to local maize intercropped with cassava since they have no input investment. Further, we find that even in the HIV/AIDS scenario with more severe cash and labour losses, the impacts on cropping choices and input investment are not dramatically different compared to the malaria simulation scenario. There is almost no additional impact from the labour losses other than loss of income from ganyu.

We therefore conclude that the impacts of morbidity on farm investment and cropping choices are largely transmitted through losses of cash rather than labour. All groups of households have surplus labour and as such, they respond to the effects of ill health by reallocating their available labour to suit the production choices that are determined by the available capital resources.

Table 6.3 summarises labour allocation to on-farm and off-farm employment across the different types of households and simulation scenarios. The results show that across all household types, labour is not depleted and less than half of the available labour is employed on-farm in most of the simulation scenarios. In the "dimba" type of households however, labour utilised in the second cropping season (dimba) is not accounted for in the model estimations.

In section 6.3.2, we discuss the impacts of morbidity in consumption expenditure and earnings.

Table 6.3: Base and simulation models' allocation of labour to on-farm and off-farm activities and leisure time

Type of household	Simulation scenario	% own farm labour	% ganyu labour	% (semi) skilled labour	% total on & off-farm labour	% leisure time
Dimba	Base	36	10	0	47	53
	Malaria 1	37	10	0	47	53
	Malaria 2	37	10	0	47	53
	HIV	46	10	0	56	44
Poor female headed	Base	33	12	0	45	54
	Malaria 1	33	12	0	45	54
	Malaria 2	33	12	0	45	54
	HIV	47	12	0	59	40
Employed	Base	38	10	23	71	28
	Malaria 1	38	10	23	71	28
	Malaria 2	34	10	23	68	32
	HIV	44	10	29	83	16
Non-farm Enterprises	Base	43	10	4	57	42
	Malaria 1	43	10	4	57	43
	Malaria 2	42	10	4	56	43
	HIV	53	10	5	68	32
Remittances & other income	Base	40	10	0	51	49
	Malaria 1	40	10	0	50	49
	Malaria 2	40	10	0	50	49
	HIV	49	10	0	59	41
Credit	Base	42	10	4	56	43
	Malaria 1	42	10	4	56	44
	Malaria 2	42	10	4	56	44
	HIV	51	10	5	65	34
Poor male headed	Base	32	10	0	43	57
	Malaria 1	32	10	0	43	57
	Malaria 2	32	10	0	43	57
	HIV	41	10	0	51	48

Source: Author's calculations

6.3.2 Impacts on consumption expenditure

In this section, we discuss the welfare changes resulting from the effects of morbidity and the mechanisms through which they are transmitted to poor rural farm households. Specifically, we highlight the differential production and consumptions responses of the seven household types to the effects of increasing effects of morbidity, and thus resulting into changes in the households' consumption expenditure and earnings.

In development economics literature, indicators of households' welfare and poverty status are often conceptualised with reference to consumption expenditure and/or income sources at varying frequencies (Ravallion 1996; Ravallion 2015). To determine welfare changes in this study, we examine the changes in expenditure by consumption categories that include calories, cash and farm inputs. In addition, we examine changes in earnings, which include income from sales of farm output, value of food from own production that is consumed by households, income from off-farm employment in the informal ganyu and the (semi) skilled rural labour markets, and revenue from remittances, business and investments.

In the examination of the welfare impacts of varying levels of loss of unskilled labour and cash due to ill health, four main production and consumption responses emerge. These are: (1) reduction in the value and absolute amounts of farm inputs used at an increasing magnitude to cope with the increasing effects of morbidity; (2) reduction in income earned from the sale of farm output as a result of changes in the level of investment in inputs and reduced land under tobacco, which is input intensive but with high returns to capital; (3) hiring out of labour to the ganyu labour market up to the maximum allowed limit (10% of total household's labour supply for all other household groups, and up to 15% in the pre-harvest periods for the "poor female headed" type of household) but there are ganyu income losses that are proportional to the amount of time hired out in the HIV/AIDS scenario; and (4) reduction in the level of consumption of cash and calories for households that fail to meet their required consumption levels in at least one of the four seasonal periods modelled.

Table 6.4 summarises the changes in income, expenditure on farm inputs and in the consumption of cash and calories by the different types of households, and with increasing severity of morbidity. The results present differences in the magnitude of the reported parameters from the base models' results in percentage terms, and the last column in the table presents the changes in the welfare indicator, the per capita daily total consumption expenditure.

Table 6.4: Individual households' welfare effects of morbidity and the effects transmission mechanisms presented as percentage loss from the base estimates

Type of household	Simulation scenario	Per capita daily income	Expenditure on farm inputs	Per capita daily cash consumed	Per capita daily calorie consumed	Downward adjustment of consumption	Per capita daily total expenditure
Dimba	Malaria 1	0.6	4.2	-0.8	1.2	5.0	-0.1
	Malaria 2	-0.3	-2.7	-1.4	0.3	5.0	-1.1
	HIV	-3.4	-3.2	-7.2	-5.5	10.0	-6.7
Poor female headed	Malaria 1	-1.1	-25.0	-1.1	-1.5	0.0	-1.8
	Malaria 2	-0.8	-15.8	-2.1	-0.3	5.0	-2.0
Employed	Malaria 1	-0.1	-0.4	-0.3	-0.1	0.0	-0.3
	Malaria 2	-5.9	-29.4	-3.7	-0.7	0.0	-6.3
	HIV	-2.8	-8.0	-3.2	-5.4	0.0	-4.2
Non-farm Enterprises	Malaria 1	-0.5	-2.7	-0.4	-0.5	0.0	-0.8
	Malaria 2	-1.8	-9.3	-1.7	0.0	0.0	-2.5
	HIV	-2.9	-6.6	-4.8	-3.8	0.0	-4.9
Remittances & other income	Malaria 1	-0.3	-1.7	-0.4	-0.4	0.0	-0.6
	Malaria 2	-0.6	-3.7	-0.9	-0.7	0.0	-1.1
	HIV	-2.8	-6.0	-4.8	-4.1	0.0	-4.8
Credit	Malaria 1	-0.5	-2.2	-0.6	-0.6	0.0	-0.9
	Malaria 2	-1.1	-4.5	-1.1	-1.4	0.0	-1.9
	HIV	-4.0	-8.1	-5.3	-7.8	0.0	-6.3
Poor male headed	Malaria 1	-0.7	-10.2	-0.8	-1.3	0.0	-1.3
	Malaria 2	-1.4	-18.8	-1.5	-2.4	0.0	-2.4
	HIV	-4.9	-19.2	-7.8	-8.8	5.0	-8.5

Source: Author' calculations

Notes: In the model formulation, adjustments in consumption of cash and calories per seasonal period is at 5% intervals.

The findings presented in Table 6.4 show that, in terms of change in the total per capita daily expenditure, investment in farm inputs is the main driver of changes in welfare, through the input-output multiplier effects. The results show a clear relationship between the proportionate change in investment in farm inputs and the subsequent welfare losses. The input-output multiplier effects differ across the household types, mainly due to differences in the changes of the level of production of input intensive cropping activities such as tobacco, and thus loss in income from sale of tobacco.

With the exception of the “dimba” households whose investment in farm inputs increases marginally in the less severe malaria scenario, the findings show that increasing effects of morbidity result in reductions in the level of investment in farm inputs and thus earnings, across all household types.

In the “dimba” group, households respond to the effects of less severe malaria by reducing their level of consumption of cash and calories by up to 5%, and increasing their level of input investment for tobacco production marginally. Consequently, the area under tobacco production increase from 0.097 ha at the base level to 0.102 ha (see Table 6.2) in the less severe malaria simulation scenario, resulting in a rise in income (Table 6.4).

Among the “remittances and other income”, “credit” and “poor male headed” households, there is steady decline in input investment, and hence income, and thus resulting in loss of welfare by increasing magnitudes with the severity of morbidity. In the “employed” and “non-farm enterprises” groups, we observe reduction in input investment by lower magnitudes to allow more tobacco production and compensate for losses in income from ganyu employment due to loss of unskilled labour in the HIV/AIDS scenario. In the “poor female headed” type of household, severe malaria results in the downward adjustment of consumption of cash and calories by up to 5%.

Overall, our findings show that for the majority of the household types, the magnitude of loss in the value of farm inputs is highest in the HIV/AIDS simulation scenario. As a consequence, such households are observed to experience larger losses in income and consumption of cash and calories in the HIV/AIDS scenario, and thus higher welfare losses. On average, expenditure on inputs in the HIV/AIDS simulation scenario is reduced by between 3% and 19%, while welfare losses are between 4% and 8.5% (see Table 6.4).

As we already noted in the base models’ results in section 5.4 of chapter 5, the “dimba”, “poor female headed” and “poor male headed” types of households appear to be extremely poor, and in the estimation of the base model, allowance for downward adjustment in cash and caloric consumption are made, and further adjustments are allowed for if a feasible solution is not found under the base level consumption requirements. In the HIV/AIDS simulation scenario, the “poor male headed” type of households has the largest loss in welfare (8.5%) while a feasible solution is not found for the “poor female headed” group. Similarly, “dimba” households have relatively higher welfare losses (6.7%) in the HIV/AIDS simulation scenario compared to the better off households.

In addition to the losses in earnings and investment in inputs, households in the “dimba” and “poor male headed” groups also make a downward adjustment in the level of consumption of cash and calories as a coping strategy to the effects of HIV/AIDS. Despite acquiring inputs through borrowing, the “credit” type of households who are also asset poor are observed to experience welfare losses of up to 6.3% in the HIV/AIDS simulation scenario.

Finally, as indicated in Table 6.2, the poorer households have low investment in inputs originating from severe cash constraints across all simulation scenarios. With increasing effects of morbidity, they respond by reducing inputs, and the input-output multiplier effects result in more severe cash constraints, thereby triggering welfare losses. Their total daily per capita consumption expenditure over the base and all the simulation scenarios is below the Malawi’s national ultra-poor poverty line of less than US$ 0.42 (National Statistical Office (NSO) 2012a), and further tightening of the cash constraints would result in infeasible solutions.

Table 6.5 summarises the per capita total daily earnings and consumption expenditure predicted by the models for the different types of households. From our analysis, the per capita daily total consumption estimates predicted by the models indicate that at the base level and simulation scenarios, 59.7% of the sample are below the Malawi’s ultra-poor level with per capita daily consumption below US$ 0.42. In addition, 76% of households have their per capita daily consumption below the national poverty level of US$ 0.66.

As we noted in chapter 5, our models’ prediction of poverty levels is above the Malawi’s government estimates from the LSMS-IHS data where 25% of the population were estimated as ultra-poor and 50.7% as poor (National Statistical Office (NSO) 2012a). A simple explanation to the difference is in the quality of data and in the computation of consumption expenditure as already explained in chapter 5. In section 6.4, we reflect on the findings of the simulation models.

Table 6.5: Base and simulations models prediction of per capita daily total income and consumption expenditure

Type of household	Simulation scenario	Per capita daily total income (MK)	Per capita daily total income (US$)	Per capita daily total expenditure (MK)	Per capita daily total expenditure (US$)	Downward adjustment in consumption of cash and calories (%)
Dimba	Base	59.65	0.40	54.77	0.37	5
	Malaria 1	60.03	0.40	54.70	0.36	10
	Malaria 2	59.50	0.40	54.16	0.36	10
	HIV	57.63	0.38	51.10	0.34	15
Poor female headed	Base	49.51	0.33	49.57	0.33	10
	Malaria 1	48.98	0.33	48.70	0.32	10
	Malaria 2	49.11	0.33	48.56	0.32	15
Employed	Base	145.09	0.97	142.81	0.95	0
	Malaria 1	144.93	0.97	142.40	0.95	0
	Malaria 2	136.58	0.91	133.77	0.89	0
	HIV	141.09	0.94	136.86	0.91	0
Non-farm Enterprises	Base	106.92	0.71	101.88	0.68	0
	Malaria 1	106.37	0.71	101.10	0.67	0
	Malaria 2	105.01	0.70	99.38	0.66	0
	HIV	103.77	0.69	96.90	0.65	0
Remittances & other income	Base	105.35	0.70	95.73	0.64	0
	Malaria 1	105.06	0.70	95.19	0.63	0
	Malaria 2	104.71	0.70	94.64	0.63	0
	HIV	102.39	0.68	91.16	0.61	0
Credit	Base	96.27	0.64	91.09	0.61	0
	Malaria 1	95.81	0.64	90.24	0.60	0
	Malaria 2	95.19	0.63	89.40	0.60	0
	HIV	92.41	0.62	85.37	0.57	0
Poor male headed	Base	58.76	0.39	54.87	0.37	10
	Malaria 1	58.32	0.39	54.15	0.36	10
	Malaria 2	57.94	0.39	53.54	0.36	10
	HIV	55.91	0.37	50.20	0.33	15

Source: Author' calculations

6.4 Summary of findings

This chapter set out to present the results of the simulation models investigating the welfare effects of increasing levels of morbidity. Our analysis reveals the following key findings. First, the relationship between investment in farm inputs and welfare changes is evident. As the findings show, reduction in the investment in farm inputs affects households' welfare by a multiplier effect.

Over the simulation scenarios, households respond to the increasing effects of morbidity by reducing their investment in farm inputs. Subsequently, the level of production of input intensive but high return to capital crop choices such as tobacco declines, and hence resulting in the reduction of income from crop sales.

In addition, labour losses, particularly in the HIV/AIDS simulation scenario results in losses in ganyu income proportional to the reduction in the amount of time hired out to the ganyu labour market. As the amount of income generated from crop sales and ganyu decline, the poorer households, the "dimba", "the poor female headed" and the "poor male headed" are unable to satisfy their seasonal consumption requirements in at least one of the four seasonal periods, and hence cut back on their consumption of cash and calories at the base level and across all the simulation scenarios.

Second, in all groups of households, there is abundant supply of unskilled family labour and households primarily use family labour. As shown in chapter 4, landholdings are relatively small, with a sample average of one hectare per household. The land-to-labour ratio is low and there is therefore little demand for hired in labour. Households respond to the increasing effects of morbidity by reallocating the available labour to the crop choices that are feasible under each simulation scenario. The findings therefore show that the welfare effects of ill health are transmitted to poor households through the loss of cash resources rather than labour.

It is however important to note that our model formulation only accounts for labour allocation to on-farm production activities and off-farm employment by household members of productive age. Labour allocation to domestic chores and households' reproduction activities is not incorporated in the model and consequently, some of the labour resource that is assumed to be reallocated to agriculture may indeed be used in other domestic activities. Irrespective of such reallocation, our results reveal evidence of labour abundance and as Table 6.3 shows, all types of households do not completely deplete their labour resources even in the most severe HIV/AIDS morbidity scenario. It is interesting to compare our findings with those of Beegle

(2003), who found that in the Kagera region of Tanzania, prime-age mortality resulted in reductions in the supply of labour to male dominated crops (coffee and bananas) in the short-run. In the long-run however, supply of labour within households stabilised as lost labour was replaced by the surviving members of the households. Our study however does not incorporate gender disaggregated roles.

Third, our models simulate relatively small losses in cash resources in the first period of the production cycle (up to MK 739.36 or US$ 4.9), but there are discernible welfare losses triggered by the effects of such modest losses. In addition, in the simulation of cash and labour losses due to the effects of HIV/AIDS, our findings indicate that with the exception of the "employed" type of household, the welfare effects of long-term conditions that persist over the entire production cycle are larger compared to the effects of malaria whose effects are short-term and simulated in the first period of the cropping year only. However, we cannot understate the significance of the effects of malaria on livelihoods. Although the simulated malaria effects are modest and short-term, they feed through into households' consumption expenditure over the entire production year.

Fourth, although the welfare changes resulting from the impacts of ill health may not be large enough in absolute values to push households into more severe poverty, our findings show that modest changes in the available cash and labour resources trigger adjustment in the investment in farm inputs and therefore cropping patterns or the level of production of certain crops. For the poorer types of households, such changes result in downward adjustment of consumption of cash and calories to levels that are lower that the basic level of consumption.

For example, over the base and the all the simulation scenarios, households in the "dimba", "poor female headed" and "poor male headed" groups drop their consumption of cash and calories by between 5% and 15%. This adjustment in consumption implies that in at least one of the four seasonal periods, households in these groups cannot meet their base level of consumption. For the "poor female headed" group, the households cannot function under severe cash and labour constraints results from the effects of HIV/AIDS and the associated infections.

Finally, the results of the simulation models show differences in households' responses to different levels of morbidity. There are however no systematic differences between the responses of the better off ("employed", "non-farm enterprises", "remittances and other income" and "credit") and the poorer types of households ("dimba", "poor female headed" and "poor male headed"). We therefore conclude that our analysis of the seven types of households, and whose classification is adopted from previous modelling activities of Andrew Dorward in rural Malawi (A. Dorward 2002), is critical in revealing differential production and consumption responses to the effects of morbidity across different types of households.

Chapter 7: Conclusion

7.1 Rationale of the study

This study set out to extend the empirical understanding of the linkages between health and agriculture in farm households in poor economies, and investigate the welfare impacts of morbidity in poor farm households, with particular reference to Malawi. A comprehensive review of literature on the pathways through which health and agriculture interact is presented in chapter 2. In chapter 3, we explain the methodological approaches adopted in the investigation of the health and agriculture interactions. Chapter 4 uses core data from the LSMS-IHS3 for Malawi to describe the sample's characteristics, including patterns of time utilisation and occurrence of morbidity.

In addition, we estimate deterministic models of the different types of farm households in chapter 5, and in chapter 6, we use simulation models to determine the magnitude of change in the welfare of poor farm households resulting from seasonal losses of cash and unskilled household labour due to the effects of malaria and HIV/AIDS. Welfare in the current study is measured by the consumption expenditure on food and non-food items.

In the conceptualisation of the current study, we found that while there has been a growing body of literature on the critical health, agriculture and welfare linkages, many of the empirical studies neglect the seasonality of agriculture production in many agrarian low income economies, and the associated patterns of income and consumption expenditure, resulting from seasonal financial and labour constraints. Additionally, many of the existing studies treat poor rural farm households as a homogenous group, ignoring differences in asset endowments, demographic characteristics and access to alternative livelihood strategies. Further, most of the previous studies adopt econometric techniques that often use reduced form models, and thus only measure the welfare outcomes, but do not determine the pathways through which the impacts on welfare are transmitted.

This study therefore sought to extend the methodological approaches in modelling farm households through the adoption of an extended farm household model structure that incorporates both the seasonal nature of agricultural production and heterogeneity of poor rural farm households. In addition, our model formulation allows for the estimation of the welfare impacts of morbidity as well as the pathways through which they are transmitted.

To establish a causal relationship between morbidity and welfare losses in farming communities, the study uses the agriculture farm household modelling approach, and adopts a farm household model that integrates into a single model framework critical aspects of rural agricultural livelihoods. In addition to the seasonality of agricultural production and heterogeneity of poor rural households, other livelihood aspects integrated into the model include multiple on-farm and off-farm activities, interaction with imperfect markets and labour market constraints, households' food security objectives and non-separability of consumption and production decisions.

The farm household model builds on previous modelling activities of Andrew Dorward (A. Dorward 1999; A. Dorward 2003; A. Dorward 1994; A. R. Dorward 1996; A. Dorward and Parton 1997; A. Dorward 2012; A. Dorward 2006), and is estimated using a set of dynamic non-linear programming models of the heterogeneous groups of farm households. In the base case, we use the models to solve deterministic optimization problems for the different types of rural agricultural households, and then examine three alterative ill health effects scenarios that simulate the welfare impacts of different levels of morbidity.

In the first and second scenarios, we simulate the welfare effects of different levels of losses of unskilled family labour and cash resources in the first seasonal period of the production cycle due to the effects of malaria. The modest labour and cash resource losses are calculated from the LSMS-IHS3 data, and the cash losses represent out-of-pocket spending for treatment in a private health facility.

We simulate the effects of malaria since it is endemic in most of Malawi. Indeed, the findings from the descriptive analysis presented in chapter 4 show that 46% of persons with acute illness in the two weeks preceding the interview reported to have been infected with malaria/fever. In Malawi, poor households are heavily dependent on free government funded health care facilities for treatment. Our simulations examine the potential welfare implications of out-of-pocket payments in the absence of the government policy on free health care.

In the third scenario, we simulate the welfare effects of cash and unskilled labour losses throughout the production year due to the effects of HIV/AIDS. From our analysis in chapter 4, we found that 11% and 15% of all the cases of chronic conditions among adult men and women respectively, were HIV/AIDS related. Compared to malaria, HIV/AIDS is rarer but with more serious effects on livelihoods.

In the HIV/AIDS simulation scenario, loss of unskilled labour is equivalent to 50% of the time supplied by an unskilled adult male per seasonal period. For cash losses, we calculated the incidental expenses incurred by households with a HIV/AIDS patient. The calculated cost per seasonal period, however, excludes the cost of anti-retroviral therapy (ART), which is provided free in government funded health facilities, because the majority of Malawian rural households simply could not afford it.

Compared to the malaria scenarios, the HIV/AIDS simulation scenario entails expenditure in every period throughout the year, rather than just in the November-January cropping period, and a much greater loss of household labour throughout the cropping year. As a result of the larger losses in labour, there are also losses in income from ganyu in this scenario.

7.2 Main findings

To begin with, our review of the multiple and bi-directional linkages between agricultural and health in chapter 2 provides a conceptual framework that is key to our understanding of the interrelationships between morbidity and the poor people's livelihoods outcomes. We show that there are multiple and bi-directional pathways through which agriculture and health interact. On one hand, agriculture provides nourishment and income that makes households resilient to shocks. However, agricultural systems can also have adverse health impacts through low dietary diversity and nutrients deficiency, exposure to disease pathogens and environmental degradation.

On the other hand, morbidity that afflicts the agricultural labour force may negatively affect agricultural production through loss of productive labour and decreased ability to perform manual farm work, reduced employability hence loss of income, and (cash) capital losses in coping with the consequences of ill health. In the absence of free health care, expenditure on health care may reduce cash resources that might otherwise be used in farm inputs investment.

Our review of existing literature reveals that although numerous studies have identified the critical importance of agriculture and health linkages, there are gaps in literature as many studies neglect the seasonality effects and the consequent seasonal cash and labour resource constraints. In addition, many authors use econometric techniques that limit the ability of the models to investigate both the outcomes and pathways through which the effects of health shocks are transmitted to poor rural farm households.

From the results of the descriptive analysis in chapter 4, we find that while the initial classification of households through cluster analysis presented seven different types of households, two broad categories emerge based on the social economic characteristics. These are the poorer households that include the "dimba", "poor female headed" and "poor male headed" types of households, and constitute 60% of the sample. They are characterised by low levels of consumption expenditure, lack of skilled or semi-skilled persons within the household, low literacy levels and low value of asset holdings.

In the process of calibrating and estimating base models of the seven types of households in chapter 5, difficulties in getting the models to find feasible solutions highlighted how desperately cash constrained poor households in Malawi are. For example, we find that for the poorer household types, a downward adjustments of the minimum consumption requirements of cash and calories, particularly in the pre-harvest periods, was required in order to get the models to solve.

In the formulation of the model, minimum caloric consumption requirements are set below the international standards for adults engaged in physical labour, while cash requirements are equated to the actual cash expenditure (includes expenditure on non-staple and non-food items) of the poorest type of household, the "poor female headed". Consequently, the downward adjustment of the basic cash and caloric consumption levels by the poorer households means that even at the models' prescribed minimum levels of consumption, the poorer households find it difficult to meet the basic consumption levels, more so in the pre-harvest periods.

In Malawi, the pre-harvest seasonal periods, November to January and February to March, are characterised by low food stocks and high prices of key staples such as maize. In addition, the risk of infections from diseases such as malaria increases as conditions for pathogen development are conducive, due to a combination of rainfall, high temperatures and humidity. In the February to March seasonal period, households face low demand and wages for ganyu labour, the only alternative livelihood strategy for the poorer groups of households.

The findings from the LSMS-IHS3 and field work also show that Malawi's non-farm rural economy is underdeveloped with limited opportunities for off-farm labour. There is also a high population density and small landholdings, and hence labour is abundant.

The results of the simulation models in chapter 6 show varied dynamics in the responses of the poorer households to the effects of morbidity. Under the two malaria simulation scenarios, "poor female headed" and "poor male headed" groups reduce their investment in farm inputs thereby reducing production of tobacco which is input intensive but with the highest returns to capital among the crop choices predicted by the models. The "dimba" type of household has a marginal increase in input investment and area under tobacco production in the less severe malaria scenario (Malaria 1), but accompanied by a 5% drop in cash and caloric consumption expenditure.

In the HIV/AIDS simulation scenario however, reduction in investment in farm inputs alone is not sufficient to cope with the consequences of the disease, and for the poorer group of households, further downward adjustment in the level of cash and caloric consumption is necessary, particularly in the first seasonal period.

In addition to input expenditure in the first period of the production cycle, households also face high food expenditure as prices of key commodities are on the rise and food stocks from own production are low or depleted. Consequently, the effects of morbidity are likely to be more severe in the first and second seasonal periods.

Although our model formulation does not fully incorporate assets as essential resources that households could use to cope with the increasing effects of ill health, we find very low levels of livestock and other asset holdings by households in chapter 4. As a result, the poor households' ability to cope with the effects of ill health is diminished.

Physical assets or livestock can be sold to replace the cash lost in meeting health care expenditure. In their examination of the interactions between health and farm labour productivity, Asenso-Okyere, Chiang, and Andam (2011) conclude that asset portfolio, including human, financial and physical assets, greatly influence the ability of a households to cope with health shocks.

For the poorest household, the “poor female headed” type, we find that more severe cash and unskilled labour losses due to the effects of HIV/AIDS result in an infeasible model solution. An infeasible solution means that under the severe seasonal cash constraints, households in the “poor female headed” group are unable to meet their basic consumption requirements in at least one of the four seasonal periods of the cropping year, particularly the pre-harvest periods. To avoid destitution due to severe effects of ill health, such household would require food or cash aid through social cash transfer programmes or aid through their social networks.

In contrast, the economically better off types of households which include “employed”, “non-farm enterprises”, “remittances and other income” and “credit” have higher consumption expenditure, alternative livelihood strategies, higher value of asset holdings, higher literacy levels and skilled or semi-skilled persons within the household. The alternatives sources of non-farm income are important in increasing households’ resilience to the effects of ill health.

In the base model estimation, their pre-seasonal stocks of cash and grain, combined with their income from non-farm sources, are sufficient to cover consumption and farm investment over the pre-harvest seasonal periods. Under the malaria and HIV/AIDS simulation scenarios, we observe that reduction in input investment and in the production of tobacco, which is both capital and labour intensive but with higher returns to capital, is enough to absorb the cash losses resulting from the effects of ill health, and there is therefore no adjustment in the consumption levels.

For the “credit” type of household, investment in farm inputs is driven by the accessibility to inputs on credit, and as the effects of ill health become severe, there are reductions in input investment but by smaller magnitudes. Credit therefore cushions them against large welfare losses.

Our analysis further reveals differences in the relative importance of cash and unskilled labour losses in impacting on households’ welfare. A priori, we presumed that both losses in cash and unskilled labour resources due to the effects of ill health contribute to driving people into poverty. However, we find that under the malaria and HIV/AIDS simulation scenarios, the welfare effects of morbidity are transmitted to poor households through the loss of cash resources rather than labour.

The lack of a discernible welfare effect of labour losses results from the specific features of the Malawi's rural sector that we highlighted earlier. These include an underdeveloped non-farm economy with limited off-farm activities, high population density and small landholdings. As a result, labour is abundant. High population density and small landholdings however is not unique to Malawi. In a recent study, T. S. Jayne, Chamberlin, and Headey (2014) describe SSA as "two Africas", one which is land abundant and another one which is land constrained. The authors note that in SSA, high population growth has resulted in rising land pressure, and 43% of the rural population of SSA resides in the most densely populated 5% of rural land area, with a mean population density of 235 persons per Km^2. Their findings however do not indicate what proportion of such rural population is capital constrained.

Across the seven types of households, there is abundant supply of unskilled family labour with relatively small landholdings (1 Ha on average). Households therefore respond to the effects of malaria largely by reducing labour allocation to agriculture depending on the cropping choices predicted by the models. As the effect of morbidity become more severe from HIV/AIDS, households reduce leisure and domestic activities time and allocate more labour to agriculture relative to the available labour resources.

In contrast, loss of cash to health care expenses leads to reduction in input investment across all household types, thus resulting in changing cropping patterns, losses in farm income and subsequent welfare losses through the input-output multiplier effects. The modest losses in cash rather than labour therefore trigger discernible negative welfare changes among poor rural households.

In the HIV/AIDS simulation scenario, there are much larger losses in unskilled labour across the four seasonal periods. Consequently, the absolute number of hours hired out to ganyu labour is reduced, thus reducing income from ganyu employment, and thereby cash resources available to the households. In the two malaria simulations scenarios, the losses in unskilled family labour are very small and the losses in ganyu income are negligible.

In the initial conceptualisation of the study, our modelling aspirations included investigating embedded risk in agriculture and the determination of the farmers' tactical and sequential responses to the effects of seasonal cash and labour constraints occasioned by health shocks. However, the Malawian smallholder agriculture sector is characterised by low productivity due to low fertilizer use (the FISP notwithstanding), and those who do only use basal fertilizer during the planting time (Denning et al. 2009; Chirwa and Dorward 2013). Consequently, in the models, investment in production inputs such as fertilizer, hybrid maize seed and chemicals are therefore made in the first stage of the production cycle, with no further investment in agricultural inputs other than labour in the subsequent production stages or seasonal periods. As a result, seasonal financial constraints that occur after the first seasonal period have no effect on inputs expenditure or cropping patterns.

Additionally, since labour is plentiful within poor rural households, seasonal labour losses resulting from ill health are easily substituted, although we recognise that the models may underestimate short term spikes in labour demand for agricultural tasks that are closely tied to detailed weather patterns e.g. planting.

Under these conditions, embedded risk is less of a problem than originally thought and we therefore do not pursue modelling of embedded risk. However, in more input and labour intensive production systems that require input investments (e.g. topdressing fertilizer, pesticides and herbicides, and hired in labour) in the first seasonal period and in the subsequent periods after the initial decision making stage, consideration for embedded risk is critical. As A. Dorward and Parton (1997) note, considerations for embedded risk in farm household modelling are worthwhile in situations where there are opportunities to make tactical adjustments to external shocks that unfold during the season.

Finally, we find that across all household types, the results of the base and simulation models predict production of hybrid maize, but only up to the maximum amount of hybrid maize and Nitrogen fertilizer provided under the Malawi government’s farm inputs subsidy program (FISP). However, the level of production of hybrid maize is nearly similar to the actual production calculated from the LSMS-IHS3 data, thus indicating accuracy in the models’ predictions. We also note that in the majority of the household types and across all the simulation scenarios, production is concentrated to production of local maize intercropped with cassava.

In addition, there is production of crops such tobacco and soybeans, crops that generates the same or higher returns to land compared to hybrid maize, despite requiring no capital inputs, as they have higher output prices than maize. In severely cash constrained households, it is rational for the farmers to opt for crops with higher returns to capital. In the non-separable model formulation, consumption and production decisions are made simultaneously, and decision makers allocate constrained resources to enterprises that generate more income to meet households' consumption needs.

In our analysis, we recognise the importance of maize of as a major staple crop in Malawi, and one of interest not only in government's pro-poor policies but also in the political arena. Its prominence and the adoption of hybrid maize in rural Malawi is documented in literature (see Katengeza et al. 2012; Ricker-Gilbert and Jayne 2012; Chirwa and Dorward 2013).

In the following section, we make some recommendations for policy based on the findings of the current analysis.

7.3 Recommendations for policy

It is evident from our analysis that the Malawi's government policy of free health care is crucial to the provision of health services to poor people who are often faced by bouts of ill health, particularly recurring malaria. Even with the quality problems in the provision of health care services in Malawi that has been highlighted in literature (e.g. Oxfam 2016), we find that there is considerable dependency on the free government health facilities, and more than half (56%) of persons reporting illness in the two weeks prior to the interview were treated at government funded free health care facilities.

The fact that LSMS-IHS3 shows that some households, who could afford to do so, sought health care services from the private health facilities at a fee may also indicate the existence of poor service in the free health facilities. Nevertheless, public facilities remain the service of necessity if not of choice for the majority of the rural population precisely because they are free. Furthermore, we find that that user fees at private health facilities are generally low, but they may not be affordable for some of the poorer households.

From the results of the simulation models in chapter 6, we see that the modest but discernible welfare losses triggered by as little as MK 739.36 (US$ 4.9) in the first period of the production cycle in the malaria simulation scenarios, and in all seasonal periods in the HIV/AIDS scenario, demonstrate the importance of the government policy of free health care in Malawi. Indeed, if the state did not pick up the cost of health care, rural farm households who are already severely cash constrained and suffering from recurring ill health would have to make out-of-pocket payments for treatment or risk falling into more severe illness. Consequently, they would be more likely to suffer larger welfare losses that would push households into more severe levels of poverty.

Despite the critical role of free health care in improving the wellbeing of poor people, its value as a safety net for poor people is often underappreciated in livelihoods literature.

For some while, agencies such as the World Bank advocated for increase of financing of public health care via user fees (R. P. Ellis 1987; Litvack and Bodart 1993; World Bank 1987; Whitehead, Dahlgren, and Evans 2001). There is however a growing body of literature in the recent years that has advocated for the exemption of user fees (e.g. Robert and Ridde 2013; Dzakpasu, Powell-Jackson, and Campbell 2013), recognising that introduction of user fees would pose a barrier to accessing the essential health services, particularly for a significant proportion of the population who are poor, thus undermining the value of the free health care system. In this study, we reinforce the exemption of user fees to enable affordable health care for the poor.

However, whilst it may be important for the Malawi government to improve on the financing and delivery of free health care services, recommendation of strategies to improve the health systems is beyond the scope of this study.

As our analysis reveals, households in the "poor female headed" type of household are desperately poor, and under severe ill health such as that resulting from the effects of HIV/AIDS, they cannot meet the basic consumption requirements. Such households would therefore benefit from government assistance, such as the Social Cash Transfer Programme implemented in some districts in Malawi (Covarrubias, Davis, and Winters 2012; Overseas Development Institute 2015). We therefore recommend scaling up of the program to include more households, particularly the severely cash constrained and multiply deprived such as those in the "poor female headed" type of household.

Our analysis has also shown that there is an abundance of unskilled labour within poor rural households, but with demand restrictions in off-farm employment opportunities. With the right policies such as “cash for work” (e.g. the Ethiopian Productive Safety Nets programme (World Food Programme 2012) and the India’s Mahatma Gandhi National Rural Employment Guarantee Act (Government of India Ministry of Rural Development 2016), the surplus labour could be engaged in for example, improvement of irrigation and road infrastructure, thus increasing food production, access to markets and improved food prices.

With farms becoming more productive, the poor smallholder farmers become a leverage point to achieving food security and reduction of poverty. Furthermore, development of infrastructure could lead to growth in agricultural through diversification into crops with high returns to capital, such as fruits and vegetables, thus increasing farm income.

In the long-run, government policies that promote development of a non-farm rural economy, that would generate both wage work and self-employment opportunities, are essential to take advantage of the abundant rural supply of labour and reduce poverty. Together with investment in road, irrigation and market infrastructure, development of a non-farm rural economy would promote diversification of households’ livelihood strategies, which is an important component of poverty reduction in rural areas.

7.4 Limitations of the study and areas for future research

Initially, an important limitation that we considered in the use of multiple periods and heterogeneous household types in farm based programming models was in the demand for data. Through the modelling process, we found that unlike in the econometric techniques where data is specific and parameter values are often calculated from the primary data set, a programming model is flexible, and allows for use of data gathered from different sources, a key advantage of the programming approach.

However, for studies that use econometric techniques to investigate health and agricultural linkages, many of the available survey data sets in low income economies, such as the Living Standard Measurement Surveys (LSMS) for a number of countries in SSA, are lacking in the way information on health and agriculture is gathered. In many cases, data is gathered over different recall periods, and thus incompatible.

Future studies should therefore aim to provide guidelines and insights into ways in which household survey coverage of health and agricultural variables could be improved to allow analysis of the critical health-agriculture linkages. In addition, we find inconsistencies in the income and consumption expenditure data in the LSMS-IHS3 survey data. Consumption expenditure is higher than income indicating errors in the quality of both income and consumption data, or underreporting of the data on income.

An important challenge in the use of the dynamic non-linear programming models of farm households in the current study is in the complexity of the models. The model formulation process, calibration and validation requires expertise, and despite our best efforts to formulate logical and consistent models of the different types of households, it was challenging to get the models to find a solution, particularly for the severely cash constrained types of households.

In the severe malaria simulation scenario for the "employed" type of household for example, we find that the downward adjustment of the input investment by a much larger magnitude than the simulated shock is not plausible. Such as internal tipping point in the model can be difficult and time consuming to resolve as the problem may be from errors in the syntaxes or a result of an underlying household behaviour.

In regards to further research, we recommend that future modelling activities endeavour to explore embedded risk, particularly when production systems shift to more labour and input intensive technologies.

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Appendix

Appendix A: Checklist for gathering information in the qualitative survey

Insights were sought on the following key aspects:

1. **The functioning of the ganyu labour market in Malawi**. We explored the following questions:

   a. What are the constraints to finding ganyu labour, e.g. search and other transaction costs? (if a household member wants to hire out labour on a given day, what is the probability they can do it and what factors determines it)

   b. How is ganyu wage labour mediated? (role of social capital in hiring as opposed to impersonal market forces; benevolence, patron-client relationships; reciprocity; importance of trust, reputation and/or kinship)

   c. What are the seasonal/monthly ganyu wage rates? (determine trends in the current season, are they typical and what determines patterns)

   d. How are the wage rates determined?

   e. Is there differentiation of wage rates by gender?

   f. How long is a typical day for ganyu wage work? Or is it by piece rate?

   g. If a household member does obtain non-farm work, what happens to the money? (Is it pooled within the household? Does it depend on who earns it?)

Respondents: Households that regularly hire in/ hire out labour (for b,c,d,e,f,g); households that occasionally hire in/hire out labour (for a); village elder

2. Health shocks and coping mechanisms:

a. What are the most common illnesses in the area? Who are the most vulnerable (age differentiation)? When are these illnesses most prevalent?

b. Where do the people seek medical care from?

c. How far are health facilities from the area?

d. How much do they pay for health care?

e. What is the respondents view on the agricultural production impacts of health shocks?

f. How do households respond to health shocks? Do they seek assistance from friends and relatives (social capital) to replace lost labour or for borrow cash? Can they rent out land and what are the land rental rates?

g. If there is a health shock, who within the household is responsible for paying for it?

Respondents: Village community health workers, teachers, village elders (for a-e); households known to have experienced recent health shocks (for b, d, e, f, g); host household; anybody contacted for questions 1 and 2.

3. **Natural resources:**

   a. Is there extraction of natural resources for financial returns in the Kasungu-Lilongwe livelihood zone? If so, what are they and what is the wage rate?

Respondents: village elders; host households; extension worker

4. **Time utilisation within households**. This will involve finding out how households spend their time especially during the off-peak periods/ account for time utilisation. To specifically observe the following:

   a. Are there activity patterns for particular groups within the village e.g. children, women, those working in the fields or particular days e.g. market day activities, Sundays?

   b. How do people without farm work spend their time?

   c. To what extent is there gender/age differentiation in farm and household chores?

   d. What proportion of households' time is allocated to farm work?

   e. How do these patterns vary in the other seasons?

Direct observation (for a, b, c), spent three days observing before asking any questions

Respondents: Host household, N.B unlikely to be a poor male or poor female household type (for d, e)

Record activities of household member throughout the day

Time	Men (activities)	Women	Other
0600			
0700			
0800			
0900			
1000			
1100			
1200			
1300			
1400			
1500			
1600			
1700			
1800			
1900			
2000			
2100			
2200			
2300			
2400			

Table A1: The relationship between commonly occurring acute illnesses and the treatment options sought

	no treatment not serious		no treatment due to lack of money		home stock of medicine or remedies		government health facility		church mission and private health facility		bought medicine from local pharmacy or grocery		traditional and faith healers, and others		Total
Acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count
Fever, Malaria	21	3.3	9	1.4	16	2.5	374	58.3	66	10.3	154	24.0	2	0.3	642
Stomach ache	15	13.9	2	1.9	1	0.9	56	51.9	6	5.6	27	25.0	1	0.9	108
Flu	12	11.9	1	1.0	3	3.0	44	43.6	11	10.9	30	29.7	0	0.0	101
Lower respiratory(Chest, lungs)	6	6.8	0	0.0	4	4.5	49	55.7	3	3.4	26	29.5	0	0.0	88
Upper respiratory(sinuses)	6	8.1	0	0.0	1	1.4	34	45.9	8	10.8	24	32.4	1	1.4	74
Diarrhoea	4	8.3	0	0.0	3	6.3	31	64.6	1	2.1	8	16.7	1	2.1	48
Headache	1	2.3	0	0.0	6	13.6	20	45.5	4	9.1	13	29.5	0	0.0	44
Measles	0	0.0	0	0.0	0	0.0	38	92.7	3	7.3	0	0.0	0	0.0	41
Skin problems	1	3.3	0	0.0	0	0.0	19	63.3	6	20.0	2	6.7	2	6.7	30
Dental problem	1	4.3	1	4.3	3	13.0	13	56.5	1	4.3	4	17.4	0	0.0	23
Backache	5	21.7	2	8.7	0	0.0	9	39.1	2	8.7	5	21.7	0	0.0	23
Wound	2	9.5	2	9.5	2	9.5	11	52.4	1	4.8	2	9.5	1	4.8	21
sore throat	2	12.5	0	0.0	0	0.0	12	75.0	0	0.0	2	12.5	0	0.0	16
Total	76	6.0	17	1.4	39	3.1	710	56.4	112	8.9	297	23.6	8	0.6	1259

Table A2: The relationship between commonly occurring acute illnesses and the type of diagnosis

	Medical personnel		Self or by other non-medical personnel		Total
Acute illness	Count	% within acute illness	Count	% within acute illness	Count
Fever, Malaria	253	39.50	388	60.50	641
Stomach ache	22	20.40	86	79.60	108
Flu	12	11.90	89	88.10	101
Lower respiratory(Chest, lungs)	26	29.50	62	70.50	88
Upper respiratory(sinuses)	25	33.80	49	66.20	74
Diarrhoea	11	22.90	37	77.10	48
Headache	10	23.30	33	76.70	43
Measles	38	92.70	3	7.30	41
Skin problems	9	30.00	21	70.00	30
Dental problem	5	21.70	18	78.30	23
Backache	4	17.40	19	82.60	23
Wound	4	19.00	17	81.00	21
sore throat	7	43.80	9	56.30	16
Total	426	33.90	831	66.10	1257

Table A3: The relationship between commonly occurring acute illnesses and the type of person

	Adult males		Adult females		Infants		Elderly		Children (5-10 years)		Children (11-14 years)		Total
Acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count	% within acute illness	Count
Fever, Malaria	77	12.0	108	16.8	240	37.3	14	2.2	160	24.9	44	6.8	643
Stomach ache	19	17.4	29	26.6	24	22.0	2	1.8	30	27.5	5	4.6	109
Flu	17	16.8	19	18.8	27	26.7	0	0.0	28	27.7	10	9.9	101
Lower respiratory(Chest , lungs)	18	20.2	24	27.0	31	34.8	2	2.2	8	9.0	6	6.7	89
Upper respiratory(sinus es)	8	10.8	14	18.9	32	43.2	2	2.7	15	20.3	3	4.1	74
Diarrhoea	5	10.2	8	16.3	29	59.2	0	0.0	6	12.2	1	2.0	49
Headache	8	18.2	14	31.8	4	9.1	0	0.0	13	29.5	5	11.4	44
Measles	6	14.6	3	7.3	12	29.3	0	0.0	14	34.1	6	14.6	41
Skin problems	6	20.0	2	6.7	9	30.0	4	13.3	7	23.3	2	6.7	30
Dental problem	6	26.1	12	52.2	0	0.0	2	8.7	3	13.0	0	0.0	23
Backache	6	26.1	8	34.8	0	0.0	9	39.1	0	0.0	0	0.0	23
Wound	9	42.9	7	33.3	1	4.8	0	0.0	3	14.3	1	4.8	21
sore throat	3	18.8	4	25.0	3	18.8	2	12.5	3	18.8	1	6.3	16
Total	188	14.9	252	20.0	412	32.6	37	2.9	290	23.0	84	6.7	1263

Table A4: The relationship between commonly occurring acute illnesses, treatment options and loss of productive time to illness

Acute illness	no treatment not serious		no treatment due to lack of money		home stock of medicine or remedies		government health facility		church mission and private health facility		bought medicine from local pharmacy or grocery		traditional and faith healers, and others		Total	
	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Fever, Malaria	10	1.2	2	3.5	4	3.8	87	6.0	15	8.3	66	4.0	1	0.0	185	5.1
Stomach ache	6	0.8	2	13.0	0	0.0	24	5.4	4	10.0	12	1.4	0	0.0	48	4.5
Lower respiratory(Chest, lungs)	4	2.5	0	0.0	1	0.0	20	4.2	2	3.5	15	2.9	0	0.0	42	3.4
Flu	7	1.4	0	0.0	1	0.0	9	6.1	2	12.0	17	3.2	0	0.0	36	4.0
Upper respiratory(sinuses)	3	5.0	0	0.0	1	4.0	8	5.1	2	4.0	7	1.9	1	6.0	22	4.0
Headache	0	0.0	0	0.0	5	3.2	12	5.9	1	4.0	4	5.8	0	0.0	22	5.2
Dental problem	1	0.0	1	3.0	3	5.7	8	4.6	1	7.0	4	2.3	0	0.0	18	4.1
Wound	2	0.0	1	2.0	1	3.0	8	8.9	1	14.0	2	3.5	1	17.0	16	7.1
Backache	3	1.3	2	6.5	0	0.0	6	3.3	1	14.0	2	13.5	0	0.0	14	5.6
Diarrhoea	2	0.0	0	0.0	3	1.3	5	3.8	0	0.0	2	6.5	0	0.0	12	3.0
Asthma	0	0.0	0	0.0	0	0.0	7	4.1	1	2.0	1	7.0	0	0.0	9	4.2
Measles	0	0.0	0	0.0	0	0.0	9	12.3	0	0.0	0	0.0	0	0.0	9	12.3

Table A5: Sources of data

Data/ Information	Source (s)	Comments
Pricing coefficients		
Fertilizer and hybrid maize seed	(Government of Malawi 2013; Famine Early Warning Systems Network (FEWSNET) 2010; Food and Agriculture Organisation (FAO) 2016) and LSMS-IHS3	
Input subsidy level	(Chirwa and Dorward 2013)	In 2010-2011 fertilizer subsidy level was set at 91 % and at 95 % for hybrid maize
Ganyu wage rate	Dorward's model estimates, filed work and LSMS-IHS3	
Commodity prices	NSO	
Market wedges: sale price as % of market price; Mark-up and mark down on commodity and inputs market price	Andrew Dorward's model syntaxes and LSM-IHS3	
Transaction costs: Transport costs as % of input purchase; Ganyu supervision and search cost	Andrew Dorward's model syntaxes	
Technical coefficients		
Plant density and weeding	Andrew Dorward's model syntaxes	
Fertilizer and seed rate	Andrew Dorward's model syntaxes	
Seasonal labour inputs per ha by field operation	Andrew Dorward's model syntaxes	Originally, information of labour utilisation was gathered through Andrew's previous modelling activities over several years in Malawi
Yield & their relationship with input rates and field operations	Andrew Dorward's model syntaxes and (Southern Africa Root Crops Research Network and International Institute of Tropical Agriculture (IITA) 2007)	
Other coefficients		

Land holding sizes	Calculated from LSMS-IHS3	
Household asset holdings & grain and cash stocks	Calculated from LSMS-IHS3	Very little information is available on this so we use estimated values from available data
Household labour supply	Calculated from LSMS-IHS3	
Household consumption expenditure and income	Calculated from LSMS-IHS3	
Household composition	Calculated from LSMS-IHS3	
Calorific requirements	(Institute of Medicine 2002; Food and Agriculture Organisation (FAO), World Health Organisation (WHO), and United Nations University (UNU) 2001)	
Interest rate	Andrew Dorward's model syntaxes	

Table A6: Crop budget - technical and price coefficients for hybrid maize technologies

Crop	Hybrid Maize			
Description	HybMazZeo	HybMazLow	HybMazMed	HybMazHig
Plant density/ ha	30000	30000	30000	30000
Weeding (no.)	2	2	2	2
Seed rate (Kg/Ha)	20	20	20	20
N Fertilizer rate (Kg/Ha)	0	20	40	80
Other inputs (MK/Ha)	0	0	0	0
Yield (Kg/Ha)	1040	1520	1920	2520
Labour (Hours/Ha)				
November-January	630	638	646	661
February-March	30	30	30	30
April-June	52	77	97	127
July-October	336	336	336	336
Seed price (MK/Kg)	450	450	450	450
Seed cost (MK/Ha)	9,000	9,000	9,000	9,000
Fertilizer price (MK/Kg)	333	333	333	333
Fertilizer cost (MK/Ha)	0	6,660	13,320	26,640
Total costs (MK/Ha)	9,000	15,660	22,320	35,640
Commodity market price (MK/Kg)	29	29	29	29
Expected farm gate price (MK/Kg)	19	19	19	19
Gross revenue (MK/Ha)	19,726	28,830	36,417	47,797
Net Revenue (MK/Ha)	10,726	13,170	14,097	12,157

Table A7: Crop Budget - technical and price coefficients for local maize technologies

Crop	Local maize technologies													
Description	lonoone	lonotwo	loferone	lofertwo	loferhione	loferhitwo	hinoone	hinotwo	hiferone	hifertwo	hiferhione	hiferhitwo	mixweed1	mixweed2
Plant density/ ha	20000	20000	20000	20000	20000	20000	30000	30000	30000	30000	30000	30000	15000	15000
Weeding (no.)	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Seed rate (Kg/Ha)	12	12	12	12	12	12	20	20	20	20	20	20	10	10
N Fertilizer rate (Kg/Ha)	0	0	20	20	40	40	0	0	20	20	40	40	0	0
Yield (Kg/Ha)	695	790	905	1120	1035	1370	715	810	995	1210	1195	1530	690	785
Nov-Jan Labour (Hours/Ha)	434	602	442	610	450	618	462	630	470	638	478	646	420	588
Feb-March Labour (Hours/Ha)	30	30	30	30	30	30	30	30	30	30	30	30	30	30
April-June Labour (Hours/Ha)	35	40	46	56	52	69	36	41	50	61	60	77	35	40
July-Oct Labour (Hours/Ha)	336	336	336	336	336	336	336	336	336	336	336	336	336	336
Seed cost (MK/Ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilizer cost (MK/Ha)	0	0	6,667	6,667	13,333	13,333	0	0	6,667	6,667	13,333	13,333	0	0
Total costs (MK/Ha)	0	0	6,667	6,667	13,333	13,333	0	0	6,667	6,667	13,333	13,333	0	0
Commodity market price (MK/Kg)	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Expected farm gate price (MK/Kg)	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Gross revenue (MK/Ha)	13,182	14,984	17,165	21,243	19,631	25,985	13,561	15,363	18,872	22,950	22,666	29,020	13,087	14,889
Net Revenue (MK/Ha)	13,182	14,984	10,499	14,576	6,298	12,652	13,561	15,363	12,206	16,283	9,332	15,686	13,087	14,889

Table A8: Crop Budget - technical and price coefficients for tobacco, legumes and root and tubers cropping activities

Crop	Groundnuts							Burley tobacco			Cassava				
Description	GnW1L	GnW2L	GnW1H	GnW2H	GnIntW1	GnIntW2	Soybean	TobaccoL	TobaccoM	TobaccoH	BeansInt	PigeonP	Cassava1	CassInt	SweetPot1
Weeding (no.)	1	2	1	2	1	2	2	.	.	.	.	.	1	.	1
Seed rate (Kg/Ha)	40	40	80	80	11	11	60	4	4	4	12	10	12000	3000	13
N Fertilizer rate (Kg/Ha)	0	0	0	0	0	0	0	0	74	150	0	0	0	0	0
Other inputs (MK/Ha)	7645	7645	15290	15290	0	0	0	4825	9650	14475	0	0	0	0	0
Yield (Kg/Ha)	424	530	581	726	180	225	600	350	700	1000	150	130	3000	1000	3000
Nov-Jan Labour (Hours/Ha)	810	1090	1006	1286	670	950	950	839	839	839	84	40	554	105	506
Feb-March Labour (Hours/Ha)	30	30	30	30	30	30	30	452	603	732	0	0	0	0	0
April-June Labour (Hours/Ha)	868	1136	1264	1630	254	367	434	384	768	1097	126	0	0	0	546
July-Oct Labour (Hours/Ha)	336	336	336	336	336	336	336	371	371	371	0	130	671	117	259
Seed cost (MK/Ha)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fertilizer cost (MK/Ha)	0	0	0	0	0	0	0	0	24,666	50,000	0	0	0	0	0
Total inputs costs (MK/Ha)	7,645	7,645	15,290	15,290	0	0	0	4,825	34,316	64,475	0	0	0	0	0
Commodity market price (MK/Kg)	138	138	138	138	138	138	136	177	177	177	181	123	49	49	27
Expected farm gate price (MK/Kg)	90	90	90	90	90	90	88	115	115	115	118	80	32	32	18
Gross revenue (MK/Ha)	38,033	47,541	52,116	65,122	16,146	20,183	53,040	40,268	80,535	115,050	17,648	10,394	95,550	31,850	52,650
Net Revenue (MK/Ha)	30,388	39,896	36,826	49,832	16,146	20,183	53,040	35,443	46,219	50,576	17,648	10,394	95,550	31,850	52,650

Table A9: Individual household types' welfare effects of malaria and HIV/AIDS morbidity (change from base scenario estimates)

Type of household	Simulation scenario	Total inputs (MK/HH)	Commodity sales (MK/HH)	Ganyu income (MK/HH)	Cash consumption (MK/HH)	Caloric consumption (MK/HH)	Total expenditure (MK/HH)	Total income (MK/HH)	% on-farm labour use	Downward consumption adjustment(%)	percap daily expenditure ($)
Dimba	Malaria 1	175	120	-57	-512	221	-116	620	0.1	5	0.000
	Malaria 2	-111	-203	-109	-940	55	-996	-246	0.2	5	-0.004
	HIV	-131	639	-3050	-4902	-989	-6022	-3319	9.2	10	-0.024
Poor female headed	Malaria 1	-334	-398	-86	-522	-189	-1046	-643	0.0	0	-0.006
	Malaria 2	-211	-425	-164	-957	-41	-1209	-479	0.1	5	-0.007
Employed	Malaria 1	-110	-218	-57	-496	-28	-635	-247	0.1	0	-0.003
	Malaria 2	-7873	-15445	-109	-5715	-264	-13852	-13044	-3.6	0	-0.060
	HIV	-2130	-6451	-3050	-4940	-2058	-9128	-6136	6.4	0	-0.040
Non-farm Enterprises	Malaria 1	-581	-1479	-57	-469	-134	-1184	-839	-0.3	0	-0.005
	Malaria 2	-1966	-762	-109	-1857	-10	-3833	-2931	-1.2	0	-0.017
	HIV	-1403	1252	-3050	-5230	-996	-7629	-4826	9.6	0	-0.033
Remittances	Malaria 1	-291	-328	-57	-494	-111	-896	-489	0.0	0	-0.004
	Malaria 2	-625	-786	-109	-1010	-189	-1823	-1073	-0.1	0	-0.007
	HIV	-1001	-842	-3050	-5514	-1154	-7669	-4974	8.3	0	-0.030
Credit	Malaria 1	-647	-4108	-57	-558	-164	-1370	-747	-0.3	0	-0.006
	Malaria 2	-1302	-4862	-109	-1053	-360	-2715	-1736	-0.5	0	-0.011
	HIV	-2350	-4849	-3050	-4817	-2018	-9185	-6213	8.2	0	-0.038
Poor male headed	Malaria 1	-375	-404	-57	-487	-212	-1073	-656	-0.1	0	-0.005
	Malaria 2	-693	-759	-109	-915	-387	-1995	-1223	0.0	0	-0.009
	HIV	-708	96	-3050	-4869	-1415	-6992	-4265	8.7	5	-0.031