

# Impacts of the Farm Input Subsidy Programme in Malawi: Informal Rural Economy Modelling

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## Abstract

This paper presents a partial equilibrium model of the impacts of the Malawi Farm Input Subsidy Programme on smallholder livelihoods in two major and contrasting livelihood zones over the period 2005/6 to 2010/11. Despite inherent difficulties in modelling the multi-scale and complex relationships that are involved, model findings show direct impacts on subsidy recipients (increasing maize production and real incomes), differences between poorer and less poor households (with poorer households normally gaining more proportionally but not necessarily absolutely from the same subsidy package), and differences between central and southern region maize growing areas with different rates of poverty incidence and land pressure (with greater absolute and proportional gains in poorer southern region areas). The results also show the impacts of the programme on wages and maize prices. However, a significant finding of model simulations is that beneficial indirect effects may be greater than direct impacts in maize growing areas with high rates of poverty incidence and high land pressure. These indirect effects arise through increases in the ratio of wages to maize prices, and benefit poorer households (who sell *ganyu* labour and buy maize) while potentially harming in the short term the incomes of less poor buyers of *ganyu* labour and sellers of maize (these households should however gain in the medium and long run from increased livelihood opportunities with wider economic growth). This finding has important implications for programme design, implementation and evaluation. Much more emphasis should be placed on ensuring that the programme and other policies are managed to maximise these indirect benefits, and on assessing these benefits in programme evaluation. There are particular implications for the design and management of area and household targeting and graduation.

# 1.0 Introduction

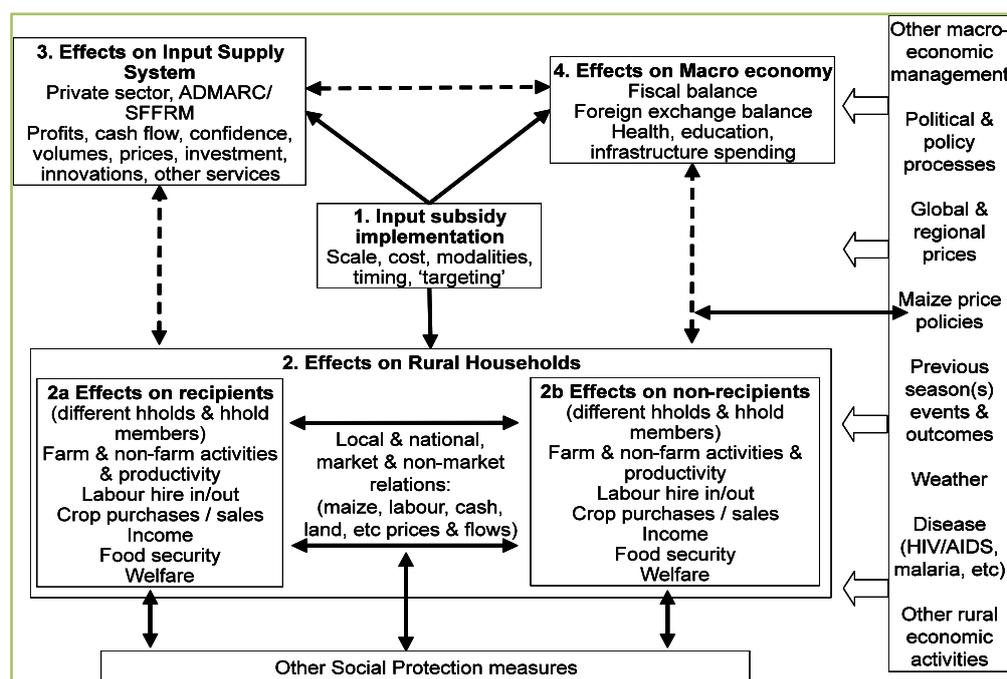
This paper describes the use of detailed livelihood models in rural economy simulations to investigate partial equilibrium impacts of the Malawi Farm Input Subsidy Programme (FISP) from 2005/6 to 2010/11. We use the models and simulations to provide insights into potential impacts of the programme on maize prices and wages and, through these, on different beneficiaries and non-beneficiaries. In addition, we also investigate questions about targeting, displacement, and graduation. In the remainder of this section we set out different impacts which may be expected from the programme, discuss difficulties faced in examining these impacts and review the strengths and weaknesses of published reports assessing these impacts. Section 2 then describes methods used in the paper to model the informal rural economy, and discusses their strengths, weaknesses and limitations. Section 3 details and discusses results from various simulations. Section 4 summarises the paper and sets out principal conclusions.

The major processes and factors that affect the impact of the input subsidy programme are set out in Figure 1. At the heart of Figure 1 is the implementation of the input subsidy programme (1). Its scale and the way it is done impact directly on coupon recipients (2a), on the input supply system (3), and on the macro-economy and its management (4). The livelihoods, activities and welfare of coupon recipients then affect relationships within rural communities and local and wider markets (for maize and ganyu) and this impacts upon non-recipients (2b). All of these components interact with each other and with wider factors in the environment, shown on the right hand side of the diagram. In this context we identify five major challenges in FISP evaluation:

1. the wide scope of the different potential impacts (multiple direct impacts on beneficiaries and on input suppliers, fiscal impacts on the economy, multiple indirect impacts through labour and maize markets on non-beneficiaries and on the wider economy) which demands a wide set of studies of different systems and of the impacts of the FISP on them;
2. the complexity of each of the systems impacted (with complex and varied livelihoods, complex supplier businesses and supply systems, a complex macro-economy);
3. the multiple interactions between the systems (for example between different households' livelihoods and farm and non-farm activities, with input suppliers and the macro-economy, with interactions through maize and labour markets and through fiscal effects);
4. difficulties in obtaining reliable data on key variables in the different systems – such as crop yields and production in different systems under different circumstances, labour use, wages, commercial input sales, opportunity costs of resources used;
5. confounding effects of external or semi-external influences such as rainfall, international fertiliser prices, tobacco prices and sales, and policies affecting for example maize markets and prices, exchange rates, interest rates, inflation, infrastructural development, agricultural research and extension.

A further challenge arises from the multiple objectives of different stakeholders in the FISP. These include promotion of increased land and labour productivity; of smallholder food crop production; of household and/or national food self sufficiency; of food exports; of economic growth; of poverty reduction; of reduced

**Figure 1 Analytical framework for evaluation of FISP impacts**



Source: SOAS et al (2008).

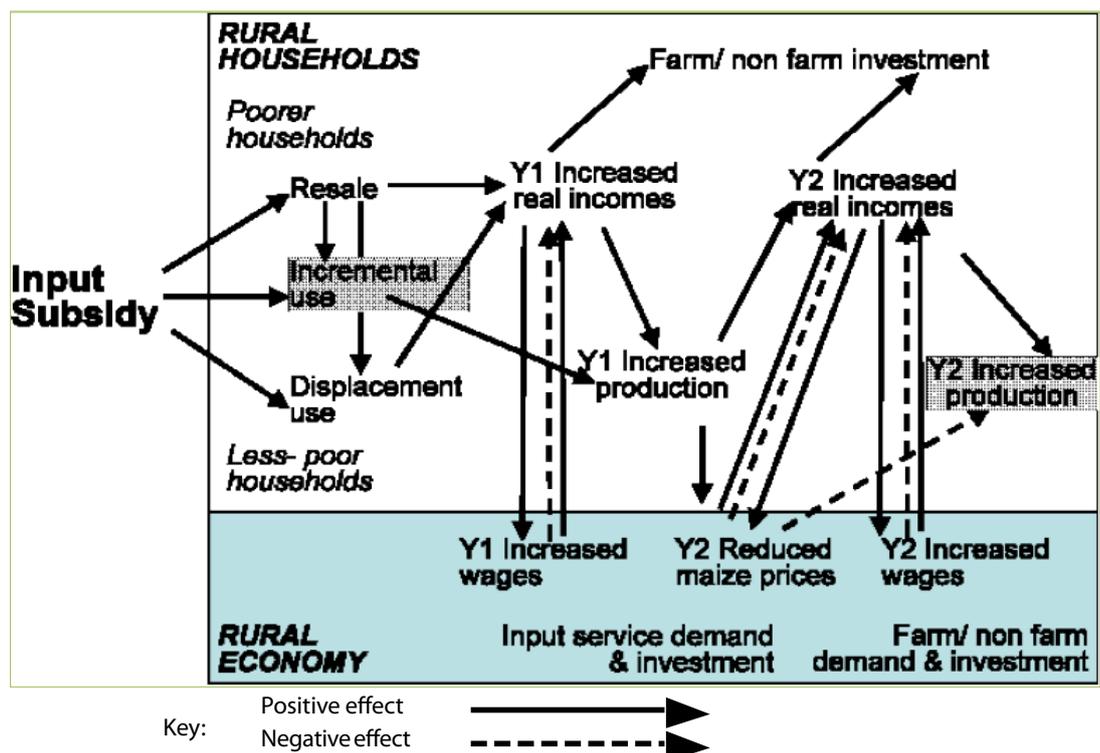
vulnerability to food insecurity, hunger and poverty; of development of the private sector agro-dealer (input) network; of improved equity; and of benefits to women and disadvantaged individuals and households (for example the elderly, orphans, chronically ill) (Dorward and Chirwa, 2009; SOAS et al., 2008). This requires a range of topics and issues to be studied in evaluation of impacts within and across systems.

A review of studies of the impacts of the FISP shows that there has been substantial analysis of many of the direct beneficiary impacts of the programme, but there has been less on the indirect impacts on both beneficiaries and non-beneficiaries. This is modelled in broad terms in two studies using CGE models (Buffie and Atolia, 2009; Filipski and Taylor, 2011) and these, with Dorward and Chirwa (2011b) show that indirect impacts are likely to be important. However, only limited work on livelihoods and informal rural economy, reported briefly in SOAS et al. (2008), has attempted to examine these impacts in any detail. This paper addresses that gap and examines estimates of direct and indirect subsidy impacts on real incomes of different beneficiaries and non-beneficiaries under different conditions. However, the models and simulations also provide broad information on displacement of unsubsidised by subsidised fertiliser sales, on incremental production, on graduation processes and on targeting options.

Figure 2 shows the rather complex set of potential direct FISP impacts on the livelihoods of programme beneficiaries over time, and how their demand for and supply of *ganyu* labour (casual labour) and their production of maize may, with sufficient numbers of beneficiaries, affect *ganyu* wages and maize prices. The

interactions between beneficiaries' and non-beneficiaries' livelihoods and these labour and maize market impacts have been widely reported by rural people in focus group discussions (Chirwa et al., 2011; Dorward et al., 2010a; SOAS et al., 2008). There is also survey and anecdotal evidence of rising real wages (relative to maize prices) over the life of the programme, particularly in 2006/7 following the first year of implementation (Chirwa et al., 2011; Dorward and Chirwa, 2011a). Further direct and indirect subsidy impacts postulated in figure 2 are greater farm and non-farm investment (in human, social, financial, natural and physical capital) and increased demand for locally produced goods and services, including non-staple foods. Chirwa et al. (2011) report empirical evidence on investment in human capital (education and nutrition/ health) by programme beneficiaries but – with Holden and Lunduka (2010a) and Ricker-Gilbert and Jayne (2011) – find limited evidence for programme beneficiaries increasing their investments in physical capital. There was anecdotal evidence of increased demand for locally produced goods and services, including non-staple foods, in the second half of 2011, with reports of increased demand for horticultural pest and disease control chemicals and of increased market supply of horticultural produce. Chirwa et al. (2010a) suggest that where this allows increased demand for and production of nitrogen fixing legumes then these can further improve soil fertility while reducing reliance on and costs of inorganic fertiliser use (Snapp et al., 2010). Processes of capital accumulation by beneficiaries and of structural change in livelihoods and the rural economy are critical to questions about escape from a 'low maize productivity trap' and 'graduation' (Chirwa et al., 2010a; Dorward and Chirwa, 2011a).

**Figure 2 Tracing out direct and indirect subsidy impacts over time**



## 2.0 Methods

The development of household and rural economy models follows the approach described in Dorward (2006) with, first, the development of a typology of rural households. We then develop a standard household/livelihood model structure for simulation of effects of and responses to different situations by different types of household in different areas. Individual household behaviour is then aggregated into a simulation of their interaction with each other through maize and labour markets in the rural economies in which they are located. We describe the methodology in four parts:

1. specification of household types;
2. construction of individual household livelihood models;
3. integration of household livelihood models into an 'informal rural economy'
4. specification of simulation scenarios

### 2.1 Specification of household types and livelihood zones

The development of the household typology must take account of both geographical variation across Malawi and variation between households within geographical areas. The livelihood zones developed by the Malawi National Vulnerability Assessment Committee (2005) provided a geographical classification of Malawi taking account of agro-ecological and socio-economic differences between areas. The two largest livelihood zones (in terms of population coverage) were chosen for study, the Kasungu-Lilongwe Plain (KAS) and the Shire Highlands (SHI) as (a) between them they include just over 40% of rural households in Malawi and (b) they represent examples of less and more densely populated areas in the centre and south of the country, respectively.

Cluster analysis of data from the 2004/5 Integrated Household Survey (IHS2) was then used to develop a household/livelihood classification within the livelihood zones. This adopted the same broad procedures as described by Dorward (2002) when conducting a similar analysis with the 1998 Integrated Household Survey (IHS1). The cluster analysis was carried out using the following standardized variables<sup>1</sup>:

- cultivated area of rainfed land per household member;
- cultivated area of *dimba* (valley bottom irrigated) land per household member;
- household dependency ratio, gender of household head;
- estimated post-harvest stored maize per household member;
- participation or non-participation in wage employment in the month prior to interview at a wage greater than 55MK per day;

- participation or non-participation in a non-farm enterprise in the month prior to interview at a profit more than 4000 MK last month;
- remittance income per household member in the 12 months prior to interview;
- enterprise borrowings per household member in the 12 months prior to interview;
- highest school class attended by the household head;
- asset index per household member (with an index of 2 points per chicken, 7 points per radio, 9 points per sheep or goat, 12 points per bicycle, and 20 points per ox-cart (Binauli et al., 2000));
- distance to tar road; and
- distance to the nearest ADMARC (Agricultural Development and Marketing Corporation) market – a parastatal agricultural marketing agency.

Using the SPSS K means procedure for 7 or 8 clusters, a separate cluster analysis was then carried out for each livelihood zone. Several different iterations were conducted for each zone and a cluster set was selected from among these, taking account primarily of the stability across different runs, but also looking for some degree of comparability or consistency in patterns of variation across different livelihood zones. Clusters' characteristics defined for the KAS and SHI livelihood zones are presented in Annex 1 tables A1 and A2. To show the wider applicability of the classifications, tables A3 and A4 present the characteristics and incidence of broadly similar clusters found across the 10 largest zones in Malawi.

Although there are differences between the three household type categorisations in these tables, there are also important similarities. All three categorisations include poor female-headed, poor-male headed, remittance-dependent, large farm, *dimba* and wage households. The broad patterns of difference between these categories are also similar as regards cropping patterns, relative poverty incidence, fertiliser use, and per capita consumption. There are however differences, first in the number of categories identified (SHI has 7, KAS has 8, while the categorisation for 10 livelihood zones has 9). The additional categories are for households with access to credit for agricultural borrowing (as expected, associated with more burley tobacco, hybrid maize and fertiliser use and not identified as an important group in SHI) and remote households. The proportions of poor male- and female-headed households were also greater in SHI, with a higher incidence of poverty among them (as expected).

### 2.2 Construction of individual household livelihood models

Household livelihood models were then developed for the Kasungu Lilongwe Plain and the Shire Highlands zones. These models follow the same structure as those described in Dorward (2006), with an objective function that maximises expected utility using a linear expenditure

system (LES). Modifications to the earlier specification were introduced to allow for the need to simulate access to subsidised seed and fertiliser separately from other crop inputs and to allow for different rates of fertiliser use in tobacco production. Coefficients were updated to reflect prices after 2003/4. Some relatively minor changes were made to technical coefficients, as outlined in annex 2. No information was available on *dimba* (wetlands) cultivation and this is not allowed for in the model. Non-farm activities are modelled purely through non-farm wage rates. Similar technical and price coefficients were used for modelling in the two different zones in most cases.

A major feature of the structure of the livelihood model is separate consideration of labour use and supply, consumption, cash flows, varying prices and wages, and cropping activities in four seasons – a cropping period (roughly November to January), a pre-harvest period (February to March), a harvest period (April to June) and a post-harvest period (July to October). This effectively describes problems of seasonal cash flow constraints and the ‘hungry gap’ for poorer households in the cropping and pre-harvest periods. The model also allows for risk aversion leading to a preference for maize cultivation by including in the objective function utility achieved under three states of nature, with post-harvest maize consumption and maize stocks valued at ‘expected’, ‘low’ and ‘high’ maize prices. A higher subjective probability of higher prices encourages subsistence maize production and discourages reliance on cash crop or wage income to fund market purchases of maize. A full description of the model is found in Annex B.

## 2.3 Integration of household livelihood models into the ‘Informal Rural Economy’ (IRE)

Aggregation of the model results for the different household types in each livelihood (with the contributions of each household types weighted by the proportion of households it represents in the zone) provides a model of the informal rural economy (IRE) in that zone – describing the activities and associated resource flows among smallholder farmers (as a result of both their farm and non-farm activities), but excluding the activities of commercial or estate agriculture and the activities of organisations operating in rural areas (whether businesses, government agencies, or NGOs). Interactions between the IRE and the rest of Malawi (other agents and activities not explicitly allowed for in the household models, whether located physically in rural space or in other parts of Malawi) are sales of cash crops; purchases of agricultural inputs; net purchase or sale of maize; purchase of tradable commodities for consumption; receipt of remittances or transfers; and sales of labour, of labour services or of goods produced by labour and not accounted for under sale of cash crops or maize.

Within the IRE, households interact in a number of ways:

- a. households sell maize to each other;
- b. households hire out unskilled labour to work on other households’ farms or to provide other unskilled services to satisfy local demand;
- c. households may also hire out skilled or semi-skilled labour to provide services to satisfy local demand;
- d. households may use skilled or unskilled labour to produce products for local sale to satisfy local demand;
- e. households may buy maize (produced locally or imported from outside the area); and
- f. households buy local services and products produced with local labour.

Maize prices and wages within the IRE are determined by the balance of flows (supply and demand) with the rest of Malawi. Maize prices in Malawi are relatively independent of global prices, as are wages, and maize prices and wages will therefore be determined by the elasticities of supply and demand for labour and maize in the rest of Malawi. Where there is an equilibrium which is disturbed by a shock, then a partial equilibrium can be found by looking for price adjustments that lead to matching supply and demand changes in the IRE and the rest of Malawi.

This allows us to investigate the effects of different subsidy interventions, by

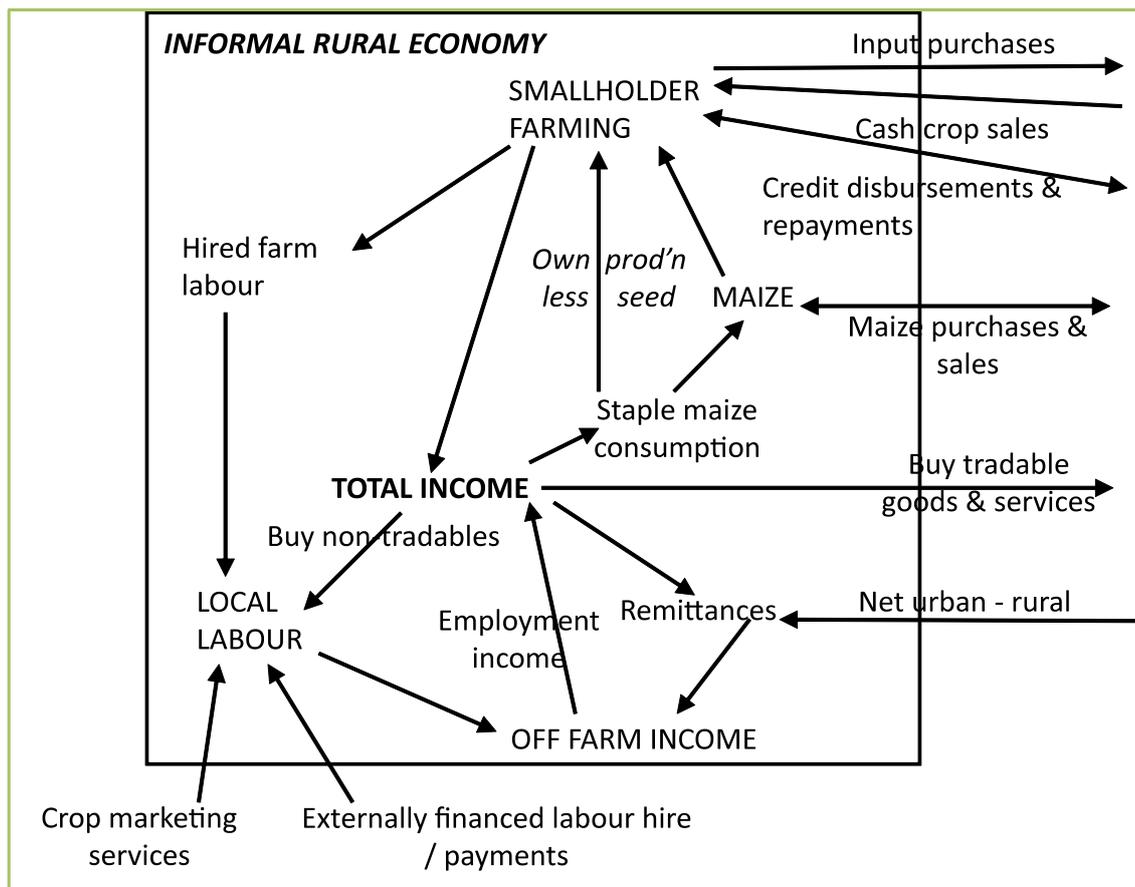
1. modelling the effects of these interventions on household supply and demand for maize and labour at constant prices,
2. observing the aggregate effect of this on labour and maize supply and demand, and then
3. finding price changes which modify those changes in ways that are consistent with the supply and demand price elasticities in the rest of Malawi (allowing for the effects of seasonality in maize production and prices).

Potential difficulties arise here as

- a. maize and unskilled labour supply and demand price elasticities for the rest of Malawi are not known,
- b. there are difficulties in determining the timing of household expenditures, and
- c. computational difficulties mean that suitable prices have to be found iteratively. Variations across seasons also pose challenges.

Difficulties (a) and (c) are not as great as might be feared, however, because results are not very sensitive to the precise elasticities applied. This means that reasonably robust results can be obtained without either specifying a very exact elasticity or conducting large numbers of iterations to reach this exact figure. Difficulty (b) however presented greater problems. Previous versions of the model Dorward (2006) did not allow for different proportionate changes in maize prices and wages in seasonal periods. It was felt that this was an

**Figure 1 Analytical framework for fvaluation of FISP impacts**



Note: (arrows show financial flows, materials and services flows in the opposite directions)  
Source: Dorward (2003)

important weakness, so different wage and maize price changes were allowed in the cropping/ pre-harvest and harvest/ post-harvest periods. To allow for this without undue modelling complexity required the removal of linkage or multiplier effects from increased demand for local goods and services. However, estimation of changes in the overall labour market allowing for this demand provides a check on likely bias resulting from this.

## 2.4 Specification of simulation scenarios

Investigation of the impacts of the subsidy programme requires a comparison of 'with' and 'without' subsidy scenarios. The modelling approaches described above allow such investigation, in principle, by taking the set of prices achieved in 'with subsidy' years and then modelling the effects of removal of the subsidy, finding IRE equilibrium prices as described above, and then examining welfare and other changes between the 'with' and 'without' scenarios. Our basic set of simulations follows this approach, examining for each livelihood zone and each year from 2005/6 to 2010/11 with and without subsidy scenarios. There are, however, some difficulties with this approach.

First, there are difficulties in specifying the 'with subsidy' scenario. It is widely observed that targeting of

subsidy delivery to different households is (a) highly variable between different areas, and (b) not clear-cut, with different categories of household being more and less likely to receive coupons, but no category of household universally receiving or not receiving coupons (see for example Chirwa et al., 2010b; FUM (Farmers Union of Malawi), 2011; Houssou and Zeller, 2011; Ricker-Gilbert et al., 2011; SOAS et al., 2008). It is also clear that FISP impacts vary with distribution of subsidised inputs to different households, for example through higher and lower displacement rates among less poor and poor households respectively (Ricker-Gilbert et al., 2011; SOAS et al., 2008). Trying to duplicate actual patterns of subsidy access in the livelihood and IRE models is not practical. We therefore address this by examining two different subsidy distribution and access scenarios: a universal distribution of 50kg fertiliser (with 35% N (nitrogen) content) with 2kg hybrid seed, and a targeted distribution of 100kg fertiliser (with 35% N content) plus 2kg hybrid seed to the poor female-headed and poor male-headed household types. Comparisons between these two scenarios are of interest in themselves, but an average taken across them is likely to be closer to distribution patterns actually achieved. However, it should be recognised that this is likely to over-estimate access by poorer households (although this targeting scenario does not include all poor households as there is still poverty incidence in other household types - see tables A1 and A2).

Another set of difficulties arises with annual comparisons of 'with' and 'without' subsidy scenarios because subsidy impacts are not restricted to one year, they may be transmitted from one year to the next. Thus, as outlined earlier in figure 3, increased production from a subsidy one year may depress maize prices, increase poor households' working capital, and stimulate higher real wages in the following year. In addition, farmers' and policy-makers' expectations about maize and labour markets one year may be affected by a subsidy the previous year, thus affecting both cropping and policy decisions in the following year. We attempt to address these issues by examining links between years in two ways. First, we examine possible effects of capital accumulation by setting the marginal propensity to save working capital at a little under 20% and carrying this forward for beneficiary households as an increase in starting working capital in a season following subsidy provision.<sup>2</sup> Second, possible effects of price and wage carry forwards are investigated by choosing a year with the subsidy when maize markets were not substantially affected by government interventions (we chose 2006/7). We then estimated maize prices in the cropping and pre-harvest periods of the following year (2007/8) using a linear regression estimate of the relationship between Jul-October prices one crop year and the Nov-January and Feb-March prices of the following crop year, estimated from Ministry of Agriculture market price data from the 2000/1 to 2010/11 seasons (with these prices highly correlated,  $R^2=0.91$  for Jul-Oct and Nov-Jan prices and  $R^2=0.72$  for Jul-Oct and Feb-Mar prices). Equilibrium wage rates and harvest and post-harvest maize prices were then found for the IRE as a whole. This approach not only seeks to investigate links across years and a trajectory of subsidy impacts, it also seeks to investigate impacts of the subsidy in the absence of other changes (such as in weather, in maize export and market policies, or in tobacco prices and earnings) that might have affected maize prices and wages from 2005.6 to 2010/11.

Table 1 therefore sets out the three different sets of scenarios used to examine subsidy impacts on the IRE. The 'basic with household savings' and the 'equilibrium price trajectory' scenario sets were only implemented in the SHI livelihood zone, not in the KAS livelihood zone. Both the 'basic' and the 'basic with household savings' scenario sets were applied to all years from 2005/6 to

2010/11. For the 'equilibrium price trajectory' set, however, 2005/6 was not used as the base year due to the imbalance in cropping and pre-harvest period prices and wages as a result of the very poor harvest in 2004/5, and problems with the 2010/11 simulations led to the rejection of results from that crop year.

## 2.5 Model challenges

We conclude this section on modelling methods with a brief consideration of challenges faced in model development and applications. Some of these have already been discussed as considerations in model design and development, but it is important to consider them together with other challenges to allow an appreciation of some of the possible limitations of the results presented in the next section. We consider two main groups of challenges faced in the development and application of the model: data and structural challenges. First, however, we highlight two core and interacting features of Malawian smallholder agriculture and the informal rural economies that agriculture is located in: variability and complexity.

Variability and diversity are pervasive in rural Malawi. There is a spatial dimension to this (with agro-ecological and infrastructural variation between plots, farms and areas, for example), a social dimension (with educational, wealth, education, cultural, and other variations between households and communities) and a temporal dimension (with, for example, seasonal, political and demographic cycles, economic and demographic trends, covariant and idiosyncratic shocks from extreme weather and illness events, and natural variations in all these, and other, variables).

Complexity is also pervasive. This arises because of the large number of activities and variables that are components of, and impact on, rural livelihoods and wider 'livelihood systems' (Dorward and Kent, 2012). The multiple and often non-linear interactions and feedbacks between these variables combined with the inherent variability discussed above makes the behaviour of these systems very complex and difficult to study, understand and manage.

Table 1. Scenario sets

Scenario set	Description	Livelihood zones investigated	Years simulated
Basic	Compare model outcomes with subsidy with actual prices against outcomes without subsidy with estimated equilibrium prices	SHI, KAS	2005/6 - 2010/11
Basic with household savings	As for basic scenario but with 20% incremental savings carried forward by each beneficiary household	SHI	2005/6 - 2010/11
'Equilibrium price trajectory'	Compare model outcomes with subsidy against outcomes without subsidy in each case using a trajectory of equilibrium prices	SHI	2006/7 - 2009/10

## 2.5.1 Data challenges

Data challenges arise because some important variables and the relations between them are very difficult to observe and/or measure. These difficulties are compounded by variability and complexity in poor smallholder agriculture, by limited resources available for routine collection of good quality data, and by limited coordination in research and information assimilation and archiving.

We highlight particular data 'gaps' regarding

- household labour availability and different activities' labour demands;
- crop yields and the effects of different management and input regimes (including seeds and fertilisers) on yields (see Dorward and Chirwa, 2010);
- household wealth and capital; and
- individuals' and households' exposure to and responses to different risks and uncertainties.

An advantage of the use of a programming model (as opposed to an econometric model) is that it allows data to be assimilated from a variety of sources: yield, price and household coefficients used in the model are therefore drawn from a wide range of sources. Variability is addressed to some extent by the modelling of different household types in two different livelihood zones over several years. This, with specific sensitivity analysis to investigate the reliability of results in the context of uncertainty about model variables, attempts to address this issue. However, the lack of good quality data and information on the variables listed above does pose questions about the results obtained from the modelling work in this paper – and about all work on the topics addressed here, even (perhaps especially) where studies do not recognise these data challenges. Results obtained should be taken as indicative of the types of likely relations and should be questioned, not taken as providing precise estimates of particular outcomes. They should also be used to generate insights into particular questions and issues that may be important, but have not received particular attention in the past.

## 2.5.2 Structural challenges

We consider here particular variables or relations that are not considered in the models developed in this paper, due to difficulties in representing them within the modelling framework and/or data difficulties regarding these variables. The following are particular issues that we are aware of:

- 'Intra-household issues' (age and gender relations) are important determinants of individuals' and households' behaviour and welfare, but are not modelled. Their consideration would require another 'layer' of modelling within households, and very limited information on the nature of relationships and on specific variables affecting these relations means that the value of the extra information

generated from this does not justify the very considerable costs involved.

- 'General equilibrium issues' concern the links within the whole Malawian economy between subsidy investments and the local agricultural changes they stimulate with impacts throughout the economy, including macroeconomic variables (such as aggregate government expenditure, trade and foreign exchange balances, interest rates), and investments, supply, demand and prices in different sectors. Such breadth and scope can be captured in CGE models, but at the expense of the diversity and detail of livelihood modelling in this paper, with greater or similar challenges as regards data and the other structural challenges considered here.
- Environmental and natural resources are critical to Malawian rural livelihood systems, and in the medium term interact with potential impacts of the subsidy programme as regards, for example, soil fertility, erosion and run off, hydrology, climate change impacts (Harewelle International Limited, 2011) deforestation, and biodiversity. The timescale of the modelling in this paper, its scope, and the data and modelling challenges involved in including these issues mean that the value of the extra information generated from attempting to formally model these issues does not justify the very considerable costs involved.
- Demographic change is a major process in Malawi, with very dramatic population increases expected over the next 30 years or so (National Statistical Office (2011) estimates an approximate tripling of the population to 45 million people by 2050). This will have very severe social, economic and environmental impacts. Subsidy investments may also have some effect on rates and distribution of population growth and on the social, economic and environmental impacts of population growth. Again, the timescale addressed in this paper, and data and modelling challenges involved in including demographic issues, preclude their formal consideration.
- Stimulation and facilitation of structural economic change may be an important element of FISP's contribution to Malawi's growth and development (Dorward and Chirwa, 2011a), but this is extremely difficult to model. However, this depends critically on increasing land and labour productivity with rising wages and falling maize prices, which are modelled and indeed are an explicit focus of the paper.
- Risk and uncertainty are endemic in smallholder agriculture and rural life in Malawi. They affect not only end of season yields and prices, but also resource availability during a season, leading to 'embedded risk', which is understandably but regrettably widely ignored in studies of risk (Dorward, 1999; Dorward and Parton, 1997). The extent and nature of risk and

uncertainty, and attitudes to and management of different forms of risk and uncertainty, are also variable, little understood and difficult to model. Although there is some attention to this in the model as regards maize prices, this is limited.

- Diversity and averaging issues arise because the behaviour of a diverse system is often not well represented by the behaviour of 'average' agents in 'average' conditions – dispersion matters, and behaviour may not be symmetrical around the mean or median, with, for example, a change in conditions affecting agents with below average values on some variables but not affecting agents with above average values on these variables. This is recognised by the separate consideration of two livelihood zones and by the categorisation and modelling of different household types within those livelihood zones. However similar considerations will apply within these household types, with for example particularly poor members of the poor male or female household groups likely to be affected differently from less poor members of these groups.

Both data and structural challenges in modelling therefore pose questions about the modelling results presented in the remainder of this paper (and about other formal modelling and less formal studies of change associated with the FISP). The specific modelling results presented here should be taken as indicative of the types of likely relations, and used to generate questions and insights, not taken as providing precise estimates of particular outcomes (any estimates made should be triangulated and considered as corroborating or questioning other estimates that may be available from other studies using other methods).

### 3.0 Results and Discussion

Detailed results on the main variables are presented for all scenario sets by year in Annex Tables A5 to A8. Results are presented for four different scenario set simulations, as summarised earlier in table 5. A basic scenario set was run for each of the SHI and KAS zones from 2005/6 to 2010/11 comparing model outcomes with the subsidy and actual prices against outcomes without the subsidy, allowing for estimated equilibrium price changes. Two further scenario sets for the SHI zone investigated the possible impacts of accumulated household savings and an 'equilibrium price trajectory' for both the subsidy and no subsidy situation (from 2006/7 to 2009/10). In all scenario sets, the 'with subsidy' situation is represented by an average across two simulations, a universal smaller subsidy per household (50kg fertiliser plus hybrid seed) and a targeted subsidy (providing 100kg fertiliser plus hybrid seed to 'poor male-headed' and 'poor female-headed' household types).

For each scenario set three simulations were run:

- a. with subsidy with actual prices (for the basic scenario sets) or estimated equilibrium prices (for the 'equilibrium trajectory' scenario set),
- b. no subsidy but the same 'with subsidy' prices as (a)
- c. no subsidy with 'no subsidy estimated equilibrium prices'

Comparison of results obtained under (a) and (b) provides an estimate of direct effects of subsidy receipt on recipient households, while comparison of results obtained under (a) and (c) allows estimation of total (direct and indirect) effects of the subsidy. Comparison between (b) and (c) gives an estimate of the indirect effects of the subsidy programme on non-recipients. Although estimates were obtained for each household type in all simulations, we present aggregate results for 'target households' (households in the 'poor male-headed' and 'poor female-headed' household types) and all households (including both target and 'non-target' households).

We now consider results on key variables from the different scenario sets before discussing some of the implications of the results for graduation and targeting.

### 3.1 Cropping patterns

Tables A5 to A8 provide information on simulated aggregate cropping patterns. To provide some indicators on the validity of the model, figures 4 and 5 compare survey and basic 'with subsidy' model estimates of cropping patterns by household type in the Shire Highlands and Kasungu – Lilongwe Plain (SHI and KAS) livelihood zones.

Overall holding sizes in the model are determined from household type parameters estimated in the clustering from the Integrated Household Survey (IHS2) in 2003/4, except where households are unable to cultivate all their land due to working capital constraints. Survey estimates are subject to sampling errors, whereas model estimates are sometimes sensitive to very small changes in yields or prices – a common problem with programming models. Survey estimates tend to show more intercropping (and more intercropped cassava) and more crop diversity than model estimates, but less variation in cropping patterns between household types. These differences may appear large in Figures 4 and 5, but this is partly due to the way that intercropping is shown, with total cultivated area per crop irrespective of intercropping.

Holding sizes also tend to be a bit smaller than in model estimates, which have higher proportions of 'local maize' and lower proportions of 'hybrid maize'. The latter may be due in large part to a definitional issue, as farmers may report recycled hybrid seed as hybrid maize whereas in model results 'hybrid maize' refers to maize grown from fresh seed purchased that season. Survey data show

surprisingly little tobacco cultivation in the KAS zone, particularly in 2008/9, and, as expected, little in the SHI zone. The results are reasonably robust in terms of the nature of differences between households, as seen from the simulations of subsidy effects.

Estimated differences in cropping patterns between subsidy and no-subsidy scenarios are summarised in Table 2 for the Basic scenario set in the two livelihood zones. This shows that in both the Shire Highlands and Kasungu - Lilongwe Plain zones the subsidy is estimated as leading to a fall in local maize area and an increase in hybrid maize area. This leads to a fall in overall maize area since hybrid maize areas are smaller than local maize areas (not shown in the table but see, for example, Figure 4). This releases land for diversification into other pure stand crops (such as tobacco and cassava in table 2) but reduces land under intercrops with maize. Similar results are obtained with the other scenario sets in the SHI zone. These changes are found among subsidy recipients and are not an indirect impact of the FISP. Similar patterns are found in survey data and are reported from surveys by Holden and Lunduka (2010b), but Chibwana et al. (2012) estimate increasing maize and tobacco areas for subsidy recipients in their smaller survey.

### 3.2 Maize production

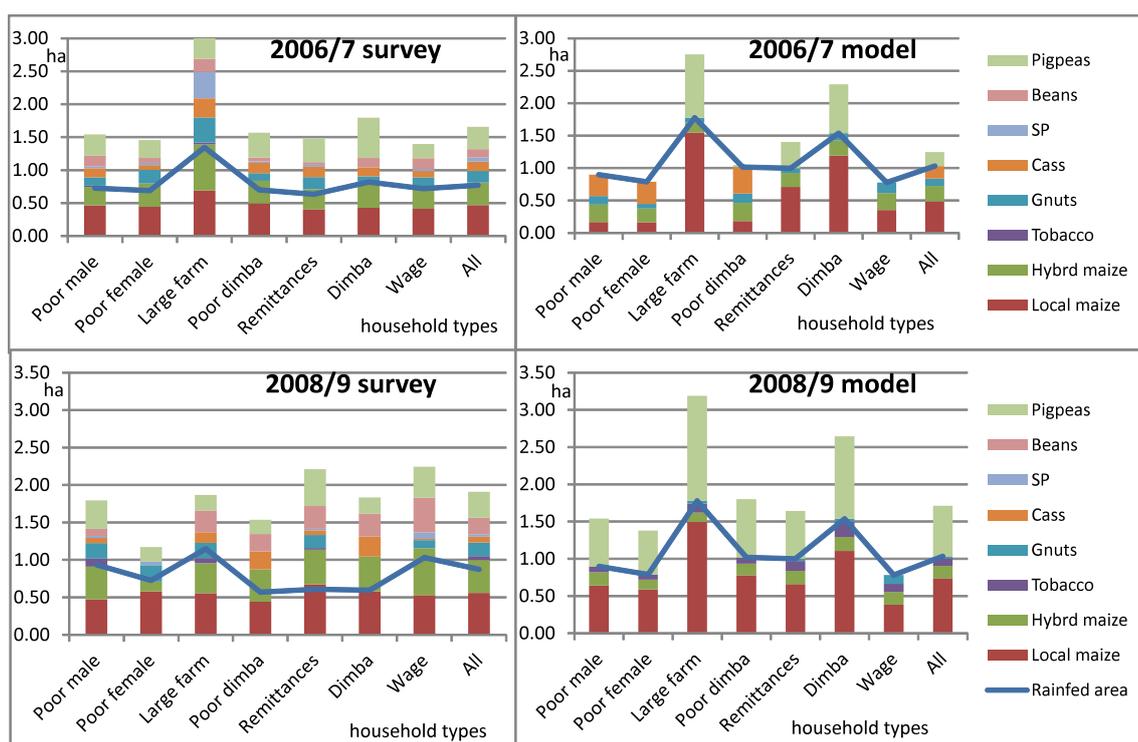
Table 3 shows estimates of changes in maize production under different scenarios. There is a consistent estimated increase of 10 to 20% across all households, with the subsidy, with higher increases among target households (poor recipients) of 30 to 40%. There is, however, some variation between years, with lower increases estimated for 2007/8 in SHI (indeed a decline

is estimated with the equilibrium trajectory, as a result of wild price swings and low maize prices in 2006/7 – actual prices did not fall so low, due in part to maize exports). These changes are found among subsidy recipients and are not an indirect impact of the FISP. Survey reports by Ricker-Gilbert et al. (2009), Holden and Lunduka (2010b) and Chibwana et al. (2012) also find subsidy receipt leading to higher maize production. Higher proportionate increases are estimated for the SHI zone than the KAS zone. Overall increases in maize production arise from the increased yields with fertiliser and hybrid seed, but are offset by reduced land under maize.

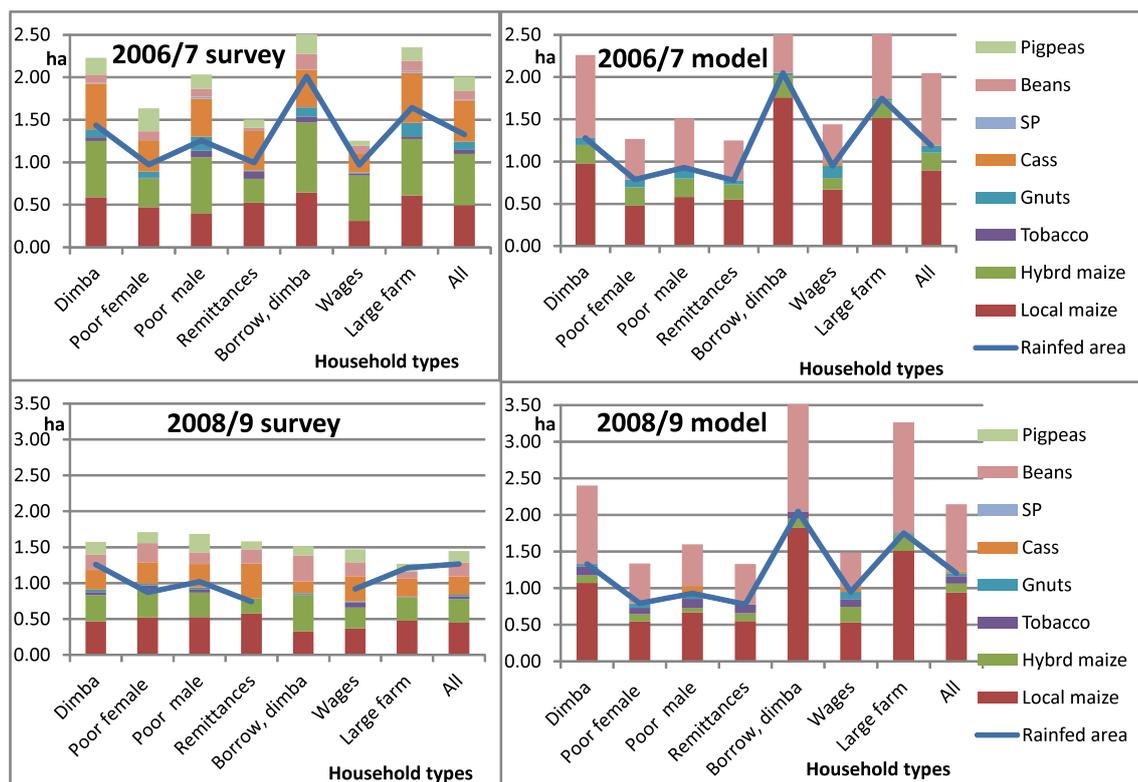
### 3.3 Wages and prices

Table 4 shows estimates of changes in wage to maize price ratios for the different cropping periods. There are consistent estimated small increases in wages and larger falls in maize prices with the subsidy<sup>3</sup>. In the Basic scenarios for both SHI and KAS these are found mainly in the harvest and post-harvest periods because cropping and pre-harvest maize prices are largely exogenously determined, by production in the previous season. Only in the 'equilibrium trajectory' scenario set for SHI do cropping and pre-harvest maize prices differ between subsidy and no-subsidy scenarios. The failure of the other scenarios to 'carry forward' subsidy benefits from one crop year to the next means that wage and maize price changes and consequent indirect benefits to poorer households are underestimated in these scenario sets. These issues are also relevant to consideration of the effect of consumption linkages, whereby increased household incomes lead to increased demand for local goods and services, tightening the labour market.

**Figure 4 Comparison of survey estimates and model cropping patterns, SHI 2006/7 and 2008/9**



**Figure 5 Comparison of survey estimates and model cropping patterns, KAS 2006/7 and 2008/9**



**Table 2. Cropped areas with subsidy as % of 'no subsidy' with estimated equilibrium prices**

		Area/hh						
	Year	Local	Hybrid	Tobacco	Gnuts	Cassava	Beans	Pig.peas
Shire Highlands (SHI) zone	2005/6	61%	203%	143%	..	n.a.	46%	..
	2006/7	76%	124%	..	93%	n.a.	..	44%
	2007_8	75%	143%	n.a.	91%	323%	..	75%
	2008/9	78%	n.a.	n.a.	52%	..	..	73%
	2009/10	78%	114%	239%	61%	122%	..	0%
	2010/11	n.a.	97%	n.a.	89%	94%	..	..
	Medians	71%	135%	n.a.	61%	590%	n.a.	32%
	Means	74%	144%	n.a.	78%	140%	46%	60%
Kasungu- Lilongwe Plains (KAS) zone	2005/6	96%	136%	105%	77%	87%	96%	..
	2006/7	92%	157%	..	102%	32%	87%	..
	2007_8	91%	143%	125%	75%	88%	99%	..
	2008/9	96%	99%	729%	60%	142%	95%	..
	2009/10	98%	114%	97%	21%	91%	99%	..
	2010/11	57%	n.a.	n.a.	107%	161%	0%	..
	Medians	95%	128%	160%	68%	108%	94%	..
	Means	89%	148%	127%	87%	117%	84%	..

Notes: n.a. indicates not available due to division by zero or very small number but some increase; .. indicates zero in both scenarios; hh stands for household

**Table 3. Maize production with subsidy as % of 'no subsidy' with estimated equilibrium prices**

	SHI Basic		SHI Savings		SHI Equilibrium trajectory		KAS Basic	
	All hh	Target hh	All hh	Target hh	All hh	Target hh	All hh	Target household
2005/6	118%	124%	122%	124%	n.a.	n.a.	104%	101%
2006/7	121%	150%	129%	164%	118%	130%	116%	160%
2007_8	105%	106%	107%	106%	86%	91%	115%	124%
2008/9	140%	149%	138%	145%	151%	145%	107%	118%
2009/10	116%	134%	122%	144%	121%	187%	106%	123%
2010/11	118%	143%	120%	143%	n.a.	n.a.	126%	166%
Means	119%	133%	123%	138%	117%	139%	111%	131%

Notes: n.a. indicates no estimation; hh stands for household

Omission of this from the model appears to have very small effects on estimated wage changes in these scenario sets (depressing wages by 5% or less), but, as might be expected, does cause a much larger reduction in estimated wage increases with the subsidy in the 'equilibrium trajectory' of perhaps 30%. This would lead to further increases in the wage: maize price ratio, perhaps increasing the mean to 160% and 260% in the cropping/pre-harvest and harvest/post-harvest periods respectively.

### 3.4 Household incomes

Tables 5 to 7 show estimates of changes in real household income for target and non-target households with and without the subsidy under different price and subsidy scenarios. Table 5 compares real income estimates with and without the subsidy, with estimated changes in equilibrium wages and maize prices (as presented in table 4). It therefore provides an estimate of the total direct and indirect subsidy impacts on both recipients and non-recipients of subsidised inputs. Gains averaging 10% across all households and around 25% across poorer beneficiary households are estimated in the Shire Highlands. There are significantly higher gains

for targeted households for three reasons: first their preferential targeting in the simulated subsidy scenarios (see section 2.4) means that they receive more subsidised inputs than other households; second, they benefit more from subsidised inputs as their poverty means that they are more capital constrained and have higher returns to capital; finally they are net sellers of labour and buyers of maize, and hence benefit indirectly from the wage and maize prices changes detailed in Table 4.

Table 6 provides estimates of these indirect gains, which arise purely from the wage and price changes set out earlier in table 4. These are estimated to be very substantial for target households in the SHI zone. Since these households are also included in the figures for 'all households', some household types (buyers of labour and sellers of maize) suffer a fall in real income from these wage and price changes. Estimated indirect gains are not estimated for the 'equilibrium trajectory' scenario set but since similar direct gains would be expected and overall gains (in table 5) are slightly higher, we can infer that estimated indirect gains are slightly higher. Furthermore, as noted earlier, further indirect gains would be expected with allowance for consumption linkages through non-farm labour demand, but these

**Table 4. Wage: Maize price ratios with subsidy as % of 'no subsidy' with estimated equilibrium prices**

	SHI Basic		SHI Savings		SHI Equilibrium trajectory		KAS Basic	
	Pre harvest	Post harvest	Pre harvest	Post harvest	Pre harvest	Post harvest	Pre harvest	Post harvest
2005/6	116%	190%	116%	190%	n.a.	n.a.	100%	245%
2006/7	96%	158%	107%	179%	100%	154%	106%	130%
2007_8	100%	107%	100%	109%	152%	103%	105%	109%
2008/9	102%	224%	105%	231%	87%	184%	104%	115%
2009/10	108%	134%	108%	154%	178%	265%	100%	140%
2010/11*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	111%	115%
Medians	113%	207%	108%	183%	108%	157%	103%	129%
Means	119%	173%	106%	168%	126%	205%	105%	132%

Notes: 'Medians' and 'Means': % change in 'medians' and 'means' (not median and mean % changes). \* An equilibrium set of maize prices could not be found for the 2010/11 SHI scenarios; hh stands for household.

**Table 5. Real incomes<sup>4</sup> with subsidy as % of those with 'no subsidy' and estimated equilibrium prices**

	SHI Basic		SHI Savings		SHI Equilibrium trajectory		KAS Basic	
	All hh	'Target' hh	All hh	'Target' hh	All hh	'Target' hh	All hh	'Target' hh
2005/6	106%	124%	106%	124%	n.a.	n.a.	109%	119%
2006/7	104%	106%	103%	108%	108%	117%	100%	100%
2007_8	109%	116%	110%	118%	106%	116%	105%	108%
2008/9	114%	147%	117%	160%	107%	144%	103%	108%
2009/10	105%	110%	104%	111%	126%	162%	103%	106%
2010/11*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	101%	100%
Means	110%	122%	111%	125%	111%	131%	103%	106%
Mean (MK)	1,521	2,558	1,594	2,834	1,410	2,906	525	831

Notes: n.a. indicates no estimation; hh stands for household

are not allowed for in the simulation results presented here.

Estimates of direct gains to subsidy recipients are presented in table 7. In SHI these are of smaller magnitude than the gains from the indirect effects (in table 6), particularly for target households. This is an important finding. This is not the case in the KAS zone where both direct and indirect gains are considerably lower: it has a less poor population so that not only are the direct impacts of subsidy receipt lower for recipients, but the smaller proportion of households receiving the subsidy in the targeted scenario reduce the wage and maize price changes (see table 4) and a smaller proportion of households benefit from the higher wage: maize price ratio. However, estimates of indirect subsidy programme impacts in the KAS zone might be increased if simulation results with an 'equilibrium trajectory' scenario set were available.

### 3.5 Displacement of unsubsidised fertiliser

Table 8 shows estimates of displacement of commercial, unsubsidised fertiliser sales by subsidy sales,

with displacement  $D$  defined as the proportion of subsidised sales that replace unsubsidised sales:

$$D = \frac{(C_N - C_S)}{S}$$

where  $D$  = displacement rate,  
 $C_N$  = commercial fertiliser sales in the absence of the subsidy,  
 $C_S$  = commercial fertiliser sales in the presence of the subsidy, and  
 $S$  = subsidy sales

Although the estimates in table 8 should be taken as indicative, the broad patterns are of considerable interest.

- Estimates for 2006/7 and 2008/9 are broadly similar to estimates from panel survey data for the same years, with estimates of displacement rates of 22% and 3% in 2006/7 respectively (Ricker-Gilbert and Jayne, 2010; Ricker-Gilbert et al., 2011). Chirwa et al. (2011) estimate a displacement rate of 15% in 2010/11.
- Displacement estimates are on average higher with a universal subsidy than with a targeted subsidy, though this is not always the case. The general finding is in line with survey estimates

**Table 6. Real incomes with no subsidy but 'with subsidy' prices as % of those with 'no subsidy' and no subsidy equilibrium prices**

	SHI Basic		SHI Savings		KAS Basic	
	All hh	'Target' hh	All hh	'Target' hh	All hh	'Target' hh
2005/6	103%	119%	103%	119%	107%	117%
2006/7	100%	100%	99%	102%	99%	99%
2007_8	101%	102%	101%	102%	100%	101%
2008/9	108%	132%	110%	142%	100%	101%
2009/10	102%	105%	103%	107%	100%	102%
2010/11*	n.a.	n.a.	n.a.	n.a.	99%	99%
Means	106%	113%	106%	116%	101%	102%

Notes: The 'no subsidy with subsidy prices' scenario was not simulated for the SHI equilibrium trajectory. \* An equilibrium set of maize prices could not be found for the 2010/11 SHI scenarios; hh stands for household.

of displacement (Chirwa et al., 2011; Ricker-Gilbert et al., 2011) and is due to poorer, targeted households being less able to afford unsubsidised fertilisers. However higher rates of displacement with targeting may arise if these households engage in substantial secondary selling of subsidised fertiliser to less poor households, who then use these purchases largely to reduce their unsubsidised purchases.

- Displacement estimates are higher for KAS than for the SHI zone, due to greater incidence and depth of poverty in the latter zone and lower displacement rates with poorer beneficiaries.
- Displacement rates show a declining trend for the Basic scenario sets with both livelihood zones. This may be due to a trend of rising unsubsidised fertiliser prices (which were particularly high in 2008/9 but fell back to price levels still high in comparison to previous years). This trend is exacerbated for the SHI scenario set where subsidy beneficiaries save 20% of their extra income, with apparent crowding in of commercial sales rather than displacement or crowding out in 2009/10. This may be the result of increasing ability to afford unsubsidised purchases despite rising prices. No such trend is shown for the SHI Equilibrium trajectory, the reasons for this are not clear.

### 3.6 Direct and indirect impacts

As noted earlier, comparison of 'no subsidy' outcomes at actual (ie with subsidy) prices against outcomes with estimated equilibrium 'no subsidy' prices allows estimation of the indirect impacts of the subsidy on non-recipients. The difference between outcomes for subsidised households between receipt and non-receipt of the subsidy at actual (with subsidy) prices also allows estimation of the direct impacts of the subsidy at these prices. Tables 4 to 7 above provided estimates of wage and maize price changes and of direct, indirect and total subsidy impacts on real net incomes of subsidy recipients and non-recipients. It was noted that all of the scenario sets underestimated the impacts of subsidies in one year on wages, and prices in the subsequent year. Separate direct and indirect subsidy impacts were not estimated for 'equilibrium trajectory' scenario set, but direct benefits are expected to be similar to the other scenarios, meaning that indirect benefits will be higher (since total benefits are higher). These are likely to be further increased if account is taken of possible consumption linkages from rising demand for locally produced goods and services. As a result the indirect benefits of the subsidy for poor households (both recipients and non-recipients) are underestimated in these scenario sets. Nevertheless tables 5 to 7 show very substantial indirect effects which in the SHI zone are estimated for poor subsidy recipients to be larger than the direct impacts.

**Table 7. Real incomes with subsidy as % of those with 'no subsidy' at constant prices**

	SHI Basic		SHI Savings		KAS Basic	
	All hh	'Target' hh	All hh	'Target' hh	All hh	'Target' hh
2005/6	103%	105%	103%	105%	101%	102%
2006/7	104%	106%	103%	106%	101%	102%
2007_8	108%	114%	109%	115%	104%	107%
2008/9	106%	111%	107%	113%	103%	107%
2009/10	103%	105%	102%	103%	102%	105%
2010/11	103%	104%	103%	104%	102%	102%
Means	104%	107%	104%	107%	102%	104%

Note: The 'no subsidy with subsidy prices' scenario was not simulated for the SHI equilibrium trajectory; hh stands for household.

**Table 8. Estimated displacement of commercial fertiliser sales by scenario set**

Targeting*	SHI Basic			SHI Savings			SHI Equilibrium trajectory			KAS Basic		
	US	TS	All	US	TS	All	US	TS	All	US	TS	All
2005/6	26%	33%	29%	22%	35%	27%	n.a.	n.a.	n.a.	69%	70%	69%
2006/7	47%	18%	33%	37%	12%	25%	32%	35%	33%	60%	20%	45%
2007_8	24%	16%	20%	24%	13%	19%	33%	33%	33%	38%	73%	51%
2008/9	3%	4%	3%	3%	4%	3%	3%	3%	3%	0%	0%	0%
2009/10	10%	3%	7%	-23%	-44%	-33%	38%	30%	34%	38%	36%	38%
2010/11**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Means	22%	15%	18%	13%	4%	8%	27%	25%	26%	41%	40%	41%

Notes: \* US indicates universal subsidy, TS indicates targeted subsidy. \*\* 2010/11 scenarios outlier results omitted; hh stands for household.

This is a very important point with significant implications for programme design, management and evaluation. Programme design and management must look to boost indirect effects through complementary policies and investments that stimulate rather than depress higher wage to maize price ratios, while evaluation studies must focus as much on indirect as direct benefits. These demands on programme design and management and on evaluation methods are challenging. In the first case they require planners, managers and policy-makers to think much more widely about the programme and appropriate policies. In the second case this means that surveys which examine differences between recipients and non-recipients are likely to miss very important impacts of the programme. However, modelling of economy-wide and partial equilibrium effects of the programme are very challenging – as illustrated by the modelling and simulation in this paper. Greater attention may need to be paid to the development and use of relatively simple evaluation methods that seek to take account of indirect effects without specific modelling – with, for example, relatively simple benefit cost analysis based on estimates of multiplier effects, rather than complex and highly data-demanding general equilibrium models (Dorward and Chirwa, 2011b).

### 3.7 Graduation: Household and area trajectories

Chirwa et al. (2010a) distinguish between two levels of graduation for the FISP: household and area graduation. In each case graduation is defined as removal of access to the programme that ‘does not leave current beneficiaries supported by the programme unable to pursue sustainable independent livelihoods’. However, household graduation is achieved through a process of individual household advancement, achieved through accumulation of assets in the context of wider area changes, whereas area graduation is achieved through wider changes in economic and social activity and structures in the local economy.

Processes of household advancement and graduation were modelled in the ‘SHI Basic with household savings’ scenario set, with beneficiary households accumulating 20% of their incremental annual savings from subsidy receipt. Tables presented earlier show that this scenario gives generally limited gains over the basic scenario despite a relatively high marginal propensity to save. These gains will be lower with lower and perhaps more realistic marginal propensities to save. Duflo et al. (2009) illustrate the difficulties that poor farmers in Kenya have in saving for small fertiliser purchases. Survey findings appear to corroborate this, as Chirwa et al. (2011), Holden and Lunduka (2010a) and Ricker-Gilbert and Jayne (2011) all find no or little difference in investment in assets by subsidy recipients as compared with non-beneficiaries, although Holden and Lunduka (2010a) report general improvements in asset holdings and perceptions among most households that the subsidy programme improved school attendance. Chirwa et al. (2011) report some

improvement in school attendance, reduction in under-5 illness and reduced susceptibility to shocks among subsidy recipients as compared with non-beneficiaries. However they suggest that economy-wide effects of higher real wages are more important. The modelling results and the discussion of direct and indirect effects above support this conclusion.

Economy-wide effects should contribute to processes of area graduation, whereby sustainable livelihoods, or livelihood systems, are established across an area and farmers are collectively and individually able to escape from the low maize productivity trap as a result of (a) lower maize prices allowing them to rely on the market for maize purchases releasing resources for production to supply of non-staple and non farm products and services, and (b) higher land and labour productivity as a result of greater access to capital, lower costs of living (from lower maize prices) and higher local prices for non-staple and non farm products and services. Although the modelling methods do not allow for consumption linkages through higher local prices for non-staple and non farm products and services, or for potential organic soil fertility synergies from diversification into legumes, modelling results do present some support for this process.

The mechanisms by which this may be implemented, and their interaction with wider, national, maize prices, are difficult. A critical issue here is the need for consistent programme design and implementation and complementary policies that support the indirect benefits of the programme, as discussed earlier. This is suggested by model results with the ‘equilibrium trajectory’ scenario set, as not only does this allow for maize price gains to be carried from one season to another, it also abstracts from events and policies (such as maize exports) that increased actual maize prices from 2007 onwards, reducing the potential maize price lowering benefits of the FISP. Since these prices were used in the basic scenario sets, this should also have led to underestimates of subsidy benefits in the model results from these sets.

### 3.8 Area and household targeting

The modelling of subsidy impacts with two different household targeting systems and in two different livelihood zones provides some insights on household and area targeting. Difficulties with targeting have been widely observed (for example Chirwa et al., 2010b; Chirwa et al., 2011; Dorward et al., 2010b; Holden and Lunduka, 2010a; Ricker-Gilbert et al., 2011; SOAS et al., 2008). Changes in targeting systems and methods to address difficulties have been partially successful, but difficulties remain, and lack of transparency then fuels both opportunities for and perceptions of illegitimate diversion of subsidy coupons. At the same time there is substantial and persistent sharing of coupons between poorer recipients and non-recipients (Chirwa et al., 2010b; Chirwa et al., 2011). These difficulties, together with evidence that reduced displacement and increased

welfare gains with pro-poor targeting lead to improved programme effectiveness and efficiency (as discussed above), have led to calls for improved targeting (for example Houssou and Zeller, 2011; Ricker-Gilbert et al., 2011; Ricker-Gilbert et al., 2009). However recognition of the importance of indirect impacts, of transparency and accountability, and of the costs of targeting suggest that a smaller (but still substantial) universal subsidy although theoretically inferior to successful targeting may nevertheless in practice lead to superior outcomes (for example Dorward and Chirwa, 2011a; Dorward et al., 2010b). The very substantial indirect effects of the subsidy in the SHI zone lend support to this latter approach in poorer maize growing areas in Southern Malawi. This approach would not appear to be so efficient in less poor areas (for example in central and northern Malawi). Cost, efficiency and local implementation challenges are of course not the only considerations that need to be taken into account in the design and implementation of targeting systems: political concerns are often of overriding importance.

## 4. Conclusions

This paper presented a partial equilibrium model of the impacts of the Malawi Farm Input Subsidy Programme on smallholder livelihoods in two major and contrasting livelihood zones over the period 2005/6 to 2010/11. The emphasis on partial equilibrium effects addresses an important gap in the literature on the programme, which has been dominated by studies reporting on survey findings on the differences between subsidy beneficiaries and non-beneficiaries.

Despite inherent difficulties in modelling the multi-scale and complex relationships involved, model findings are broadly consistent with survey findings on direct impacts on subsidy recipients (increasing maize production and real incomes), on differences between poorer and less poor households (with poorer households

normally gaining more proportionally but not necessarily absolutely from the same subsidy package), and on differences between central and southern region maize-growing areas with different rates of poverty incidence and land pressure (with greater absolute and proportional gains in poorer southern region areas). They are also consistent with anecdotal reports on the impacts of the programme on wages and maize prices. A significant finding of model simulations is that beneficial indirect effects may be greater than direct impacts in maize growing areas with high rates of poverty incidence and high land pressure. These indirect effects arise through increases in the ratio of wages to maize prices, and benefit poorer households (who sell *ganyu* labour and buy maize) while potentially harming in the short term the incomes of less poor buyers of *ganyu* labour and sellers of maize (these households should however gain in the medium and long run from increased livelihood opportunities with wider economic growth). This finding has important implications for programme design, implementation and evaluation. Much more emphasis should be placed on ensuring that the programme and other policies are managed to maximise these indirect benefits, and on assessing these benefits in programme evaluation. There are particular implications for the design and management of area and household targeting and graduation.

Model results should not, however, be taken as providing precise estimates of programme impacts. Findings should rather be taken as providing indicative information on patterns of impacts and on the relative importance of different factors in different contexts. Improvements in model performance could involve better consideration of inter-year benefits, more sensitivity analysis on modelling of maize price risk and its effects, use of more recent data from the latest Integrated Household Survey, and better integration of consumption linkages into partial equilibrium analysis of the Informal Rural Economy.

Table A1. Cluster characteristics – KAS zone

	Cluster labels	Poor female headed	Poor male headed	Remittances	<i>Dimba</i>	Borrower, <i>dimba</i>	Borrower no <i>dimba</i>	Large farm	Wage	All
<b>Cluster variables</b>										
Rainfed cultivated ha per member	Median	0.14	0.16	0.27	0.23	0.30	0.21	0.34	0.15	0.20
Dimba cultivated ha per member	Median	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.00
Retained maize kg per member	Median	39.90	40	85	75	112	104	194	70	70
% Female headed		100%	0%	49%	12%	6%	9%	8%	4%	20%
Transfer income MK/cap last 12 months	Median	43	60	1100	63	75	67	86	83	88
Total enterprise Borrowings MK/cap last 12 months	Median	0	0	0	0	1,233	1,500	0	0	0
Asset index per hh member	Mean	3.3	6.2	63.5	23.9	25.8	17.0	37.3	9.4	22.9
% hh earned wage last month >55 MK per day		5%	0%	1%	17%	9%	24%	2%	100%	16%
Dependency ratio by disability	Mean	1.8	1.1	0.8	1.0	1.0	1.0	0.7	0.9	1.0
Highest class attended	Mean	4.2	5.4	5.0	5.8	6.9	7.5	6.3	8.1	6.0
<b>Other variables</b>										
Poverty incidence		60%	48%	29%	38%	16%	29%	15%	29%	36%
Ultra-poverty incidence		21%	17%	9%	9%	1%	7%	4%	7%	11%
Per capita expenditure	Median	14,292	16,624	22,218	19,247	27,186	21,302	26,405	22,854	19,909
Per capita food expenditure	Median	9,562	10,136	13,349	11,273	15,088	12,064	14,495	13,517	11,749
Per capita non food expenditure	Median	4,783	5,897	8,193	7,043	10,667	8,982	10,317	9,043	7,360
Total N use kg/ha	Median	0	0.0	0.0	3.8	42.6	15.0	28.4	6.7	3.8
Total N use kg/household	Median	2.3	4.6	3.5	8.3	50	55.8	35.5	12.5	9.2
Hybrid maize yield kg	Median	591	461	691	691	1037	922	1166	806	691
N application on Burley, kg/ha	Median	29	30	25	38	152	152	86	72	57
Burley tobacco yield, kg/ha	Median	624	528	640	584	960	1200	800	1008	703.2
% land under local maize	Mean	42%	31%	40%	31%	20%	14%	30%	25%	31%
% land under hybrid maize	Mean	28%	30%	22%	30%	29%	35%	26%	33%	29%
% land under groundnuts	Mean	20%	15%	18%	21%	13%	12%	18%	16%	18%
% land under beans	Mean	21%	14%	12%	21%	21%	14%	14%	14%	17%
% land under burley	Mean	4%	12%	6%	10%	20%	23%	14%	7%	10%
Dependency ratio by age	Mean	1.4	1.0	0.9	0.8	0.8	0.8	0.6	0.7	0.9
Persons/hh	Mean	4.9	5.5	3.1	5.3	5.9	5.6	4.6	5.1	5.0
Cluster households in zone		9%	21%	12%	29%	3%	5%	12%	9%	100%

Table A2. Cluster characteristics – SHI zone

	Cluster labels	Poor female headed	Poor male headed	Remittances	<i>Dimba</i>	Large farm	Wage	Poor dimba grower	All
<b>Cluster variables</b>									
Rainfed cultivated ha per member	Median	0.14	0.15	0.20	0.27	0.43	0.12	0.14	0.18
Dimba cultivated ha per member	Median	0.00	0.00	0.00	0.06	0.00	0.00	0.04	0.00
Retained maize kg per member	Median	58	70	93	152	187	75	53	78
% Female headed		100%	0%	62%	18%	18%	4%	21%	29%
Transfer income MK/cap last 12 months	Median	63	74	955	100	300	88	92	114
Total enterprise Borrowings MK/cap last 12 months	Median	0	0	0	0	0	0	0	0
Asset index per hh member	Mean	2.7	4.7	3.5	12.3	89.0	4.1	2.8	13.9
% hh earned wage last month >55 MK per day		7%	0%	3%	7%	20%	100%	18%	18%
Dependency ratio by disability	Mean	1.5	0.9	1.1	0.8	0.3	0.9	1.2	0.9
Highest class attended	Mean	4.7	5.7	6.0	5.7	7.3	8.7	5.8	6.4
<b>Other variables</b>									
Poverty incidence		76%	70%	39%	40%	15%	46%	73%	56%
Ultra-poverty incidence		41%	34%	15%	10%	2%	20%	34%	25%
Per capita expenditure	Median	11,326	12,060	18,529	20,016	29,871	16,869	12,342	14,514
Per capita food expenditure	Median	6,174	7,052	10,613	11,739	16,718	9,264	7,598	8,647
Per capita non food expenditure	Median	4,344	4,611	6,882	7,259	12,018	6,748	4,623	5,606
Total N use kg/ha	Median	5.7	6.2	6.9	18.3	18.0	18.9	6.0	8.5
Total N use kg/household	Median	3.45	5	3.65	23	23	18.4	4.6	6.9
Hybrid maize production kg	Median	346	499	461	691	518	835	346	461
% land under local maize	Median	65%	52%	51%	50%	43%	41%	61%	52%
% land under hybrid maize	Median	39%	40%	39%	41%	41%	38%	38%	39%
% land under cassava	Mean	18%	21%	21%	28%	24%	13%	27%	21%
% land under groundnuts	Mean	20%	16%	14%	29%	23%	18%	27%	19%
% land under beans	Mean	13%	13%	15%	17%	20%	20%	23%	16%
% land under pigeon pea	Mean	46%	46%	52%	38%	43%	34%	51%	45%
% land under burley	Mean	2%	10%	1%	7%	7%	3%	5%	6%
Dependency ratio by age	Mean	1.3	0.9	0.9	0.7	0.4	0.8	1.1	0.9
Persons/hh	Mean	4.2	4.9	3.0	4.3	3.0	5.1	5.4	4.4
Cluster households in zone		15%	32%	13%	7%	11%	13%	9%	100%

Table A3. Cluster characteristics – general clusters across 10 Zones

	Cluster labels	Poor female headed	Poor male headed	Remittances	<i>Dimba</i>	Borrower	Large farm	Wage	Poor dimba grower	Remote	All
<b>Cluster variables</b>											
Rainfed cultivated ha per member	Median	0.15	0.15	0.30	0.24	0.20	0.41	0.14	0.16	0.19	0.20
<i>Dimba</i> cultivated ha per member	Median	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.05	0.00	0.00
Retained maize kg per member	Median	47	47	104	93	93	160	62	47	47	70
% Female headed		88%	5%	48%	13%	9%	11%	5%	18%	8%	24%
Transfer income MK/cap last 12 months	Median	75	55	900	70	75	120	78	50	51	86
Total enterprise Borrowings MK/cap last 12 months	Median	0	0	0	0	1550	0	0	0	0	0
Asset index per hh member	Mean	3.5	5.3	32.0	23.6	15.0	44.7	7.0	6.4	26.3	16.3
% hh earned wage last month >55 MK per day		3%	2%	7%	15%	25%	6%	100%	13%	10%	16%
Dependency ratio by disability	Mean	1.5	1.0	0.8	0.9	1.0	0.5	0.9	1.0	0.9	0.9
Highest class attended	Mean	4.6	5.5	5.5	6.0	7.8	6.1	8.2	5.8	5.6	6.0
<b>Other variables not used in cluster analysis</b>											
Poverty incidence		65%	63%	27%	36%	29%	20%	40%	62%	53%	47%
Ultra-poverty incidence		31%	29%	8%	9%	8%	5%	13%	27%	25%	19%
Per capita expenditure	Median	13,176	13,497	22,596	20,222	22,303	25,542	18,851	13,749	15,388	16,945
Per capita food expenditure	Median	8,259	7,992	13,431	11,854	12,373	14,371	10,801	8,567	9,119	10,136
Per capita non food expenditure	Median	4,650	4,909	8,342	7,204	9,582	10,064	7,540	4,757	4,922	6,140
Total N use kg/ha	Median	0.0	4.3	4.3	7.1	20.0	11.4	9.0	0.0	5.7	4.5
Hybrid maize yield kg	Median	346	461	461	658	922	576	576	346	346	461
N application on Burley, kg/ha	Median	29	41	27	57	143	76	61	67	133	57
Burley tobacco yield, kg/ha	Median	480	528	720	698	1123	744	816	480	1087	696
% land under burley		2%	6%	2%	8%	18%	7%	3%	3%	6%	5%
dependency ratio by age	Mean	1.3	1.0	0.8	0.8	0.8	0.5	0.8	1.0	0.9	0.9
Cluster households in zone		14%	27%	11%	16%	2%	11%	9%	7%	3%	100%

Table A4. Incidence of households in general clusters across 10 zones

	Cluster labels	Poor female headed	Poor male headed	Remit-tances	<i>Dimba</i>	Borrower	Large farm	Wage	Poor dimba grower	Remote	All
Shire Highlands	BOR	15%	32%	13%	7%		11%	13%	9%		100%
Kasungu-Lilongwe Plain	KAS	9%	21%	12%	32%	5%	12%	9%			100%
Lower Shire	LSH	12%	18%	7%	10%		12%	10%	15%	16%	100%
Middle Shire	MSH	13%	25%	25%	12%		16%	9%			100%
Mzimba Self-Sufficient	MZS	14%	14%	7%	18%				28%	19%	100%
Lake Chilwa - Phalombe Plain	PHA	22%	34%	0%	5%	4%	14%	6%	15%		100%
Rift Valley Escarpment	RFT	20%	34%	16%	6%	3%	0%	8%	8%	5%	100%
Border ProductiveHighlands	SHI	20%	44%	7%	9%		11%			10%	100%
Southern Lakeshore	SLA	9%	38%		4%	3%	12%	10%	24%		100%
Thyolo-Mulanje Tea Estates	TMT	24%	15%	9%	16%	4%	13%	20%			100%
All Zones listed above		14%	27%	11%	16%	2%	11%	9%	7%	3%	100%

Table A5. Summary results from SHI basic scenario set

		Area/hh (ha)							Maize prod'n		Real net income		Wage:maize price ratio			
Year		Local ha/hh	Hybrid ha/hh	Tobacco ha/hh	Gnuts ha/hh	Cassava ha/hh	Beans ha/hh	Pigeon peas ha/hh	All hh kg/hh	Target hh kg/hh	All hh MK/cap	Local ha/hh	Nov	Jan	Jul	Oct
Subsidy with actual prices	2005/6	0.54	0.19	0.03	0.00	0.11	0.37	0.00	889	562	14,048	11,717	0.34	0.57		
	2006/7	0.57	0.22	0.00	0.09	0.14	0.00	0.28	1045	940	14,823	13,073	0.65	0.74		
	2007_8	0.61	0.15	0.05	0.05	0.17	0.00	0.61	681	689	16,832	14,701	0.67	0.34		
	2008/9	0.73	0.16	0.10	0.04	0.00	0.00	0.69	752	662	16,711	14,126	0.33	0.53		
	2009/10	0.36	0.23	0.10	0.06	0.29	0.00	0.00	1005	899	18,241	15,943	0.60	0.80		
	2010/11	0.06	0.19	0.02	0.12	0.65	0.00	0.00	542	642	18,546	16,027	1.00	1.00		
	Median	0.55	0.19	0.04	0.05	0.16	0.00	0.14	820	675	16,771	14,414	0.63	0.65		
Mean	0.48	0.19	0.05	0.06	0.23	0.06	0.26	819	732	16,533	14,264	0.60	0.66			
No subsidy, actual prices	2005/6	0.89	0.11	0.02	0.00	0.02	0.77	0.00	797	518	13,669	11,155	0.34	0.57		
	2006/7	0.75	0.18	0.00	0.10	0.00	0.00	0.64	860	626	14,274	12,294	0.65	0.74		
	2007_8	0.82	0.11	0.00	0.05	0.05	0.00	0.82	648	651	15,599	12,914	0.67	0.34		
	2008/9	0.94	0.01	0.00	0.08	0.00	0.00	0.94	537	443	15,743	12,674	0.33	0.53		
	2009/10	0.35	0.20	0.04	0.10	0.34	0.00	0.06	871	681	17,773	15,251	0.60	0.80		
	2010/11	0.01	0.13	0.00	0.14	0.75	0.00	0.00	298	241	18,048	15,428	1.00	1.00		
	Median	0.79	0.12	0.00	0.09	0.04	0.00	0.35	723	572	15,671	12,794	0.63	0.65		
Mean	0.62	0.12	0.01	0.08	0.20	0.13	0.41	669	527	15,851	13,286	0.60	0.66			
No subsidy, estimated equilibrium prices	2005/6	0.89	0.10	0.02	0.00	0.00	0.80	0.00	754	452	13,251	9,412	0.30	0.30		
	2006/7	0.75	0.18	0.00	0.10	0.00	0.00	0.64	860	626	14,280	12,310	0.68	0.47		
	2007_8	0.82	0.11	0.00	0.05	0.05	0.00	0.82	648	651	15,491	12,683	0.67	0.32		
	2008/9	0.94	0.01	0.00	0.08	0.00	0.00	0.94	538	445	14,598	9,609	0.32	0.24		
	2009/10	0.46	0.20	0.04	0.09	0.24	0.00	0.24	867	670	17,443	14,518	0.56	0.60		
	2010/11	0.01	0.20	0.00	0.14	0.69	0.00	0.00	459	448	n.a.	n.a.	n.a.	n.a.		
	Median	0.78	0.14	0.00	0.09	0.03	0.00	0.44	701	539	14,598	12,310	0.56	0.32		
Mean	0.64	0.13	0.01	0.08	0.16	0.13	0.44	688	549	15,012	11,706	0.50	0.38			

Table A6. Summary results from KAS Basic Scenario set

		Area/hh (ha)							Maize prod'n		Real net income		Wage:maize price ratio	
		Local ha/hh	Hybrid ha/hh	Tobacco ha/hh	Gnuts ha/hh	Cassava ha/hh	Beans ha/hh	Pigeon peas ha/hh	All hh kg/hh	Target hh kg/hh	All hh MK/cap	Local ha/hh	NovJan	JulOct
Year														
Subsidy with actual prices	2005/6	0.95	0.11	0.13	0.01	0.01	0.87	0.00	817	492	14,499	10,892	0.39	0.65
	2006/7	0.91	0.20	0.00	0.08	0.00	0.83	0.00	998	927	14,815	12,809	0.82	0.94
	2007_8	0.38	0.15	0.18	0.06	0.25	0.13	0.00	534	606	17,088	15,612	0.82	0.42
	2008/9	0.96	0.11	0.08	0.05	0.02	0.94	0.00	743	515	17,376	13,942	0.39	0.63
	2009/10	0.71	0.23	0.21	0.00	0.03	0.61	0.00	930	762	17,595	15,187	0.72	0.97
	2010/11	0.37	0.13	0.03	0.14	0.37	0.00	0.00	479	591	17,340	15,037	1.00	1.00
	Median	0.81	0.14	0.11	0.05	0.03	0.72	0.00	780	599	17,214	14,490	0.77	0.80
Mean	0.71	0.15	0.10	0.06	0.12	0.56	0.00	750	649	16,452	13,913	0.69	0.77	
No subsidy, actual prices	2005/6	0.99	0.08	0.12	0.01	0.01	0.91	0.00	784	488	14,285	10,715	0.39	0.65
	2006/7	1.00	0.13	0.00	0.08	0.04	0.93	0.00	862	578	14,633	12,605	0.82	0.94
	2007_8	0.43	0.09	0.16	0.07	0.30	0.13	0.00	428	364	16,363	14,577	0.82	0.42
	2008/9	1.03	0.07	0.02	0.08	0.02	1.02	0.00	670	411	16,839	13,018	0.39	0.63
	2009/10	0.80	0.18	0.20	0.01	0.04	0.69	0.00	883	613	17,172	14,531	0.72	0.97
	2010/11	0.45	0.00	0.00	0.16	0.45	0.00	0.00	261	260	17,076	14,770	1.00	1.00
	Median	0.90	0.08	0.07	0.08	0.04	0.80	0.00	727	450	16,601	13,774	0.77	0.80
Mean	0.78	0.09	0.08	0.07	0.14	0.61	0.00	648	452	16,061	13,369	0.69	0.77	
No subsidy, estimated equilibrium prices	2005/6	0.99	0.08	0.12	0.01	0.01	0.91	0.00	785	488	13,308	9,172	0.39	0.27
	2006/7	1.00	0.13	0.00	0.08	0.01	0.95	0.00	861	578	14,743	12,784	0.77	0.73
	2007_8	0.42	0.10	0.15	0.08	0.29	0.13	0.00	464	487	16,337	14,403	0.79	0.38
	2008/9	1.00	0.11	0.01	0.08	0.02	0.99	0.00	695	435	16,826	12,859	0.38	0.55
	2009/10	0.72	0.20	0.22	0.01	0.03	0.62	0.00	881	620	17,101	14,296	0.72	0.69
	2010/11	0.66	0.00	0.00	0.13	0.23	0.43	0.00	381	356	17,246	14,981	0.90	0.87
	Median	0.86	0.11	0.07	0.08	0.02	0.76	0.00	740	488	16,582	13,578	0.75	0.62
Mean	0.80	0.10	0.08	0.07	0.10	0.67	0.00	678	494	15,927	13,083	0.66	0.58	

Table A7. Summary results from SHI Basic with savings scenario set

		Area/hh (ha)							Maize prod'n		Real net income		Wage:maize price ratio	
		Local ha/hh	Hybrid ha/hh	Tobacco ha/hh	Gnuts ha/hh	Cassava ha/hh	Beans ha/hh	Pigeon peas ha/hh	All hh kg/hh	Target hh kg/hh	All hh MK/cap	Local ha/hh	NovJan	JulOct
Year														
Subsidy with actual prices	2005/6	0.54	0.18	0.02	0.02	0.12	0.36	0.01	857	562	14,271	11,717	0.34	0.57
	2006/7	0.64	0.22	0.00	0.10	0.07	0.00	0.33	1106	1019	14,756	13,011	0.65	0.74
	2007_8	0.63	0.15	0.05	0.06	0.14	0.00	0.63	696	691	17,004	14,858	0.67	0.34
	2008/9	0.71	0.17	0.11	0.05	0.00	0.00	0.66	755	664	16,815	14,290	0.33	0.53
	2009/10	0.38	0.23	0.13	0.04	0.25	0.00	0.00	1056	965	18,098	15,746	0.60	0.80
	2010/11	0.06	0.19	0.02	0.12	0.64	0.00	0.00	550	642	18,545	16,027	n.a.	n.a.
	Median	0.59	0.19	0.03	0.06	0.13	0.00	0.17	806	677	16,909	14,574	0.60	0.57
Mean	0.49	0.19	0.05	0.07	0.20	0.06	0.27	837	757	16,581	14,275	0.52	0.59	
No subsidy, actual prices	2005/6	0.89	0.10	0.02	0.02	0.01	0.76	0.02	765	518	13,882	11,155	0.34	0.57
	2006/7	0.75	0.18	0.00	0.10	0.00	0.00	0.64	860	626	14,274	12,294	0.65	0.74
	2007_8	0.82	0.11	0.00	0.05	0.05	0.00	0.82	648	651	15,599	12,914	0.67	0.34
	2008/9	0.94	0.01	0.00	0.08	0.00	0.00	0.94	537	443	15,743	12,674	0.33	0.53
	2009/10	0.35	0.20	0.04	0.10	0.34	0.00	0.06	871	681	17,773	15,251	0.60	0.80
	2010/11	0.01	0.13	0.00	0.14	0.75	0.00	0.00	298	241	18,048	15,428	1.00	1.00
	Median	0.79	0.12	0.00	0.09	0.03	0.00	0.35	707	572	15,671	12,794	0.63	0.65
Mean	0.63	0.12	0.01	0.08	0.19	0.13	0.41	663	527	15,887	13,286	0.60	0.66	
No subsidy, estimated equilibrium prices	2005/6	0.90	0.07	0.02	0.02	0.01	0.79	0.02	704	452	13,460	9,412	0.30	0.30
	2006/7	0.77	0.17	0.00	0.09	0.00	0.00	0.66	857	623	14,368	12,035	0.61	0.41
	2007_8	0.82	0.11	0.00	0.06	0.05	0.00	0.82	648	652	15,443	12,630	0.67	0.31
	2008/9	0.95	0.01	0.00	0.07	0.00	0.00	0.95	545	458	14,343	8,929	0.31	0.23
	2009/10	0.48	0.20	0.04	0.09	0.22	0.00	0.26	869	668	17,324	14,198	0.56	0.52
	2010/11	0.01	0.20	0.00	0.14	0.69	0.00	0.00	459	448	n.a.	n.a.	n.a.	n.a.
	Median	0.79	0.14	0.00	0.08	0.03	0.00	0.46	676	540	14,368	12,035	0.56	0.31
Mean	0.65	0.13	0.01	0.08	0.16	0.13	0.45	680	550	14,988	11,441	0.49	0.35	

Table A8. Summary Results from SHI Equilibrium Trajectory Scenario Set

		Area/hh (ha)							Maize prod'n		Real net income		Wage:maize price ratio	
		Local ha/hh	Hybrid ha/hh	Tobacco ha/hh	Gnuts ha/hh	Cassava ha/hh	Beans ha/hh	Pigeon peas ha/hh	All hh kg/hh	Target hh kg/hh	All hh MK/cap	Local ha/hh	NovJan	JulOct
Year														
Subsidy, estimated subsidy equilibrium prices	2006/7	0.51	0.20	0.00	0.05	0.30	0.00	0.27	903	688	14,366	12,405	0.65	0.74
	2007_8	0.78	0.09	0.08	0.08	0.01	0.00	0.78	609	588	16,217	14,028	1.00	0.31
	2008/9	0.74	0.16	0.09	0.04	0.00	0.00	0.68	766	646	13,455	11,405	0.25	0.49
	2009/10	0.69	0.24	0.02	0.05	0.22	0.00	0.02	1330	1254	14,061	11,510	0.36	2.65
	Median	0.71	0.18	0.05	0.05	0.11	0.00	0.47	834	667	14,214	11,958	0.51	0.61
Mean	0.68	0.17	0.05	0.06	0.13	0.00	0.44	902	794	14,525	12,337	0.57	1.05	
No subsidy, estimated subsidy equilibrium prices	2006/7	0.87	0.11	0.00	0.05	0.00	0.00	0.79	765	527	13,567	11,185	0.65	0.74
	2007_8	0.77	0.16	0.00	0.10	0.00	0.00	0.77	719	655	15,052	12,391	0.72	0.34
	2008/9	0.90	0.01	0.00	0.12	0.00	0.00	0.90	514	416	13,659	10,774	0.36	0.53
	2009/10	0.74	0.27	0.02	0.00	0.01	0.44	0.00	1227	872	13,031	10,529	0.33	0.80
	Median	0.82	0.13	0.00	0.08	0.00	0.00	0.78	742	591	13,613	10,979	0.50	0.63
Mean	0.82	0.14	0.00	0.07	0.00	0.11	0.61	806	617	13,827	11,220	0.51	0.60	
No subsidy, estimated no subsidy equilibrium prices	2006/7	0.87	0.11	0.00	0.05	0.00	0.00	0.79	766	528	13,331	10,577	0.65	0.48
	2007_8	0.80	0.14	0.00	0.09	0.00	0.00	0.80	712	645	15,355	12,084	0.66	0.30
	2008/9	0.89	0.01	0.00	0.13	0.00	0.00	0.89	508	446	12,574	7,945	0.29	0.26
	2009/10	0.80	0.21	0.02	0.01	0.00	0.54	0.00	1098	669	11,199	7,118	0.20	1.00
	Median	0.84	0.13	0.00	0.07	0.00	0.00	0.80	739	586	12,952	9,261	0.47	0.39
Mean	0.84	0.12	0.00	0.07	0.00	0.14	0.62	771	572	13,115	9,431	0.45	0.51	

## Annex B Model Structure

(updated from Dorward (2003))

The patchy data available, previous experience of smallholder farm/ household modelling in Malawi, and the flexibility required of the models in examining responses to different stimuli suggested the use of programming techniques. The broad structure of the model was formulated as follows:

$$\text{Max}E(U) = \sum_s P_s \prod_{j^*m} (C_{jm} - \gamma_{jm})^{\beta_{jm}} \quad (1)$$

such that

for  $m=1$  to 2

$$-t_{jm} + t_{j(m+1)} + \sum_{ij} e_{ijm} x_i + C_{jm} \leq 0 \quad (2)$$

for  $m=3$  to 4

$$-t_{jms} + t_{j(m+1)s} + \sum_{ij} e_{ijms} x_{is} + C_{jms} \leq B_{jm} \quad (3)$$

for  $m=4$

$$-t_{j(m+1)s} = t_{j(m=1)} \quad (4)$$

where

$m$  are periods within a year:  $m = 1$  describes the 'cropping period' (November to January);  $m = 2$  describes the 'pre-harvest period' (February and March);  $m = 3$  describes the 'harvest period' (April to June); and  $m = 4$  describes the 'post harvest period' (July to October).

$s$  are alternative market conditions as regards end of season maize prices (in periods  $m=3$  and  $m=4$ )

$P_s$  are subjective probabilities of alternative market conditions  $s$

$C_{jm}$  represent total consumption of commodity/ resource  $j$  in period  $m$

$g_{jm}$  are minimum consumption requirements for commodity/ resource  $j$  in period  $m$

$jm$  are the marginal propensities to consume commodity/ resource  $j$  in period  $m$

$t_{jms}$  represent transfers of commodity/ resource  $j$  from period  $m$  to period  $m+1$  in market condition  $s$

$e_{ijms}$  are technical and price coefficients of use/ production of resource/ commodity  $j$  by activity  $x_{is}$  in period  $m$  under market condition  $s$

$x_{is}$  are activities undertaken by the household. These include cropping activities, buying and selling of stocks and labour, and stock transfers between periods. For those activities which take place wholly in periods 3 or 4 these are distinguished according to the market condition  $s$  under which they are followed.

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

Commodity/ resource  $j$  include land, labour, cash stocks, maize stocks, purchased crop inputs, and post harvest cash crop stocks.

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

Equation 1 maximises expected utility using a linear expenditure system (LES). Equations 2 and 3 describe constrained resource use and production opportunities in different periods, 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. Equation 3 allows for alternative stocking, market and off farm employment strategies to be followed under different market conditions (maize price regimes) in the harvest and post-harvest periods, and to this extent allows for some embedded risk<sup>5</sup>. Equation 4 ensures that the model maintains the same opening and closing stocks from year to year and does not generate artificial windfall gains by portfolio changes (for example by replacing maize stock by cash).

The model also included upper bounds on some activities (for example input purchases financed by sale of labour, consumption of hybrid maize in the pre-harvest period, and consumption and sales of root crops). These were introduced to represent practical constraints not allowed for in the general formulation, describing, for example, the effects of limited maize storage capacity, of timing of activities within time periods (inputs cannot be purchased at the beginning of the cropping period using wage earnings from the end of the cropping period; grain or roots produced near the end of a period cannot support consumption at the beginning of that period) and constraints on specific activities (for example for most farmers there are severe transport, labour and market constraints precluding large scale sales of root crops).

Modifications to the earlier specification reported in Dorward (2003) were introduced to allow for the need to simulate access to subsidised seed and fertiliser separate from other crop inputs and to allow for different rates of fertiliser use in tobacco production. Model coefficients were also updated to reflect 2003/4 prices for crops using prices calculated from IHS2 sales and triangulated against and for later years updated with monthly market price data and data from AISS surveys in 2007, 2009 and 2011. *Ganyu* wage rates were also estimated from survey data (although there was considerable variability in these estimates), and household specific characteristics modified with data from the IHS2 cluster analysis. Price data were also compared with prices in the 1998 IHS1, adjusted with the rural retail price index. Technical coefficients for crop yields and labour requirements from the earlier model

were used except for the introduction of the possibility of growing tobacco without fertiliser, for which fertiliser yield responses were estimated from IHS2 data. Maize harvesting and fertiliser application labour rates were also modified to reflect modified estimates of labour requirements for these activities. No information was available on dimba cultivation and this is not allowed for in the model. Non-farm activities are modelled purely through non-farm wage rates, with IHS2 information on the number of persons earning wages above MK55 per day in the month prior to interview, and a skilled wage factor estimated for each household type as a mark up on *ganyu* wage rates. Maize consumption is estimated on the basis of 70% of household calorific requirements being supplied by maize. Minimum seasonal cash expenditure is estimated from seasonal cash expenditures of the poorest household types. As with the model based on the IHS1 1998 data, no information was available on opening cash stocks, and these were defined as 96 days household minimum cash expenditure for the poorest households, with increases above this for less-poor households related to median expenditures per capita estimated from IHS2 data. In most cases the same technical and price coefficients were used for modelling in the two different zones. Exceptions to this are in yield coefficients for pigeon peas, which do not grow in the central region, prices where differences were found in survey estimates, and yields where minor differences emerged in calibration processes for groundnuts, cassava and beans. The principle differences between the two zones arise in the characteristics and relative numbers of different household types.

The LES function requires the estimation of marginal propensities to consume cash, maize and leisure and to save. IHS2 data were used to estimate marginal propensities to consume cash and staples by household types by zone by time of survey (to allow for seasonal differences in consumption (Chirwa et al., 2012)). However a consumption and expenditure data set cannot provide estimates of marginal propensities to consume leisure or to save. Marginal propensities to consume for the cropping and pre-harvest periods were set at zero and extra consumption that higher incomes should lead to in these periods were carried forward as savings for consumption in the next season (this ensures that end of season income increases do not affect consumption at the beginning of the season). Marginal propensity for leisure was set at zero for all households, and given the relatively small income increases and the uncertainty about labour use and supply estimates is unlikely to affect results. Savings were investigated by setting the marginal propensity to save at zero and at 20%, and results compared.

A significant extension in the 2012 model is the separation of expected and actual prices, with expected prices (an average of the two previous years' prices) in the harvest and post-harvest periods being used in an initial run of the model. After this which cropping activities (land allocations) were fixed, and then the model rerun with actual prices to determine the outcomes that households achieved. Pre-harvest actual

prices (wage rates and maize prices) were used throughout, based on the assumption that as these were determined while farmers were making decisions then farmers would use these in making decisions. Although still a rough approximation of the difficulties farmers face in making decisions in the context of price uncertainty, this is an improvement over the previous formulation.

This model structure is able to address the major design aspirations for these models.

1. *Seasonal constraints*: The year is divided into four periods. In the 'cropping period' crops make heavy demands on labour and there are potential trade-offs between on-farm work (generating returns later, at harvest time) and off farm work (generating lower but more immediate returns which, for cash and food scarce, poor households, may be needed to sustain minimal levels of cash and food consumption prior to harvest since households are not able to borrow to meet their immediate consumption needs). In the pre-harvest period some early crops may be harvested (beans, short season maize) but there is limited on-farm labour demand and hence limited demand for off-farm work. In the harvest period crop prices are expected to fall and farm labour demand and off farm wage rates rise. In the post-harvest period crop prices rise are expected to rise, some farm labour is required for land preparation, and there are more off farm employment opportunities (for example in petty trading, in building, collecting grass, etc).
2. *Varied activities*: a range of different cropping activities are modelled within this structure, with varying seasonal demands for labour and purchased inputs, and different types of seasonal activities. The model structure allows flexibility in linking these to stocking and buying and selling activities across and within time periods. Off farm activities are described in terms of hiring out of labour at differing rates in different periods. Borrowing (for cash or tied crop inputs) can also be described. Technical change and the introduction of new crops or new income earning opportunities are described by the introduction of new activities into the model.
3. *Heterogeneity*: differences between households are described in terms of differences in the options open to them (for example different cropping activities in different agro-ecological areas), in their asset holdings (for example land, seasonal labour, pre-seasonal holdings of cash and grain stocks), and in the relation between their consumption needs and assets (the dependency ratio is important here, with interactions between labour available for on and off farm work, consumption needs, and stocks of cash and grain available for consumption prior to harvest).

4. *Partial engagement with imperfect markets:* To capture the key problems that arise from imperfect markets the model would ideally allow for different market relations with different transaction costs and risks. However this would have made the model considerably more complex, and the necessary data were not available: imperfect markets were therefore allowed for by introducing a 'wedge' between market, farm gate and local purchase prices. Farm gate sales prices are calculated in the model as market prices less a mark-down, and consumer purchase prices as market prices plus a mark-up. Imperfect markets are represented primarily by a large mark-down depressing farm gate prices, as well as by price uncertainty in food markets (discussed below). Transaction costs (but not risks) are also allowed for in unskilled labour markets, with time demands for supervision when hiring in labour, and when hiring out labour there are time demands for travelling costs (although these are relatively small as the majority of labour transactions take place within the locality (Nyirongo et al., 2001; van Donge and al., 2001)) and over-supply on 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 allowed for by introducing search costs (in terms of time) for those seeking ganyu employment. Complete credit market failure is assumed: households cannot borrow without special interventions, such as credit tied to the provision of tobacco inputs with recovery through tobacco sales. It was originally hoped to allow for both fixed and variable elements of transaction costs in the model, but this involved use of mixed integer programming and, for the base model at any rate, introduced more complexity than it was worth.
5. *Food security objectives in uncertain markets:* It is frequently argued that uncertainty as regards the reliability and costs of purchasing food cause Malawian smallholders to set a high premium on subsistence maize production, inhibiting specialisation in otherwise more productive in activities (see for example Orr and Orr, 2002; School of Oriental and African Studies et al., 2008). This is commonly modelled by setting some minimum maize production target (for example Alwang and Siegel, 1999; Simler, 1994), but this precludes investigation of the effects of improved market performance (and of trust in market performance). Food consumption was therefore modelled in terms of calorific requirements which can be met in different ways according to season. In the crop and pre-harvest periods maize can be consumed either from stocks carried forward from the previous season (different household types carried forward varying stocks to support this) or from purchases. In the harvest and post-harvest periods calories can be provided from

own farm maize production, from own farm production of other crops (cassava, sweet potato, rice, and groundnuts), and from purchases of maize. Subsistence production of maize (or root crops) was therefore encouraged by the wedge between maize purchase and sales prices, as discussed above. The effect of food price uncertainty on farmers' food security considerations is modelled by introducing three alternative market conditions in the base model, representing expected, high and low maize purchase prices.

6. *Non-separability:* The modelling of seasonal constraints, of imperfections in maize, labour and credit markets (as outlined above), and of household objectives means that there is potential for strong competition and interaction between consumption and production activities, particularly for poorer households affected by seasonal stock constraints and lack of access to credit.

## Notes

- <sup>i</sup> Standardization was carried out across the whole sample, not within each livelihood zone.
- <sup>ii</sup> A steady state or breakeven situation was assumed in the absence of a subsidy, and a 20% marginal propensity to save was applied to the difference in cash stocks accumulation between recipient and non-recipient households.
- <sup>iii</sup> As noted earlier, IRE simulations did not take into account the effect of increased incomes on increased local demand for non-tradables, tightening the labour market. Examination of balances suggests that this leads to a small underestimate of wage rises (falls) under the subsidy (no subsidy) scenarios for simulations with the basic scenario sets, leading to small increases in estimated indirect effects of the subsidy, but larger underestimate of wage changes for simulations with the 'equilibrium trajectory' scenario set, leading to larger increases in estimated indirect effects of the subsidy.
- <sup>iv</sup> Real incomes are deflated to 2005/6 prices using an endogenously estimated rural CPI specific to each household types using endogenous wage rates and maize prices and 10% annual inflation for other tradables allowing for each households' expenditure shares on non-tradable, staple food, and other tradable expenditure categories.
- <sup>v</sup> To reduce the complexity and size of the model the base formulation only explicitly allows for risk and uncertainty in maize prices, and even here uses a simple maximisation of expected utility. The model does not allow for uncertainty in yields, or for embedded risk during the cropping and pre-harvest periods as regards the effects of, for example, sickness on labour and cash availability, although these are likely to be important considerations, particularly for poorer households (Dorward, 1999; Dorward and Parton, 1997).
- <sup>vi</sup> To reflect variation between seasons as regards local maize demand and supply, farm gate (sales)

prices in the 'crop' period are not subject to the mark-down explained earlier (to allow for local demand), whereas in the harvest and post harvest periods maize can be purchased at the farmgate (marked down) price, to reflect local supply (all purchases, however, incurred a markup to represent buying costs).

vii The model also allows for income from non-farm semi-skilled labour. If a household has such labour it may be sold off the farm for a higher wage or used on farm (in which case it is treated as identical to other household labour). No attempt is made to model specific non-farm enterprises (for example in terms of capital requirements) and all non-farm activities (skilled or unskilled) earns a wage, recognising that this might in fact represent self employment in, for example, cutting firewood or thatching grass, or petty trading.

viii A distinction is made between 'local' and 'hybrid' maize varieties, in that only grain from 'local' maize varieties (from purchases or own production) can be kept beyond October. This reflects poorer storage qualities of 'hybrid' varieties.

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