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Agricultural Household Models for Malawi: Household Heterogeneity, Market Characteristics, Agricultural Productivity, Input Subsidies, and Price Shocks

A Baseline Report

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Agricultural Household Models for Malawi: Household Heterogeneity, Market Characteristics, Agricultural Productivity, Input Subsidies, and Price Shocks A Baseline Report[1]

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Abstract

This report documents agricultural household models developed for agricultural policy analyses related to the assessment of impacts of agricultural input subsidies and maize technology choices in Malawi. The models have been calibrated to a typology of households in Central and Southern Regions of Malawi based on household survey data collected for the period 2005-2010. Households are assumed to be drudgery averse and rational given their preferences and the resource constraints and imperfect markets they face. The impacts of varying access to resources, input subsidies, off-farm employment opportunities, and prices during the period of study are simulated. The models in particular demonstrate the vulnerability of land-poor households and their dependence on non-farm income for them to meet their basic needs. Access to improved maize varieties and subsidies may facilitate land use intensification and survival on smaller farms. Price shocks in form of higher fertilizer prices and lower tobacco prices contribute to further impoverishment while the costs of the input subsidy program also reached non-sustainable levels during the period of study. The models give insights about some possible avenues for scaling down the subsidy program towards a more sustainable level. Reduction of subsidies from two bags to one bag of fertilizer per household and concentration of targeting towards more land-poor households can be two important mechanisms. Rather than providing free improved maize seeds it may be better to improve the availability of improved seeds in local markets.

JEL codes: Q12, Q18.

Key words: Agricultural household programming models, Malawi, production systems, market characteristics, impact of input subsidies, fertilizer and tobacco price shocks.

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1. Introduction

This report provides basic description of applied agricultural household models that have been developed to assess the impacts of the Farm Input Subsidy Program in Malawi and the potential of improved agricultural technologies such as improved maize varieties. The traditional agricultural technologies, the basic farm household characteristics such as taste preferences and labor endowments, market characteristics, agro-ecological characteristics and their implications for seasonality in agriculture and the productivity of technologies, form much of the basic structure of the models.

Input subsidies in agriculture have received a renewed interest after Malawi and several other African countries reintroduced such subsidies at a broad scale. This followed a period of two decades of condemnation of input subsidies because of their distortionary effects and the drain on government budgets. The new design of the subsidy packages, aiming to target the poor and needy, gave hope that they could work in a smarter way than earlier subsidy programs and reach only the needy with the appropriate effects of ensuring food security for the poor (World Bank 2008). Malawi was a front-runner in this endeavor and a prestigious policy of the late president Bingu wa Mutharika from 2005 and also contributed to his re-election in 2009 after some years with increased maize production in the country, which was attributed to the success of the subsidy program.

Research on the impacts of the subsidy program in Malawi and similar programs in other countries raised questions about their efficacy. Jayne and Rashid (2013) provide a synthesis of the evidence on input subsidy programs in Africa. Lunduka et al. (2013) provide a review of the studies on farm-level impacts of the recent input subsidy program in Malawi. Holden and Lunduka (2013), using household panel data from six districts in central and southern Malawi for the period 2005/06 - 2008/09 and showed that there are substantial targeting errors and leakages in the distribution of targeted input subsidies leading to substantial errors of exclusion and errors of inclusion in the program and an informal market for leaked fertilizer. Female-headed households were less likely to receive input subsidies even though they were identified as an important group to target. Chibwana et al. (2012) similarly found that asset-poor and female-headed households were less likely to get input subsidies, using instrumental variable estimation of survey data from 2008/09. Ricker-Gilbert et al. (2011) used survey data from 2003/04 and 2006/07 (panel) and found that access to subsidized fertilizer crowded out demand for commercial fertilizer at a rate of 0.22 kg/kg subsidized fertilizer. Mason and Ricker-Gilbert (in press) used data from 2006/07 and 2008/09 (panel) and found that access to subsidized seeds crowded out commercial seeds at a rate of 0.56 kg/kg subsidized seed. Holden and Lunduka (2012) found no similar strong crowding out effect from fertilizer subsidy access on use of organic manure. Chibwana et al. (2013) used cross-section data from two locations and found that access to input subsidies was associated with less forest clearing while indirect effects on tobacco production resulted in more tree cutting for construction of tobacco drying sheds. Holden and Lunduka (2014) combined survey data and hypothetical and real experiments to investigate the demand for inputs at varying subsidy levels among smallholder farmers in Malawi. They questioned whether low demand was due to time-inconsistent behavior or by limited ability to buy inputs? They investigated the importance of package size and timing of provision of inputs. They found evidence on the importance of the cash constraint limiting the demand and that provision of smaller packages of fertilizers from harvesting season and up to planting time could stimulate fertilizer demand and be a feasible way to reduce dependency on input subsidies without negatively affecting the production.

Most of the studies above have used econometric methods to analyze household survey data. While many efforts have been made to control for endogeneity and unobserved heterogeneity the data limitations make it challenging to identify causal effects. Identification of valid exogenous instruments is challenging in a setting with multiple market imperfections causing non-separability of production and consumption decisions. Even exogenous weather shocks may not be valid instruments and so is the case with exogenous policy interventions because of the roles of social networks, particularly in relation to targeted policy interventions such as the input subsidy program in Malawi. Access to subsidized inputs is likely to be systematically related to observable and unobservable household characteristics. The household heterogeneity is highly likely to be associated with heterogeneous impacts. Under such “second-best” conditions household modeling can be a useful additional tool where strict *ceteris paribus* assumptions can be invoked to deduce clear causal effect. Such models, if properly constructed and calibrated, can be used to verify the econometric findings and their plausibility under alternative assumptions.

Dorward (2002; 2003; 2006) has developed household models for rural households in Malawi, based on a broad typology of household categories, with a focus on grain, cash crop (tobacco), and labor markets and their implications for poverty and agricultural growth.

This report presents new rural household models for smallholder agricultural households in Malawi. The purpose of these models is to model in more detail the agricultural production technologies and farming systems with associated imperfect input and output markets, variation in land access, and variation in access to input subsidies. The models can also test the plausibility of various econometric findings where it is hard to establish strict causality.

The focus is on the period from 2005/06 to 2008/09 when the subsidy program expanded and additional price shocks occurred in relation to the international “financial-fuel-food” crisis. This was a period with fairly stable weather conditions in Malawi and weather risk is therefore not a part of the analysis.

Part 2 outlines the basic behavioral assumptions that the agricultural household models rely on. Part 3 describes the socio-economic variation and classification of households into household categories for which separate models are established. In part 4 the agricultural production and farming systems in Malawi are described and how these are captured in the models in form of agricultural technology activities, seasonality and labor requirements. Part 5 describes the typical rural market characteristics that households face, followed by an outline of the relevant agricultural policies in the country that also have strong impacts on these market characteristics in form of access and prices of inputs and outputs. How these market characteristics are captured in the household models is then outlined. Part 6 gives and overview of the input subsidy program and how it has been calibrated into the household models. Part 7 presents a set of initial models that have been presented in Holden (2013a). These models have no land rental market and include limited labor market access. Part 8 provides a wider set of simulations after including land rental markets and wider variation in labor market access and assessing their implications, using 2005/06 data to investigate the implications the input subsidy program at that time. Part 9 provides further simulations with fertilizer and tobacco price shocks and limited access to input subsidies at higher subsidy levels, reproducing changes that took place in 2008/09. A final discussion of the key implications is presented in part 10.

2. Basic household behavioral assumptions

Agricultural households are assumed to behave rational in the sense that they try to utilize their scarce resources to meet their basic needs and beyond that maximize their utility. The model covers one year and includes seasonality such that the year is split in 11 periods of varying length. Utility is simply captured by building on Chayanov's theory of the drudgery-averse peasant. After satisfaction of basic needs (minimum energy and protein requirements) and a set of minimum taste preferences (such as minimum consumption levels of basic food crops such as maize, beans, groundnuts and pigeon peas), households maximize net income minus aggregate drudgery, which is similar to a weighted income – leisure goal (Holden 1993). A step function is used in each time period of the year such that drudgery is higher when working longer hours such as in peak agricultural seasons thus creating higher shadow values of time in the peak seasons than in the slack seasons when working days are shorter. The step function for drudgery is calibrated versus the going wage rates in the local labor market (*ganyu* labor). This is illustrated in Table 2.1.

Table 2.1. Shadow wage rates and *ganyu* wage rates used in models

Adjustments in shadow wage:	Unit	Increment	Total Value Per hour	Daily wage rate, 8 hour day
UP TO 70% OF MAX. TIME:	MK.	12.5	12.5	100
FROM 70 TO 90% OF MAX. TIME:	MK	6.25	18.75	150
FROM 90 TO 100% OF MAX. TIME:	MK	8.75	27.5	220

Note: Basic shadow wage rate: 100MK/8 hour day, max rate 220MK/8 hour day. The g*anyu* wage rate was set at 25MK/hour or 200MK/day, based on observed wage rates in 2005/06.

3. Household classification

The models have been developed based on survey data collected in Central and Southern Regions of Malawi. Kasungu and Lilongwe districts in Central Region and Chiradzulu, Machinga, Thyolo and Zomba Districts in Southern Region are the districts included in surveys conducted in 2006, 2007, and 2009, and 2012. The sample should be representative of smallholder households in Central and Southern Malawi, where 89% of the population of the country lives. It is the data from the first three survey rounds that primarily have been used as inputs for the modeling. Population densities are substantially higher in Southern Region than in Central Region and this causes also farm sizes to be smaller in Southern Region than in Central Region on average. Poverty levels are also higher in Southern Region than in Central Region (refs.). Another distinction between the Central and Southern Regions is that a matrilineal inheritance system dominates in the South while patrilineal inheritance dominates in the Central Region. This may give women a stronger decision-power in households in the South than in the Central region. Separate models have therefore been developed for the two regions. We also decided to split households in female- and male-headed households in each of the two regions. The difference in inheritance systems is one reason for this divide. Another reason is the fact that the Farm Input Subsidy Program has aimed particularly to target vulnerable households such as female-headed households. This makes it relevant to assess their resource situation and policy impacts on this group. Female-headed households are also more likely to be poor and ultra-poor than male-headed households with 59% of female-headed against 51% of the male-headed households living below the poverty line in 2005 (RoM and World Bank 2006).

For the male-headed households we decided to further split them up in land-poor and land-rich households while we decided to drop this for female-headed households that constituted a smaller share of the sample. We compensate for this by running sensitivity analyses to assess how variation in land access affects the situation of female-headed households. Table 3.1 outlines the basic difference between the key household categories that are modeled.

The basic nutrition requirements and labor availability for selected representative “typical” households, using median household size, for each household group are outlined in Table 3.2. Energy and protein requirements are based on standard nutrition tables from World Health Organization/FAO. Table 3.3 provides an overview of various constraints that are included in the models.

Table 3.1. Basic socio-economic data used for calibration of household models

	Southern Region			Central Region		
		Male-Headed			Male-Headed	
	Female-Headed	Land-Poor	Land-Rich	Female-Headed	Land-Poor	Land-Rich
No. of households in group	73	93	99	44	39	109
Land owned (ha)	0.94	0.61	1.37	1.39	0.78	1.97
Per capita land owned (ha)	0.27	0.10	0.44	0.35	0.13	0.41
Tropical livestock units	0.85	0.98	0.93	0.99	1.28	1.47
Male labor endowment/ha	2.2	3.5	2.8	1.1	2.8	1.2
Female labor endowment/ha	2.9	2.8	2.1	2.0	2.6	0.9
Household size (median)	4	6	4	5	6	5
Consumer units	3.3	4.3	3.3	3.7	4.5	4.0
Household labor (adult equivalents)	2.6	3.0	2.8	3.2	3.2	3.1
Male labor (adult equivalents)	1.2	1.7	1.7	1.3	1.7	1.8
Female labor (adult equivalents)	1.3	1.3	1.1	1.9	1.5	1.3
Children (median number)	3	3	2	2	3	3
Male children (median number)	1	1	1	1	1	1
Female children (median number	1	1	1	1	2	1

Source: Own survey data from 2005/06.

Table 3.2. Basic household composition, nutrition requirements and labor availability

FEMALE HEADED HOUSEHOLD IN SOUTH REGION								
Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
MOTHER	43	2200	29	722.7	7.4095	24	23	47
SON1	12	2700	32	886.95	8.176	0	10	10
DAUGHTER1	10	2350	28	771.975	7.154	10	5	15
DAUGHTER2	8	2250	25	739.125	6.3875	5	0	5
Total				3120.75	29.127			77
MALE HEADED AND LAND-POOR HOUSEHOLD IN SOUTH REGION								
Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
FATHER	39	3000	37	985.5	9.4535	0	25	25
MOTHER	29	2200	29	722.7	7.4095	24	23	47
SON1	9	2250	26	739.125	6.643	0	5	5
SON2	8	2190	25	719.415	6.3875	0	5	5
DAUGHTER1	19	2490	30	817.965	7.665	15	15	30
DAUGHTER2	5	1700	20	558.45	5.11	5	0	5
Total				4543.155	42.6685			117
MALE HEADED AND LAND-RICH HOUSEHOLD IN SOUTH REGION								
Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
FATHER	42	3000	37	985.5	9.4535	0	25	25
MOTHER	34	2200	29	722.7	7.4095	24	23	47
SON1	10	2500	28	821.25	7.154	0	10	10
DAUGHTER1	8	2100	30	689.85	7.665	5	0	5
Total				3219.3	31.682			87

Table 3.2 continued

FEMALE HEADED HOUSEHOLD IN CENTRAL REGION

Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
MOTHER	52	2200	29	722.7	7.4095	24	23	47
SON1	14	2800	37	919.8	9.4535	0	10	10
SON2	15	2900	37	952.65	9.4535	0	10	10
DAUGHTER1	9	2200	28	722.7	7.154	10	0	10
DAUGHTER2	16	2490	30	817.965	7.665	15	15	30
Total				4135.815	41.1355			107

MALE HEADED AND LAND-POOR HOUSEHOLD IN CENTRAL REGION

Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
FATHER	36	3000	37	985.5	9.4535	0	25	25
MOTHER	31	2200	29	722.7	7.4095	24	23	47
SON1	8	2700	25	886.95	6.3875	0	5	5
SON2	9	2700	26	886.95	6.643	0	5	5
DAUGHTER1	9	2490	28	817.965	7.154	10	0	10
DAUGHTER2	2	1360	16	446.76	4.088	0	0	0
Total				4746.825	41.1355			92

MALE HEADED AND LAND-RICH HOUSEHOLD IN CENTRAL REGION

Composition		Food requirement		Adjusted per year		Production labor contribution		
Members	Age	Kcal./Day	Prot./Day	MCal./yr.	Prot./Yr	Hh. Act.	Farm+	Total max
FATHER	36	3000	37	985.5	9.4535	0	25	25
MOTHER	30	2200	29	722.7	7.4095	24	23	47
SON1	9	2700	26	886.95	6.643	0	5	5
DAUGHTER1	13	2490	30	817.965	7.665	15	5	20
DAUGHTER2	8	2250	27	739.125	6.8985	5	0	5
Total				4152.24	38.0695			102

Sources: WHO ; FAO ; Holden 1991 (allocation of time study).

Table 3.3. Various constraints in household models by household type.

	Southern Region			Central Region		
Constraints in models by hh type	Female-Headed	Male-Headed Land-Poor	Male-Headed Land-Rich	Female-Headed	Male-Headed Land-Poor	Male-Headed Land-Rich
Total labor, Hours/Week	77	117	87	107	92	102
Labor constraints by time period, hours/period						
NOV1	154	234	174	214	184	204
NOV2	154	234	174	214	184	204
DEC1	154	234	174	214	184	204
DEC2	154	234	174	214	184	204
JAN1	154	234	174	214	184	204
JAN2	154	234	174	214	184	204
FEBM1	462	702	522	642	552	612
M2APR	462	702	522	642	552	612
MAY	308	468	348	428	368	408
JUNJUL	616	936	696	856	736	816
AUSEOC	924	1404	1044	1284	1104	1224
Land constraint, ha	0.942	0.611	1.373	1.392	0.779	1.974
Cash constraint, MK	2000	3000	2000	2500	3000	2500
MCAL, min. energy requirement/year	3120.75	4543.155	3219.3	4135.815	4746.825	4152.24
PROTEIN, min. requirement/year, kg	29.127	42.6685	31.682	41.1355	41.1355	38.0695
TASTEBE, min. preference/year, kg	0	42.82	33.08	37.47	45	39.78
TASTEGN, min. preference/year, kg	1	34.256	26.464	29.976	36	31.824
TASTECAS, max. preference/year, 100 kg			5			
TASTESWP, max. preference/year, 100 kg			5			
TASTEMZ, min. preference/year, 100 kg	4.43745	5.7807	4.4658	5.05845	6.075	5.3703

4. Agricultural production

The agricultural sector in Malawi is dominated by smallholder farm households with farm sizes ranging from 0.3 ha to 5 ha and most of the land cultivation is done with hoe. Maize is the main staple crop and is dominating land use but is often intercropped with other crops. Rain-fed agriculture dominates with a rainy season from November/December to March/April. Peak agricultural seasons are therefore in November/January (cultivation, planting, weeding) and April/May (harvesting).

Farm plot level data from the surveys in 2006, 2007 and 2009 were used to calibrate crop production activities for the models. Holden and Lunduka (2010a) showed that maize productivity increased significantly in this period and that this partly was explained by higher fertilizer used intensity. Maize area shares of the farms also declined in this period. Maize area shares were also larger on smaller farms. There were some systematic differences in the production systems between the Central and Southern regions with more intercropping activities in the South and with more tobacco production in the Central region. Holden (2013b) uses these farm plot level data to analyze the maize system evolution including intercropping, input use, including use of subsidized inputs and their productivity impacts. The findings in these analyses are integrated into the models that have been developed here. This means that the models aim to capture the evolutionary logic of the system and put less emphasis on the cross-sectional variation in many of the underlying variables such as in land quality and socio-economic characteristics other than those explicitly included in the models. The models are calibrated to the average land productivity for the data 2006-2009 which is higher than the productivity in 2006. The models therefore also do not aim to reproduce annual productivity levels and changes in productivity in this period. Table 4.1 provides an overview of the main crops and crop combinations in the two regions.

Table 4.1. Crop production activities in Central and Southern Malawi included in household models

Mono-cropping activities	Intercropping activities	
Hybrid maize (HYV)	HYV/OPV+Beans	
OPV	HYV/OPV+Cassava	South only
Local Maize	HYV/OPV+Pigeon pea	South only
Groundnuts	Local Maize+Beans	
Tobacco	Local Maize+Cassava	South only
Cassava	Local Maize+Pigeon pea	South only
Sweet Potato		

Source: Own survey data.

Maize yields were calibrated based on the analysis of farm plot data for maize for three production seasons. As fertilizer use on maize varied a lot and to initially avoid any functional form assumptions for the relationship between fertilizer level and maize yields for local maize, HYV and OPV, matching methods were used by grouping plot level data into intervals of fertilizer use intensity by matching on plot characteristics. The results of this exercise are presented in Table 4.2. There were too few observations with OPV maize so it was lumped together with the HYV maize. The results are also summarized in Figure 4.1.

Table 4.2. Propensity score matching to derive production functions for local and improved maize

Fertilizer rate, kg/ha	<25	25-75	75-125	125-175	175-225	225-275	275-325	325-500	Average
Mean Fert rate	0	50	100	150	200	250	300	412.5	181.25
Impr.Mz yield	981	981	1271	1585	1698	1701	2182	2844	1655.375
Local Mz yield	770	689	1022	1011	1540	1565	2101	2528	1403.25
IMPM-smooth	785	1025	1265	1505	1745	1985	2225	2705	1655
LM-smooth	550	785	1020	1255	1490	1725	1960	2430	1401.875
ATT	211	293	249	575	158	136	81	319	252.75
Smooth-ATT	235	240	245	250	255	260	265	275	253.125
n-IMPM	254	108	139	100	89	73	43	90	112
n-LM	297	91	108	94	69	58	27	48	99
t	1.868	1.984	1.443	3.208	0.529	0.579	0.158	0.781	1.31875

Note: ATT=Average treatment effect on the treated, IMPM=Improved maize, LM=Local maize, n=sample size, t=t-value. Maize yields are measured in kg/ha.

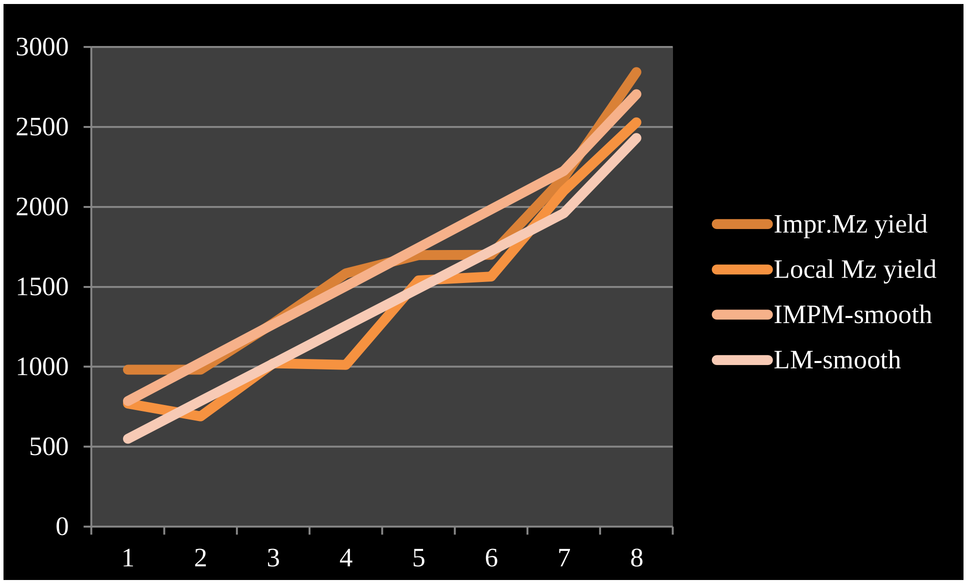

Figure 4.1. Maize production functions from propensity score matching at different fertilizer intensity ranges (before and after smoothing): Kg/ha vs. intervals (see Table 4.2).

It can be seen that the fertilizer response was fairly linear with higher yields for improved maize than for local maize. The fact that GPS was used to measure farm plots in our surveys while most nationally representative surveys have relied on farmers' own estimates of plot and farm sizes, should imply that our estimates are relatively more reliable. We also collected data on farmers' own estimated farm sizes and found large discrepancies between GPS-measured and farmer estimated plot sizes.

For the model calibration we smoothed the yields into linear functions as shown in Figure 1. No significant yield difference was found between mono-cropped and intercropped maize so we have assumed no yield difference between these. The main difference is therefore in terms of seeds and extra labor and output from the intercrops. We used the production data also to calibrate the output levels for intercrops.

The maize production activities as specified in the models are presented in Tables 4.3, 4.4 and 4.5 for mono-cropped and intercropped maize by maize type and different fertilizer levels. The labor requirements are specified per ha for the different tasks and are based on labor use studies by Holden (1991; 1993) in hoe-based farming in Zambia. Our study did not include detailed labor data collection by crop and season which is a very time-consuming task. The hoe-based agricultural systems in densely populated areas of Zambia and Malawi are similar with similar soils and rainfall pattern. The labor tasks were split across 11 time periods of varying length from half a month to three months with shorter (half month intervals) during peak agricultural seasons.

Tables 4.6 and 4.7 shows the specification of cassava, sweet potato, tobacco, groundnut and pigeon pea activities where labor is split by time periods instead of by tasks.

Table 4.3. Maize mono-cropping activities specified in the models.

MAIZE ACTIVITIES: LABOUR REQUIREMENTS PER HA										
SYSTEM	ACCORDING TO TYPE OF OPERATION									
CROP	MAIZE, local Mono-crop	MAIZE, local Mono-crop	MAIZE, local Mono-crop	MAIZE, local Mono-crop	MAIZE, improved Mono-crop	MAIZE, improved Mono-crop	MAIZE, improved Mono-crop	MAIZE, improved Mono-crop	MAIZE, improved Mono-crop	MAIZE, improved Mono-crop
CODE	MLF0C	MLF50C	MLF100C	MLF150C	MHF50C	MHF100C	MHF150C	MHF200C	MHF250C	MHF300C
NO. OF ACTIVITIES	1	1	1	1	1	1	1	1	1	1
CLEAR	0	0	0	0	0	0	0	0	0	0
CULTIVAT	450	450	450	450	450	450	450	450	450	450
PLANT	170	170	170	170	170	170	170	170	170	170
FERTLIZ	0	10	20	30	10	20	30	40	50	60
WEED	400	400	400	400	400	400	400	400	400	400
HARVEST	75	90.72	106.44	122.16	93.45	109.5	125.55	141.6	157.65	173.7
STORE	40	58.34	76.68	95.02	61.525	80.25	98.975	117.7	136.425	155.15
TOTAL LABOR hours/ha	1135	1179.06	1223.12	1267.18	1184.975	1229.75	1274.525	1319.3	1364.075	1408.85
YIELD, main crop, kg/ha	831	1093	1355	1617	1138.5	1406	1673.5	1941	2208.5	2476
FERILIZER, kg/ha	0	50	100	150	50	100	150	200	250	300

Note: Labor requirements in hours/ha.

Table 4.4. Production activities: Maize intercropped with beans

CROP	MAIZE, local	MAIZE, local	MAIZE, local	MAIZE, local	MAIZE, improved	MAIZE, improved	MAIZE, improved	MAIZE, improved
CODE	MLF0CB	MLF50CB	MLF100CB	MLF150CB	MHF50CB	MHF100CB	MHF150CB	MHF200CB
NO. OF ACTIVITIES	1	1	1	1	1	1	1	1
CLEAR	0	0	0	0	0	0	0	0
CULTIVAT	450	450	450	450	450	450	450	450
PLANT	170	170	170	170	170	170	170	170
FERTLIZ	0	10	20	30	10	20	30	40
WEED	200	200	200	200	200	200	200	200
HARVEST	304.38	304.98	306.18	307.98	156.54	169.26	181.98	194.7
STORE	68.91	69.61	71.01	73.11	75.63	90.47	105.31	120.15
TOTAL LABOR hours/ha	1193.29	1204.59	1217.19	1231.09	1062.17	1099.73	1137.29	1174.85
YIELD, main crop, kg/ha	1244	1254	1274	1304	1340	1552	1764	1976
FERILIZER, kg/ha	0	50	100	150	50	100	150	200
YIELD, intercrop, kg/ha	341	341	341	341	85	85	85	85

Note: Labor requirements in hours/ha.

Table 4.5. Production activities: Maize intercropped with pigeon peas

CROP	MAIZE, local	MAIZE, local	MAIZE, local	MAIZE, local	MAIZE, improved	MAIZE, improved	MAIZE, improved	MAIZE, improved	MAIZE, improved
CODE	MLF0SP	MLF50SP	MLF100SP	MLF150SP	MHF50SP	MHF100SP	MHF150SP	MHF200SP	MHF250SP
NO. OF ACTIVITIES	1	1	1	1	1	1	1	1	1
CLEAR	0	0	0	0	0	0	0	0	0
CULTIVAT	450	450	450	450	450	450	450	450	450
PLANT	170	170	170	170	170	170	170	170	170
FERTLIZ	0	10	20	30	10	20	30	40	50
WEED	200	200	200	200	200	200	200	200	200
HARVEST	204.24	213.51	222.78	232.05	203.46	216.48	229.5	242.52	255.54
STORE	25.58	36.395	47.21	58.025	32.37	47.56	62.75	77.94	93.13
TOTAL LABOR hours/ha	1049.82	1079.905	1109.99	1140.075	1065.83	1104.04	1142.25	1180.46	1218.67
YIELD, main crop, kg/ha	625	779.5	934	1088.5	722	939	1156	1373	1590
FERILIZER, kg/ha	0	50	100	150	50	100	150	200	250
YIELD, intercrop, kg/ha	236	236	236	236	225	225	225	225	225

Note: Labor requirements in hours/ha.

Table 4.6. Cassava, sweet potato and tobacco production activities with seasonal labor requirement by time period, yields and fertilizer use

CROP	CASSAVA mono-crop					Sweet potato mono-crop			Tobacco mono-crop	
Activity code:	CCASSA	CCASSB	CCASSC	CCASSD	CCASSE	SWP1	SWP2	SWP3	TOB1	TOB2
Labor per ha by period										
NOV1	0	0	0	0	0	0	0	0	100	100
NOV2	0	0	0	225	0	0	0	0	300	100
DEC1	0	0	0	0	0	0	0	0	0	300
DEC2	0	0	0	0	775	450	0	0	200	0
JAN1	775	0	0	0	0	0	450	450	0	200
JAN2	0	775	0	0	0	100	0	0	200	0
FEBM1	150	150	925	150	150	0	100	100	0	200
M2APR	0	0	0	550	0	50	0	0	600	0
MAY	0	0	0	0	0	100	150	0	500	600
JUNJUL	150	0	0	150	150	0	0	150	800	1300
AUSEOC	0	150	150	0	0	0	0	0	350	250
SUM	1075	1075	1075	1075	1075	700	700	700	3050	3050
YIELD, main crop	5000	5000	5000	5000	5000	2800	2800	2800	800	800
FERTILIZER, kg/ha	0	0	0	0	0	0	0	0	250	250
Output/fertilizer ratio									3.2	3.2

Note: Labor requirements in hours/ha.

Table 4.7. Groundnut and pigeon pea mono-crop production activities.

	Groundnut	PIGEON PEA mono-crop				
CROP code	GN	PP1A	PP1B	PP1C	PP1D	PP2
Labor requirement by period						
NOV1	100	100	100	100	100	100
NOV2	100	220	50	0	0	100
DEC1	150	0	170	50	0	0
DEC2		0	0	270	50	0
JAN1	100	100	100	0	270	0
JAN2		200	150	150	0	0
FEBM1	100	0	50	150	300	0
M2APR	50	0	0	0	0	0
MAY	250	0	0	0	0	0
JUNJUL	50	400	400	150	150	150
AUSEOC	200	400	400	550	550	500
SUM	1100	1420	1420	1420	1420	850
YIELD, main crop	1300	600	600	600	600	1000
FERTILIZER	0	0	0	0	0	0

Note: Labor requirements in hours/ha.

5. Market characteristics and agricultural policies

Market imperfections in Malawi are caused by the basic production relations of tropical agriculture; such as the seasonality of rain-fed agriculture, the immobility and spatial dispersion of land, the fact that all other inputs have to be brought to the land for production, the time delay from input allocation to harvest, the riskiness of production and the covariate nature of risk, moral hazard related to hiring of labor, unobservable resource quality, and bulkiness and perishability of produce, and transportation distances to markets and consumers (Binswanger and Rosenzweig 1986) as well as by policy interventions such as the input subsidy program. Important market imperfections to take into account in the modeling of the relationship between improved maize adoption and household welfare therefore include these imperfections in input markets in form of provisions of subsidized fertilizers and seeds, the informal market for fertilizer that is created by leakages of fertilizers from the official subsidy distribution system, land rental markets with transaction costs due to the immobility of land, and labor market imperfections caused by seasonality in agriculture, transaction costs and liquidity constraints. Credit and liquidity constraints also interact with the imperfections in the fertilizer, seed and labor markets.

a) Market access constraints were specified in form of constrained access to subsidized fertilizer and seed for improved maize (and tobacco for some models).

b) Restricted access to an informal market for subsidized fertilizers at a price between full subsidy and commercial price was specified based on observed access to this market based on the 2005/6 survey data (?)
c) Restricted access to off-farm employment in form of agricultural and non-agricultural *ganyu* labor of seasonal character at going seasonal wage rates in the baseline year
d) Liquidity and credit constraints that limit households' ability to purchase farm inputs, including hiring of labor
e) Transaction costs causing price bands for tradable commodities such as crop outputs and inputs
f) In the initial models it is assumed that there is no land market such that the household land constraint in binding. Although this is a restrictive assumption for individual households, local land renting activity is a zero-sum game. In later models a land rental market with high transaction costs is introduced.

The cash constraint is related to cash needs for input purchases in the early dry season. Income from sales of crops is therefore excluded from the cash constraint. An initial "carry over" of cash from the previous year is assumed and is based on survey data on cash availability.

In the initial models (Holden 2013a, and part 7 of this report) we assumed that up to 50% of off-farm agricultural employment (*ganyu*) income can be used to relax the cash constraint in agricultural production and up to 30% of other non-farm *ganyu* income can be used to relax the cash constraint in agricultural production. In later models the number of *ganyu* activities was increased to facilitate more flexible off-farm labor income opportunities and all cash income from the activity was assumed fully integrated in the cash constraint when the labor income was generated in the period from beginning of November till late January. From beginning of February till middle of March it was assumed that 50% of this income could be used to relax the cash constraint and for the dry season months August-September-October it was assumed that 30% could be saved and used in the coming rainy season. Ten percent of the income generated from sale of crops was assumed saved and available in the following year, based on a dynamic equilibrium assumption.

Buying prices for major food crops are assumed to be 10% higher than the going market prices. A post-harvest loss of 10% is assumed for consumed crops. A storage loss of 20% is assumed for all major crops but some models were run with 10 and 30% storage loss in part 8 as a sensitivity analysis.

Table 5.1 gives the 2005/06 fertilizer and seed input prices while Table 5.2 gives the output prices used in the models. The models were initially developed for the 2005/06 production year.

Table 5.1. Observed prices for inputs in 2005/06.

PRICES USED IN THE MODELS (2005/06 PRICES)			
INPUTS	UNIT KG	Subsidized Price, MK	Commercial Price, MK
Fertilizer (23-21, Urea)	50	950	3000
Fertilizer (D-comp., CAN)	50	1400	3000
MAIZE SEED, OPV	3	150	500
MAIZE seed, LOCAL	3		120
PIGEON PEA seeds (?)	3	0	150
BEAN seeds (?)	3	0	150
GROUNDNUT seeds	3	0	150

Table 5.2. Market prices for crops used in the models (2005/06 prices)

Producer Price	MWK/100kg
Beans, dry	9982
Cassava	2640
Groundnuts, with shell	5548
Maize	2690
Pigeon peas	6328
Sweet potatoes	2700
Tobacco, unmanufactured	12932

Source: Own survey data.

Note: Buying prices were adjusted up by 10% from these prices.

6. Overview of the input subsidy program and model calibration of input subsidies

Tables 6.1 and 6.2 give an overview of the total size of the input subsidy program over the period 2005/06 to 2010/11 and of the total costs of the program. We see that the program expanded in the period 2005/06 to 2008/09 and then contracted a bit after that. We also see that the subsidy level increased from 64% in 2005/06 to 91% in 2008/09. The amounts of subsidized seeds in the program also increased over the years and so did the share of hybrid maize seeds out of the total subsidized seeds. The total program costs increased sharply in 2008/09 due to the sharp increase in fertilizer and fuel prices associated with the global financial/food/energy crisis.

Table 6.3 shows the change in intensity of fertilizer use on maize in the years 2005/06, 2006/07 and 2008/09 based on our survey data. It shows that fertilizer use intensity increased with the expansion of the input subsidy program.

Table 6.1. Scale of the input subsidy program in Malawi 2005-2011

		2005/6	2006/7	2007/8	2008/9	2009/10	2010/11
Fertiliser voucher distribution (mt equivalent)		166,156	200,128	216,000	195,369	160,000	160,000
Total subsidized	planned	137,006	150,000	170,000	170,000	160,000	160,000
fertilizer sales (MT)	actual	131,388	174,688	216,553	197,498	159,585	160,531
Voucher value, approx. (MK/bag)		1,750	2,480	3,299	7,951	3,841	5,237
Subsidy % (approx.)		64	72	79	91	88	91
Subsidized maize seed (MT)		n/a	4,524	5,541	5,365	8,652	10,650
% Hybrid seed		0	61	53	84	88	80
Legume seed (MT)				24	1	1,551	2,726
Total program	planned	5,100	7,500	11,500	19,480	21,908	19,700
cost (MK million)	actual	4,480	10,346	13,362	33,922	15,526	21,868

Source: Chirwa and Dorward 2013.

Table 6.2. Total estimated costs of the input subsidy program by year (Million US$)

	2006/07	2007/08	2008/09	2009/10	2010/11
Total costs, recorded & estimated exc. cf stock	90.92	128.58	274.91	129.83	161.76
Programme budget	53.57	82.14	139.14	155.04	129.99
Funding					
Direct Donor Support, %	9.5	7.1	37.8	17.5	22.1
Balance: Malawi Govt., %	64.4	100.1	214.0	100.9	129.1
Cost, % MoAFS budget	46.8	57.2	67.6	52.7	60.1
Cost, % national budget	6.8	8.2	16.2	6.5	8.0
Cost, % GDP	2.5	3.1	6.6	2.5	3.0

Sources: Chirwa and Dorward, 2013.

Table 6.3. Fertilizer use intensity (kg/ha) by year, maize plots only

Year	Mean	se(mean)	p25	p50	p75	N
2006	192.8	14.0	0.0	63.5	207.3	747
2007	207.0	13.0	0.0	107.1	221.2	742
2009	237.2	13.6	62.3	151.3	269.6	599
Total	210.6	7.8	0.0	107.4	245.8	2088

Source: Own survey data.

We assessed the average return to fertilizer on maize and how this maize-fertilizer ratio (measured in kg output per kg gross fertilizer input) varied with the intensity of fertilizer use. Figure 6.1 shows the distribution of maize fertilizer-ratios on plots without and with subsidy access. Second we split the plots with subsidized inputs in plots with improved maize (Hybrid and OPV varieties) and plots with local maize, see Figure 6.2. We see from Figure 6.1 that plots receiving subsidized inputs had substantial lower output per kg fertilizer. Figure 6.2 shows that improved maize gave substantial more maize per kg fertilizer than local maize did. One explanation for the lower yields on plots that received subsidized inputs is likely to be that a part of the subsidized inputs arrived late. Another potential explanation could be that farmers are less careful in the use of cheap subsidized inputs that they were lucky to get than those are who have worked hard to afford to buy expensive fertilizers at the full commercial price.

Based on the fact that input costs are lower in production activities benefiting from input subsidies, separate production activities are specified in the models. Initially these are identical to the initial maize activities (and some tobacco activities) relying on commercial input access (Base models).

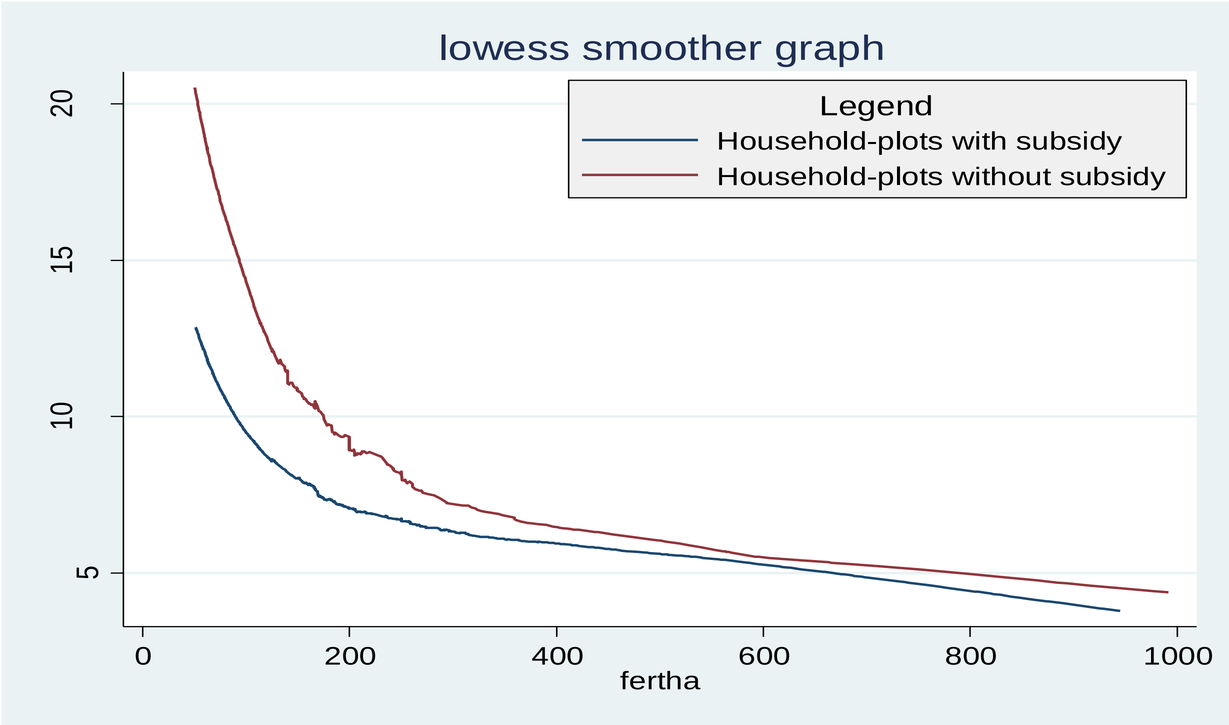

Figure 6.1. Maize-fertilizer ratios vs. fertilizer use (kg/ha) for household plots with subsidy vs. household-plots without subsidy

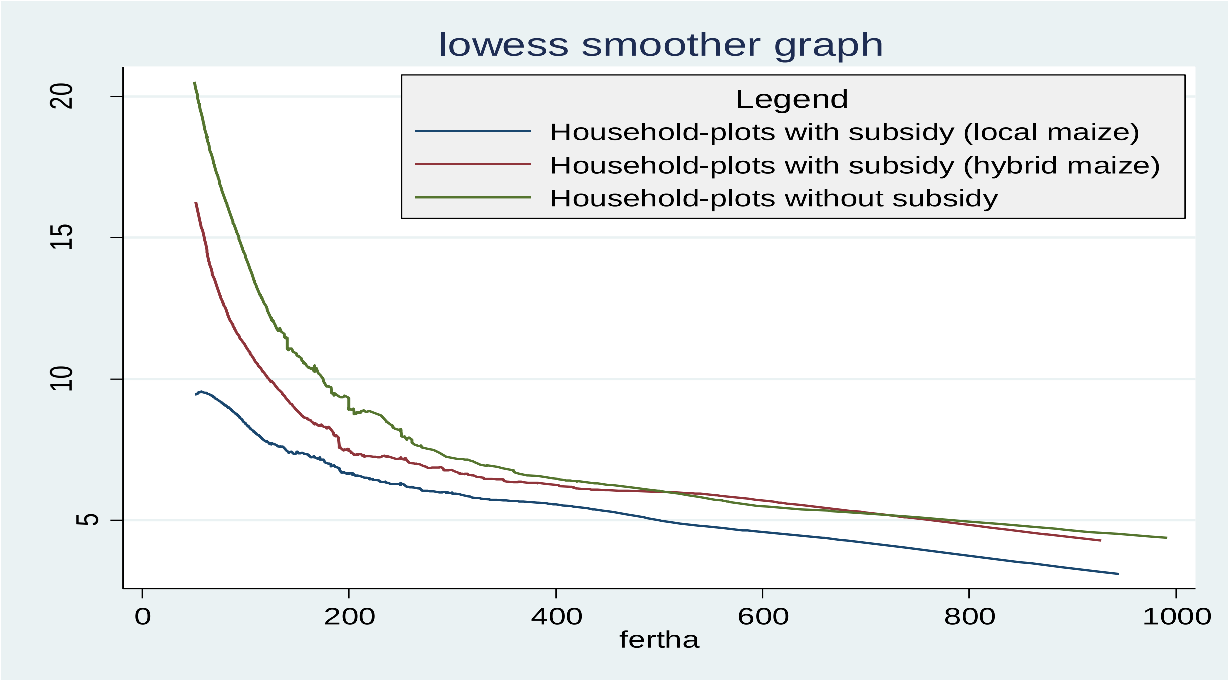

Figure 6.2. Maize-fertilizer ratios vs. Fertilizer subsidy vs. Maize type (Source: Own data from 2005/06, 2006/07 and 2008/09)

The significant difference in maize-fertilizer ratios between plots with subsidized and unsubsidized inputs at the same input intensity level suggests an adjustment for lower fertilizer use efficiency on land where subsidized inputs are used. This is handled by opening for "punishment" of production activities with subsidy benefit from access to cheaper inputs (fertilizer and seeds). It may be considered appropriate to "punish" these activities with 10-20% lower yields due to less efficient fertilizer use. The models are constructed such that it is easy to adjust this assumption by changing the % reduction in productivity associated with the subsidized production activities. This is used as a part of the sensitivity analysis with the models.

The shares of each household group that had access to input subsidies in the 2005/06 production year are presented in Table 6.4 together with the shares using hybrid and OPV maize varieties, their average fertilizer use, seed, pesticide, fertilizer costs and hired labor.

Table 6.4. Subsidy access and input use by household type in 2005/06

	Southern Region			Central Region		
		Male-Headed			Male-Headed	
	Female-Headed	Land-Poor	Land-Rich	Female-Headed	Land-Poor	Land-Rich
Fertilizer subsidy (share of households)	0.43	0.53	0.49	0.27	0.54	0.50
Hybrid maize use (share of households)	0.34	0.52	0.49	0.41	0.49	0.63
OPV maize use (share of households)	0.15	0.14	0.14	0.18	0.33	0.23
Fertilizer quantity (kg)	59	82	114	87	88	153
Seed cost (MK)	219	622	857	681	458	817
Pesticide cost (MK)	26	157	347	18	0	211
Fertilizer cost (MK)	1805	2156	3527	4190	2542	4521
Number of days of hired labor (*ganyu*)	2.9	3.2	4.6	0.9	3.4	7.4
Amount paid for *ganyu* labor (in MK)	342	423	1280	245	479	1412
Average *ganyu* daily wage	117	131	280	270	143	191

Source: Own survey data from 2005/06.

Our surveys revealed that there was an informal market for fertilizers due to leakage from the subsidy program. A significant share of our sample households managed to obtain some fertilizers from this informal market at prices between the commercial price and the full subsidy price. Our survey also revealed that this leaked fertilizer to a very limited extent came from households that had resold their coupons or subsidized inputs (Holden and Lunduka 2010b; 2013). The models have been calibrated based on the observed access to coupons and fertilizers in these informal markets for coupons and fertilizers based on observed median prices in these markets in 2005/06, see Table 6.5.

Table 6.5. Subsidy access constraints by household group based on survey data

Constraints in models by hh type	Southern Region Female-Headed	Southern Region Male-Headed Land-Poor	Southern Region Male-Headed Land-Rich	Central Region Female-Headed	Central Region Male-Headed Land-Poor	Central Region Male-Headed Land-Rich
Fertilizer access, informal coupon purchase, 50 kg bags	0.067	0.214	0.247	0.121	0.049	0.124
Fertilizer access, informal fertilizer purchase, 50 kg bags	0.167	0.378	0.192	0.121	0.164	0.146
Improved maize seed, subsidy access, kg	0	2	2	0	2	2
Tobacco, fertilizer subsidy access, 50 kg bags	0.104	0.126	0.226	0.058	0.151	0.345
Maize fertilizer subsidy access, 50 kg bags	0.652	0.970	0.911	0.460	1.034	1.241

Source: Constraints in models based on own survey data.

7. Initial models: Household model simulation results

All models assume that there is no production risk or other forms of risk that affect production and consumption decisions. Seasonality in labor demand and seasonal cash constraints are important determinants of behavior, however, but households are assumed to relate to these constraints in a rational way given their taste preferences and increasing drudgery aversion.

The initial models were calibrated without land renting activities and with a limited set of off-farm employment access (*ganyu* labor activities) either as seasonal agricultural labor or as non-agricultural labor. The first simulations were made based on this initial model formulation that is used for the simulations in Holden (2013a) and are included in part 7 of this report.

In the next part of the report a land rental market and a more diverse set of off-farm employment opportunities were calibrated in. While the simulations in part 7 assumed a 90% fertilizer subsidy level, close to what it has been after 2008/09, the models in part 8 were calibrated to the fertilizer subsidy level and prices in 2006/07.

Key findings of the simulation models earlier presented in Holden (2013a) are presented graphically to highlight variables of importance for improved maize seed demand among diverse smallholder households in Malawi and for welfare outcomes. The first section looks at how demand for maize seeds (local or improved) varies with household type and access to subsidies. The second section looks at the welfare (net income/utility) implications of the alternative policy options for different household types.

7.1. Demand for maize seed simulations

Figure 7.1 illustrates the case for a land-poor male-headed household in Southern Malawi with good access to *ganyu* employment, meaning that the household is not severely cash-constrained but is land and labor constrained during peak seasons. The household receives no subsidized fertilizer, accesses a smaller quantity of fertilizer through the informal market and purchases the rest at commercial price. With increased access to subsidized seeds, we see that commercial demand for improved maize seeds falls. Quite surprisingly the demand for local maize seeds also increases and the crowding out effect is even stronger than 1:1. It appears that this household can afford to produce and consume more local maize with the access to free seeds of improved maize and reaches a plateau in the demand for improved maize (Lunduka, Fisher and Snapp 2012).

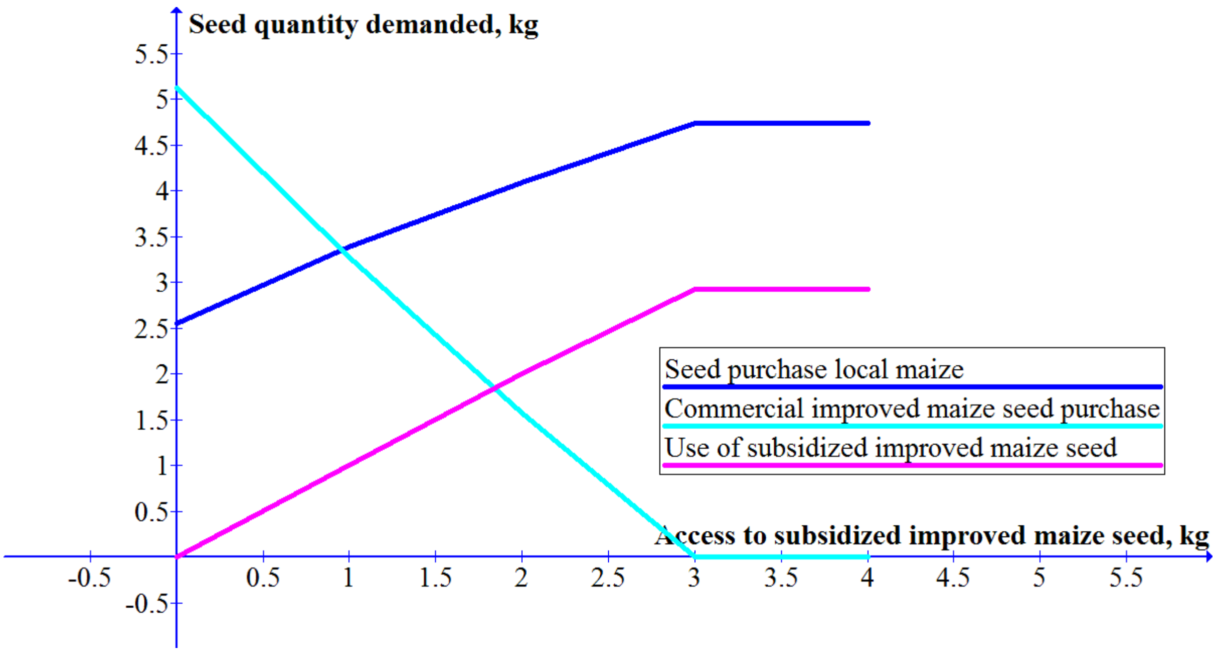

Figure 7.1. Improved maize seed experiment: Maize seed demand for land-poor male-headed household with good access to *ganyu* employment

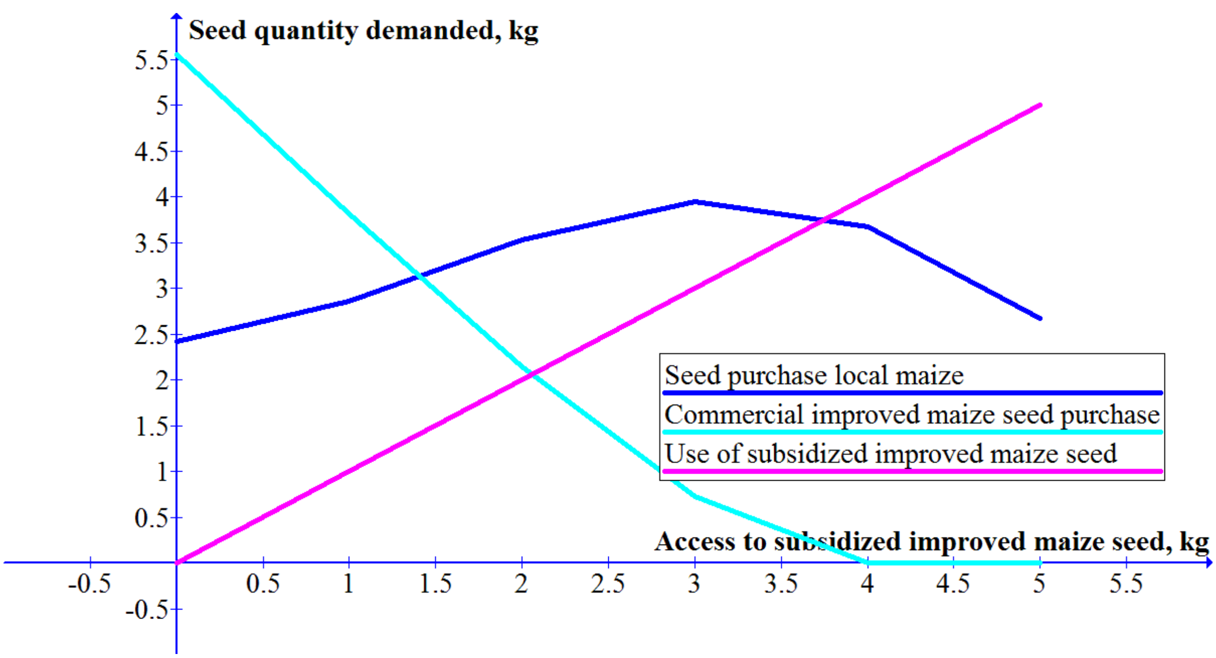

Figure 7.2. Improved maize seed experiment: Maize seed demand for land-poor male headed household with limited access to *ganyu* employment

Figure 7.2 illustrates another land-poor male-headed household in Southern Malawi with more restricted access to *ganyu* labor but with access to two bags of subsidized fertilizer (standard input package). While the initial situation without access to subsidized improved maize seeds and the initial response is similar to for the previous household, above access to 3 kg subsidized maize seeds even local maize starts to get crowded out. This household is poorer and gains more utility from utilizing larger amounts of free seeds and is then willing to reduce the consumption of local maize.

Figure 7.3 illustrates the response of a land-rich male-headed household in Southern Malawi that has access to 2 bags of subsidized fertilizer (90% subsidy) with variable access to improved maize seed at subsidized price (not free). This household uses only local maize initially, the higher land availability makes it able to meet its food needs with local maize only and it only demands improved maize seed when such seeds are offered at a reduced price. However, it is limited how much this household is willing to substitute local maize for improved maize, implying that a plateau is reached. The household prefers to grow both local and improved maize. In this case there is no crowding out effect on commercial demand and use of improved maize is expanded with increased access to seeds at a subsidized price.

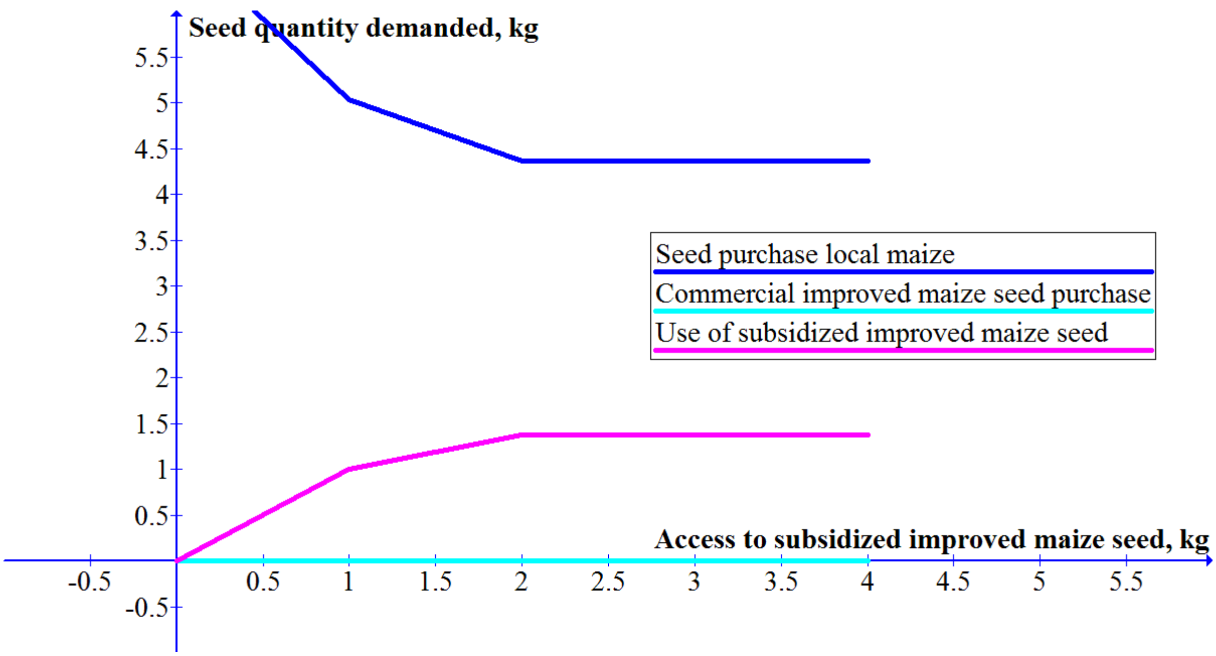

Figure 7.3. Improved maize seed experiment: Maize seed demand for land-rich household when improved maize seeds are subsidized (150 MK/kg), while commercial price is 500 MK/kg and local maize costs 120 MK/kg.

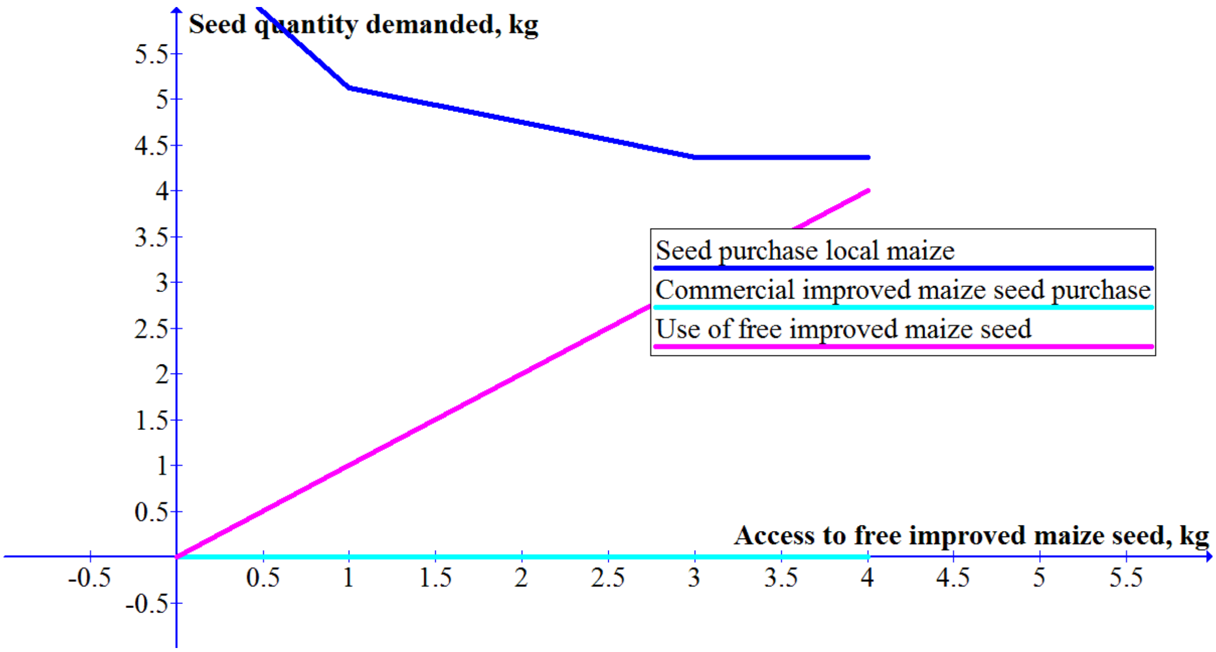

Figure 7.4. Improved maize seed experiment: Demand for maize seeds by land-rich household in southern Malawi with access to free seeds of improved maize.

Figure 7.4 makes one change in the model from Figure 7.3. The improved maize subsidy is increased such that the seed is distributed free but access is limited and the figure illustrates the impact of varying the access to free improved seed. The demand for free seed reaches no plateau while the demand for local maize seed is not reduced below about 4.4 kg. Access to free improved maize seeds leads to more maize production in form of improved maize without any crowding out of commercial demand for improved maize.

Figure 7.5 illustrates the case of a female-headed household in Southern Malawi, having 0.94 ha of land (Table 3.1) without access to subsidized fertilizer. Without access to subsidized fertilizer the demand for improved maize seed at subsidized price is limited and reaches a plateau at 2 kg while this reduces the demand for local maize seeds from 10.8 to 7.9 kg. This household does not demand any improved maize seed at the full commercial price even when it does not have access to any subsidized improved maize seed.

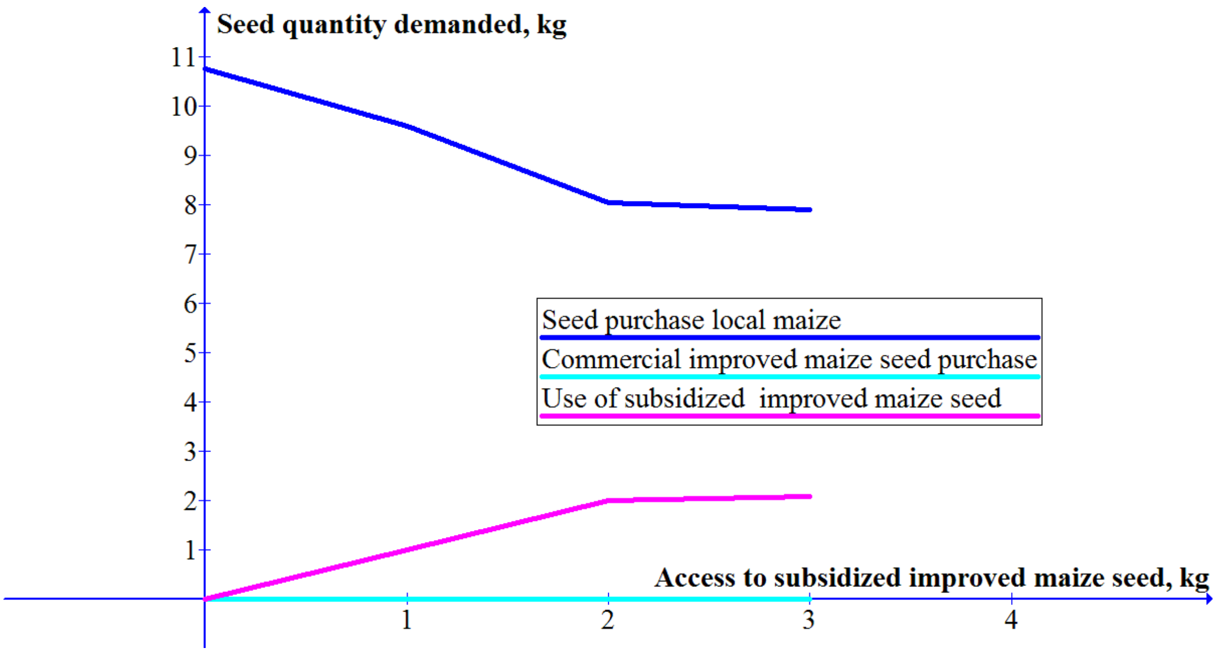

Figure 7.5. Improved maize seed experiment: Demand for maize seeds for female-headed household in Southern Malawi without access for subsidized fertilizer but with varying access to improved maize seeds at subsidized price (150 MK/kg).

Figure 7.6 assesses what happens to the demand for maize seeds with increasing access to subsidized fertilizers (90% subsidy) for this female-headed household by increasing fertilizer access from zero to one, two and three 50 kg bags of fertilizer. We see that the demands for local maize seeds and improved maize seeds respond non-linearly but the demand improved maize seed at full commercial price does not enter the solutions with improved access to subsidized fertilizer.

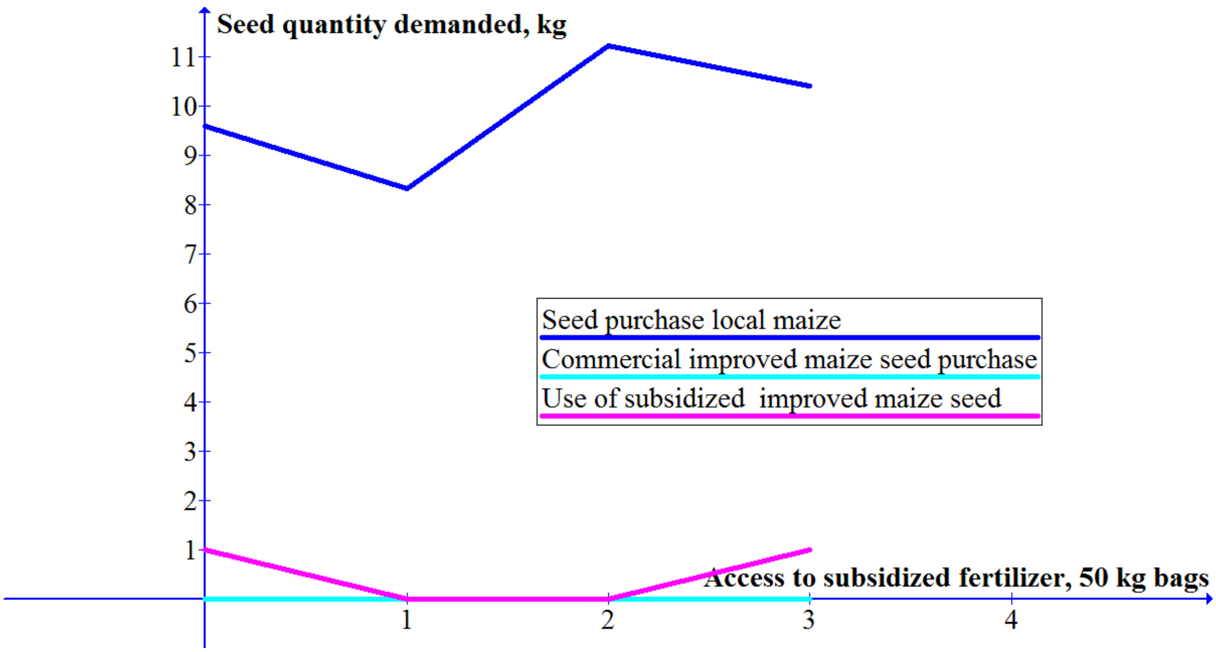

Figure 7.6. Subsidized fertilizer experiment: Demand for maize seeds for female-headed household in southern Malawi with varying access to subsidized fertilizer (from 0 to 3 bags) and access to 1 kg subsidized improved maize seed (farm size 0.94 ha).

7.2. Land constraint simulations

There was substantial variation in the farm sizes of female-headed households in our survey data. We explore the effect of varying the land access on the demand for maize seeds for this household type in the next simulation experiments in Figure 7.7. The household has access to two bags of subsidized fertilizer (90% subsidy) and two kg improved maize seed at subsidized price of MK 150/kg. The farm size is reduced step-wise from the initial level of 0.94 ha and all the way down to 0.42 ha where the model turns infeasible. We see that the demand for improved maize seed at subsidized price increases when the land constraint is tightened from 0.94 ha and reaches the restricted access of 2 kg at 0.75 ha. The reduction in farm size below 0.75 ha crowds out local maize from the solution. When the farm size reaches below 0.5 ha the crowding out of local maize turns even stronger and commercial demand for improved maize enters the solution. This demonstrates that increasing land scarcity leads to increased demand for improved maize seed to meet household subsistence needs for maize. With more limited land access complementary income from *ganyu* employment becomes increasingly important.

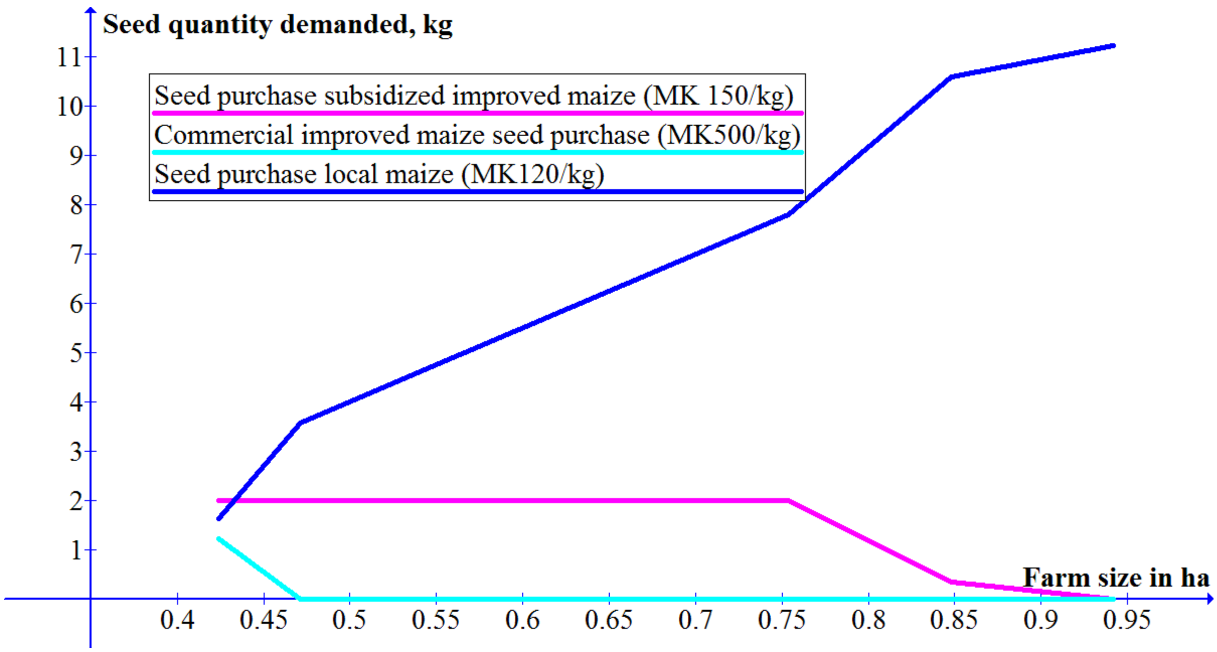

Figure 7.7. Land constraint experiment: Demand for maize seeds for female-headed household in southern Malawi with access to two bags of subsidized fertilizer and 2 kg improved maize seed when we vary (reduce) the farm size

Figure 7.8 provides additional insights into the cropping system changes if the land constraint simulation experiments for female-headed households in Southern Malawi. We see that all the local maize is intercropped with beans while all the improved maize is intercropped with pigeon pea and almost the whole farm is used to intercrop maize with legumes. Pigeon pea becomes relatively more important to beans with increasing land scarcity.

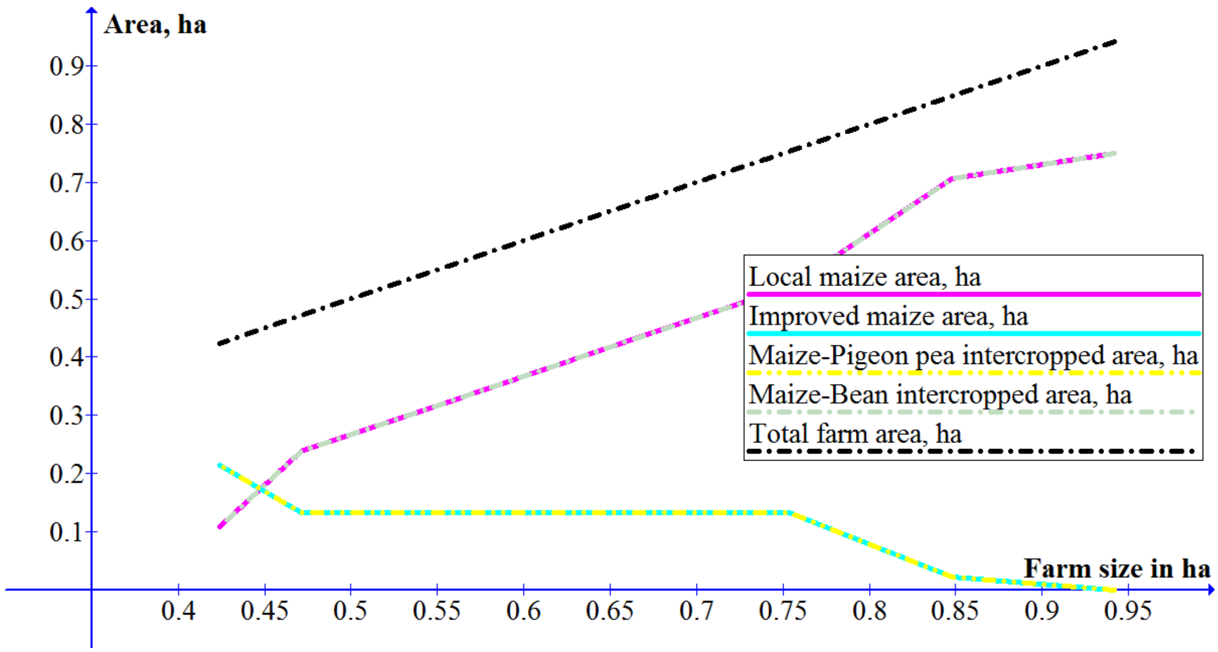

Figure 7.8. Land constraint experiment: Maize area by type of maize and intercropping for female-headed household in southern

Figure 7.9 investigates the impact on the cropping system of reducing the farm size of the land-rich male headed household in Southern Malawi. The household is assumed to have access to a full subsidized input package of two bags of fertilizer and two kg improved maize seed in all simulations. We see that the maize area even increases with reduced farm size from 1.4 ha to close to 0.5 ha while the areas of mono-cropped legumes and root and tuber crops are the ones that primarily are reduced and totally eliminated when farm sizes shrink sufficiently. Figure 10 further illustrates the impact of reduced farm size on the degree of intercropping of maize. We see that only local maize is intercropped with legumes while improved maize is grown as a mono-crop at larger farm sizes and that improved maize is increasingly also intercropped with legumes when the farm size is reduced below 1.1 ha and mono-cropped maize has disappeared when the farm size has reached down to 0.8 ha. These model simulations are consistent with findings in Holden and Lunduka (2010) and Holden (2013). Increased intercropping is an important part of the land use intensification as land scarcity increases in Malawi.

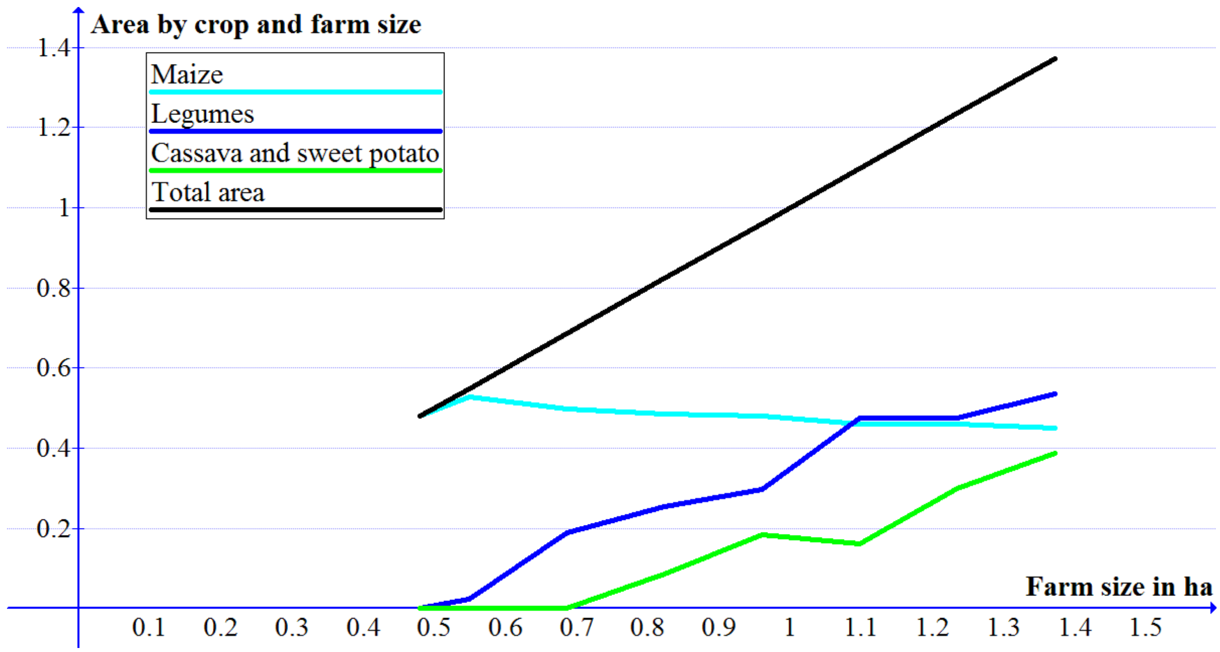

Figure 7.9. Land constraint experiment: Effect of shrinking farm size on area of maize, legumes and root and tubers for land-rich household in Southern Malawi.

Figure 7.10. Simulation of maize type and intercropping with shrinking farm size for household in Southern Malawi

7.3. Household welfare (net income utility) simulations

The following simulations assess the outcomes in form of household utility measured as net household income after having subtracted the costs of household labor based on the shadow wages used in the models. Some models also include cassava as a crop and staple food with a restricted consumption level. Three of the advantages of cassava are that it can produce large amounts of food energy per unit land, it is more flexible in terms of when it can be planted and harvested than cereal crops, and it is drought tolerant when established. Some of the limitations of the crop are that it has low protein content, and is considered as an inferior staple food in Malawi. The leaves of cassava may be used as a vegetable and are more protein-rich and cassava may be processed in many ways and has potential as a food security crop as well as a cash crop. It could be a complementary crop to maize.

Our models demonstrate that households' ability to utilize the improved maize seeds and other inputs depend on how cash-constrained households are. Cash is necessary to buy other seeds as well as pay for the subsidized inputs unless they are provided for free. Figure 7.11 illustrates the effect of tightening or releasing the cash constraint for a female-headed household in Central Malawi. We see that the cash constraint has a strong impact on the household's ability to utilize the input subsidy package as paying for the subsidized inputs is competing with other urgent needs. This is an example of what may be called a household that is "too poor to be efficient" (Holden and Binswanger 1998; Alwang and Siegel 1999). Labor and cash-constrained households may face problems utilizing the subsidized inputs efficiently. Utility is measure in net income units in the figure. We see that relatively small adjustments in cash availability at planting time has large impact on output and utility.

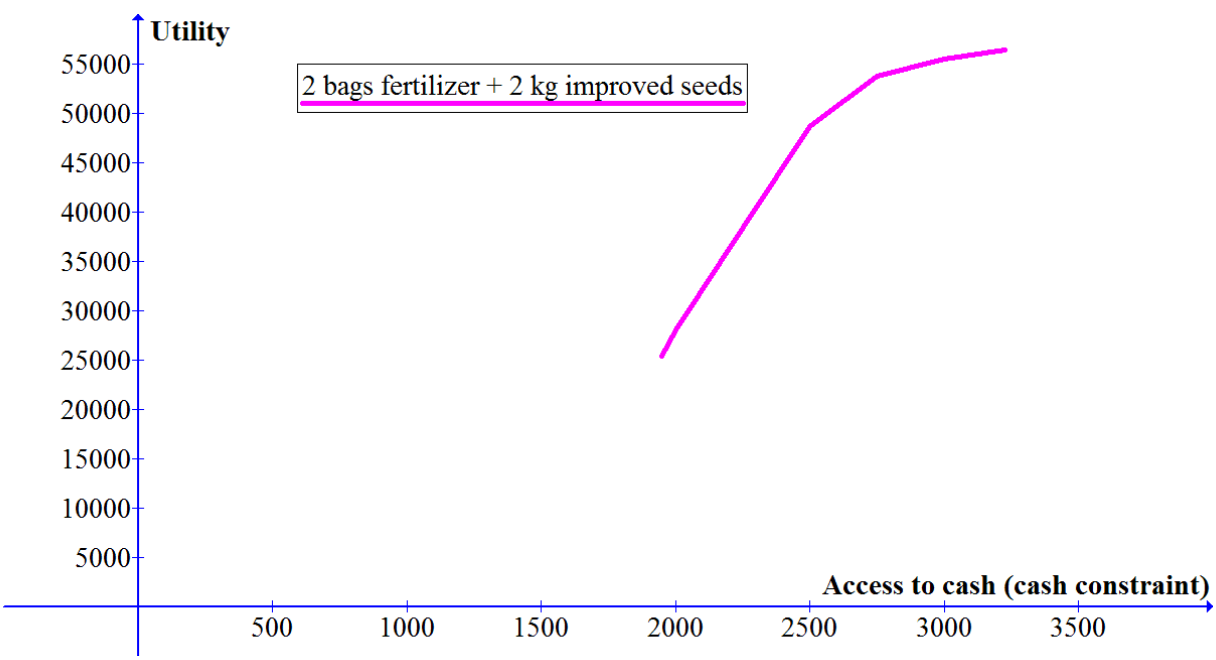

Figure 7.11. Impact of variation in cash constraint on utility of female-headed household in central Malawi from access to subsidized fertilizer and improved seeds

The following simulations are based on models for households that face a fairly tight cash constraint and do not have access to credit which we found to be the case for the majority of households in our surveys. Holden and Lunduka (2014) used choice experiments to demonstrate the impact of this cash constraint and the timing of input supply on the ability to buy inputs.

Figure 7.12 demonstrates that for a severely cash-constrained household a higher level of subsidy for improved maize seeds can increase the benefit from access to such seeds because scarce cash can be used for complementary inputs that also increase the returns from the improved seeds.

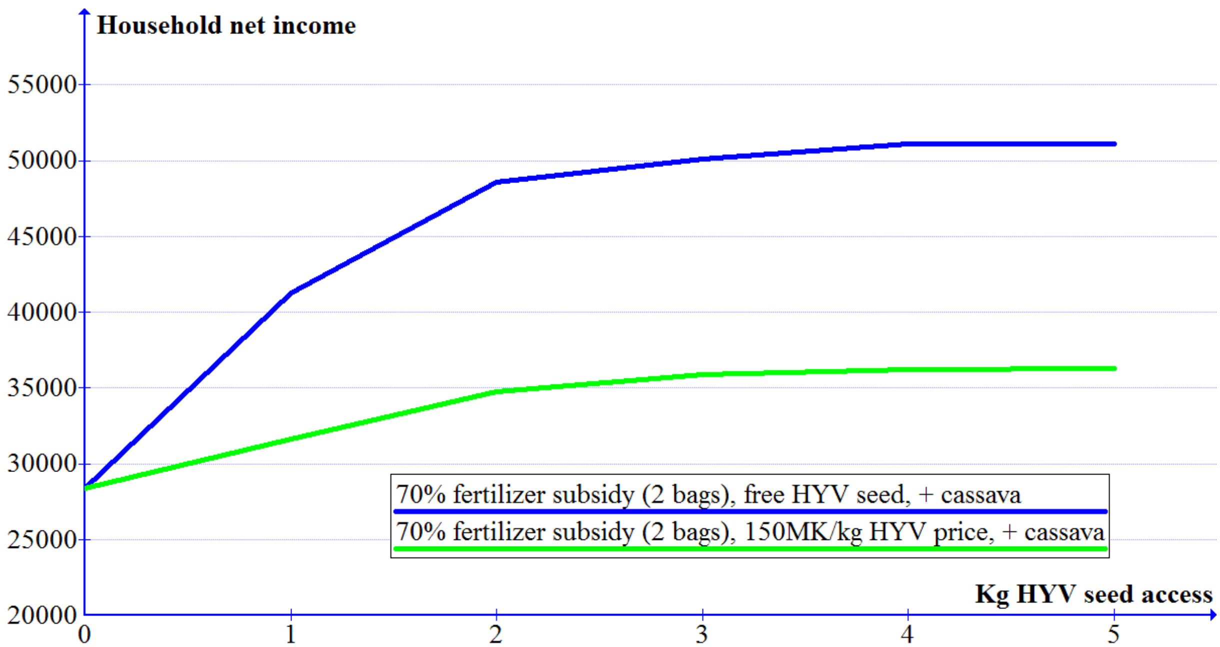

Figure 7.12. Effect of access to free seeds of improved maize for cash-constrained land-rich household with access to subsidized fertilizer (2 bags) in Southern Malawi.

Figure 7.13 compares the outcomes for a household with and without access to subsidized fertilizer (two 50 kg bags) with varying access to improved maize seeds at two subsidy levels (free seeds or seeds at MK150/kg). We see that the access to subsidized fertilizer can substantially increase the return to the improved maize seeds as they can be combined with larger amounts of fertilizer as the cash constraint of households is relaxed with access to subsidies.

Figure 7.14 demonstrates the effect of including cassava as a food crop that is used to partially satisfy the energy requirement of households. Use of cassava relaxes both the labor constraints and cash constraint indirectly for households but also reduces the need and benefit from improved maize seeds for this fairly land-rich household. This requires some adjustment in the taste preferences of households and a partial substitution of cassava for maize. The stable food *nsima* can easily be prepared with a mixture of maize and cassava flour.

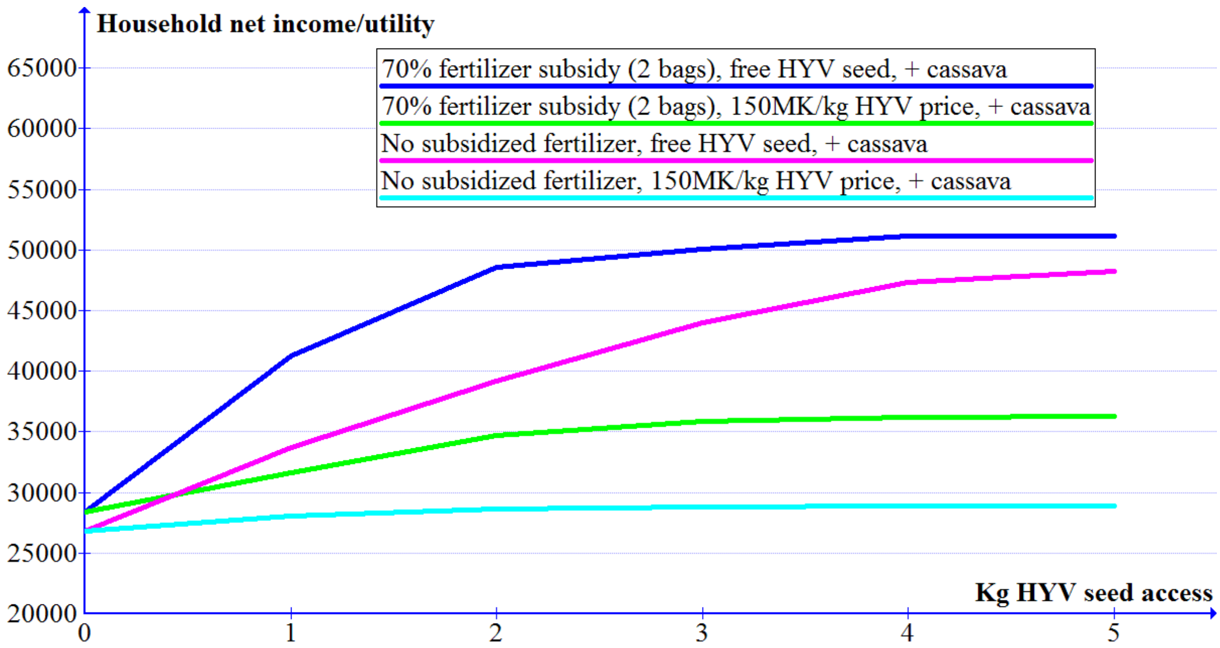

Figure 7.13. Effect of access to free or cheap improved maize seeds and subsidized fertilizer (2 bags) for cash-constrained land-rich household in Southern Malawi

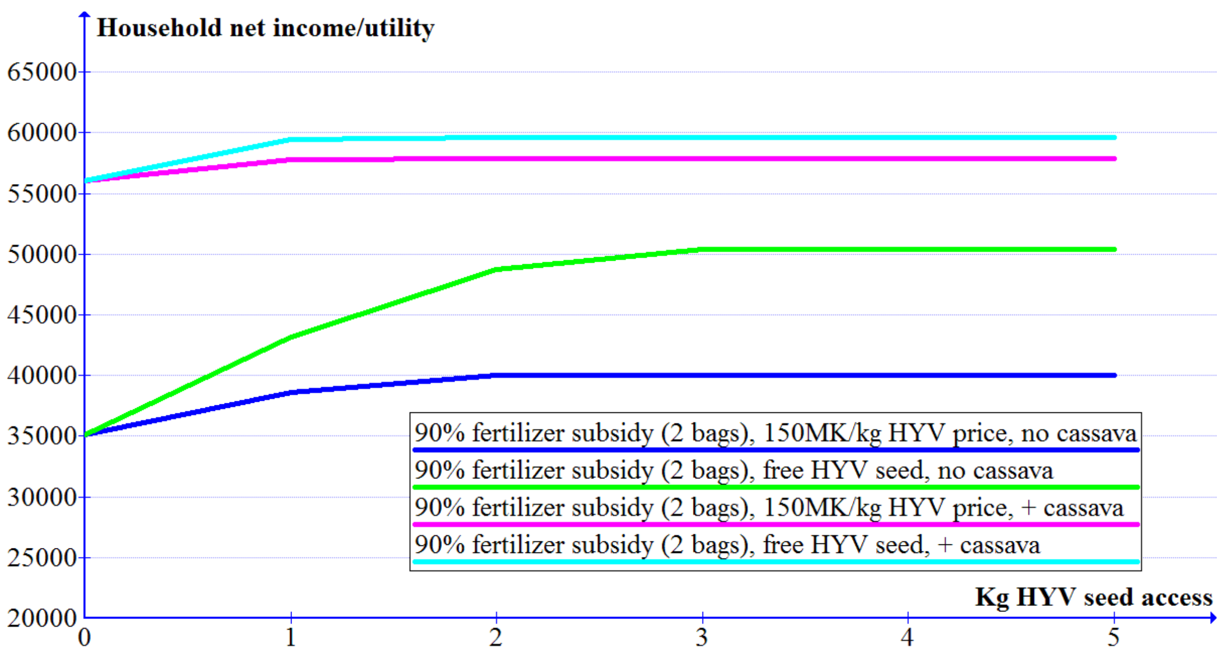

Figure 7.14. Simulation of the effect of improved maize seed access (free or at subsidized price) for land-rich household in Southern Malawi with and without cassava as a supplementary food crop.

7.4. Conclusions from initial simulations

The report started by outlining some of the complexity of identifying and measuring the impacts of improved maize technologies and has developed simple non-separable farm household models that control for key context variables i.e. household, agro-ecological, market and policy characteristics in Central and Southern Malawi. This includes variation in land and labor access, cash constraints, taste preferences and nutritional needs, seasonality of rain-fed agriculture, important cropping system characteristics such as alternative mono-cropping and intercropping practices, constrained access to input subsidies for maize and seeds, leakage and access to fertilizers through secondary markets at prices between the commercial price and the full subsidy price. Simulations were run to assess the impacts of varying the access to improved maize seeds and subsidized fertilizers on the take-up of these inputs, the effect on demand for commercial seeds of improved maize and for local maize. The importance of household characteristics was assessed by comparing the responses of male- and female-headed households in Central and Southern Malawi while also exploring the impacts of changing the land availability and the severity of the cash constraint that they face.

The simulations illustrate that there is a high risk that access to subsidized improved maize seeds can crowd out commercial demand for improved maize seeds. Such a crowding out effect is, however, very sensitive to household characteristics, market characteristics and relative prices. Second, increasing land scarcity can increase the demand for improved maize seeds as households aim to be self-sufficient in maize production and improved maize facilitates intensification among others through intercropping of maize with legumes such as beans and pigeon peas. Third, the ability of households to utilize and demand improved maize with complementary inputs depends on the severity of their labor and cash constraints. Finally, acceptance and use of cassava as a complementary staple food and cash crop can indirectly help households to relax their labor and cash constraints and serve as a food reserve stored in the ground. Future work should focus on including production risk such as climate risk and risk preferences into these models because the sustainability of the current input subsidy program hinges on the issue of food security and the ability of the whole system to tackle future climatic shocks. Further simulations should also incorporate general equilibrium effects by adjusting wages and maize prices that in particular may have been impacted by the input subsidy program (Holden 2013).

8. Sensitivity analyses: Varying land access, land rental and labor markets

In this part we carry out sensitivity analysis on the second level models that have expanded the *ganyu* labor market activities (with more flexibility than the earlier versions) as labor may be hired in or hired out and includes land rental market activities with varying prices and transaction cost assumptions. An important part of the sensitivity analysis relates to the functioning of the land rental and the labor markets themselves. Another aspect is how variation in the characteristics of these markets affects improved maize seed and fertilizer demand and the impacts of accessing input subsidies.

Some other assumptions in the models are also subjected to some sensitivity analyses. These include the assumed level of storage loss in the models. We have used 20% storage loss in the baseline models but have also assessed the impact of reducing the storage loss to 10% and increasing it to 30% in some models.

While we for male-headed households have land-poor and land-rich categories in each region, we have only one category of female-headed households in each region. We have therefore assessed the sensitivity of the female-headed household models to variation in the land access by varying the ownership holding. Particularly the effect of reducing the ownership holding and assessing how far it can be reduced before the models become infeasible (interpreted has household not being able to survive under those conditions or not being able to meet basic taste preferences). As we would expect, the models are more likely to become infeasible the tighter the land constraint is, the more restricted access to *ganyu* labor is, the higher the storage loss is, and the poorer the access to input subsidies is. The inverse of the "distance" to the infeasible solution could also be seen as a measure of the vulnerability of the household to shocks. By playing around with the constraints we identify the multi-dimensional space of feasible solutions. We present some of the results from the sensitivity analyses in the following tables. The table format gives more compact information about some of the key variables than the graphs in the previous section.

These basic models use 2005/06 prices, 20% storage loss is assumed (with some exceptions), and 64% subsidy level is assumed for the fertilizer. We assume there is no inefficiency loss in the production with subsidized inputs (with some exceptions).

8.1. Southern Region

The Southern Region of Malawi is characterized by having higher population density and consequently smaller average farm sizes than the Central and Northern Regions of Malawi. This also implies that poverty is more severe in Southern Region. Another important distinction is that matrilineal inheritance dominates in Southern Region while patrilineal inheritance dominates in Central and Northern Regions. The matrilineal system gives more power to women in control over the land and may be a reason why more female-headed households are relatively land-rich in the South. Below we explore the implication of varying access to land for female-headed households before we compare the situation of land-poor and land-rich male headed households.

8.1.1. Female-headed households (SFH)

We start by assessing a female-headed household without access to input subsidies but with good access to off-farm *ganyu* employment. The *ganyu* labor is divided in agricultural *ganyu* that is available in peak agricultural seasons and non-agricultural *ganyu* that also may be available in other parts of the year. The access is measured in person-weeks of access for each of these two categories of employment. One week gives a net income of MK.1000 and requires 40 hours of work. The land rental market has a fairly high land rental price (3x the observed renting out price in Central Malawi at the time and a 50% higher renting in price). This is based on the higher land scarcity in Southern Malawi. Key simulation results are presented in Table 8.1. The initial land endowment (average for the sample) was 0.942 ha. This area size is consecutively reduced by 20, 40, 60, 70, 75 and 78%. The model became infeasible when the constraint was set at 80% which implies a farm size below 0.2 ha.

We see that the household did not participate in the land rental market in the two initial models but when the land access is reduced by 40%, additional 0.129 ha of land is rented in. It is, however, surprising to find that when the land constraint is further tightened land renting in is reduced and is out of the solution when the land constraint is tightened by 70%. With further tightening of the land constraint, land renting is increased substantially such that operated land holding even increases. The initial land renting is used to grow local maize more extensively while the later land renting when the own farm size has been reduced by more than 7% results in adoption of improved maize and purchase of additional fertilizer at commercial price. This latter intensification also results in an increase in total labor use for the management of a larger rented-in area. This set of simulations illustrates the "sluggish" technology adoption process which results in households becoming net buyers of maize as land scarcity increases as long as they have off-farm employment that makes it affordable to buy maize. However, with further tightening of the land constraint there is a need to rent land to produce more own maize to reduce the purchased maize, given a constant access to off-farm *ganyu* employment (15 + 15 weeks).

Next we reduce the access to *ganyu* employment to 10 +5 weeks and call this "intermediate access to *ganyu* employment" and run a similar set of land constraint simulations as in Table. 8.1. The simulation results are presented in Table 8.2 and demonstrate a similar land renting response and demand for purchased maize for consumption with the tightening of the land constraint. However, neither land renting nor purchase of maize are reaching the same levels as with high *ganyu* employment access and the models become infeasible when the land constraint is tightened by 47%, and before that local maize has been mostly replaced by improved maize while purchase of maize has again been reduced to zero. It appears preferable for the more cash-constrained household to produce its own maize with improved maize than to use scarce cash to buy maize to satisfy the food consumption constraint.

Tables 8.3 and 8.4 include access to two bags of subsidized fertilizer as the only change compared to Tables 8.1 and 8.3 where Table 8.3 shows the effect on female-headed households with good access to *ganyu* employment and Table 8.4 gives the effect on female-headed households with intermediate access to *ganyu* employment. From Tables 8.3 and 8.1 we see that two important effects of access to subsidized fertilizer are that the household rents in more land, and purchases less maize for consumption when the land access is reduced. With access to land through the land rental market it is also possible to survive with less own land than without access to subsidized fertilizer as the land access can be reduced by more than 90% without the models producing infeasible solutions. We also see that the subsidy crowds out the demand for fertilizer at the commercial price except in two cases; with no reduction and 90% reduction in the land constraint, when small amounts are demanded.

When comparing Table 8.4 with Table 8.2 we see responses in the same direction as in Tables 8.3 versus 8.1. The household responds to access to subsidized fertilizer by renting in more land and purchasing less maize. Intensification with improved maize is also delayed as land renting facilitates more extensive land use. Overall, with poorer access to off-farm employment the cash constraint is tighter, the household is able to rent in less additional land, and less able to purchase maize for consumption. It responds by adopting more improved maize compared to the household with better access to off-farm employment (Table 8.3) but access to subsidized fertilizer reduces adoption of improved maize compared to the household with the same level of off-farm employment (Table 8.2). This implies that access to subsidized fertilizer both crowds out demand for commercial fertilizer and commercial improved maize seed. This is based on the assumption that households know whether they receive subsidized inputs at the time they buy their inputs at commercial price.

Table 8.1. SFH: Sensitivity to access to land with land rental market and good access to *ganyu* employment (no subsidy access).

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**
Received Improved maize seed, kg (subsidized)	0	0	0	0	0	0	0
Received subsidized fertilizer, 50 kg bags	0	0	0	0	0	0	0
Land constraint, % reduction in area	**0**	**20**	**40**	**60**	**70**	**75**	**78**
Own farm size, ha	0.942	0.754	0.565	0.377	0.283	0.236	0.207
Rented in land, ha	0	0	0.129	0.084	0	0.182	0.351
Utility (net income – drudgery cost)	9007	3606	-2384	-9788	-14197	-17625	-21079
Total labor, hours	2195	2089	2062	1767	1552	1729	1920
Net income, MK	37981	31254	24931	13461	5880	5500	6000
Purchase of maize, kg	0	164	239	532	635	337	36
Buy Local Maize seed, kg	12.04	10.08	9.19	5.69	1.82	1.81	1.81
Buy Improved Maize seed, kg (commercial)	0	0	0	0	1.67	3.71	5.82
Purchase commercial fertilizer, 50 kg bags	2.17	1.78	1.6	0.9	0.69	1.36	2.14
Fertilizer cost, MK	6994	5818	5282	3180	2527	4564	6880

Table 8.2. SFH: Sensitivity analysis with intermediate access to *ganyu* employment (no subsidy access)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	**10+5**	**10+5**	**10+5**	**10+5**	**10+5**	**10+5**
Received Improved maize seed, kg (subsidized)	0	0	0	0	0	
Received subsidized fertilizer, 50 kg bags	0	0	0	0	0	
Land constraint, % reduction in area	**0**	**20**	**40**	**45**	**46**	**47**
Own farm size, ha	0.942	0.754	0.565	0.518	0.5087	Infeasible
Rented in land, ha	0	0.111	0	0.069	0.067	
Utility (net income – drudgery cost)	3824	-2144	-11768	-15079	-16247	
Total labor, hours	1765	1677	1318	1349	1343	
Net income, MK	27244	19982	5130	2311	1102	
Purchase of maize, kg	0	24	135	0	0	
Buy Local Maize seed, kg	12.04	11.75	3.08	1.81	1.81	
Buy Improved Maize seed, kg (commercial)	0	0	4.65	6.24	6.08	
Purchase commercial fertilizer, 50 kg bags	2.17	2.12	1.93	2.21	2.23	
Fertilizer cost, MK	6994	6818	6264	7094	7164	

Table 8.3. SFH: Sensitivity analysis with intermediate access to *ganyu* employment (with fertilizer subsidy access)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**
Received Improved maize seed, kg (subsidized)	0	0	0	0	0	0
Received subsidized fertilizer, 50 kg bags	2	2	2	2	2	2
Land constraint, % reduction in area	**0**	**40**	**60**	**75**	**80**	**90**
Own farm size, ha	0.942	0.565	0.377	0.236	0.1884	0.094
Rented in land, ha	0	0.205	0.315	0.321	0.323	0.477
Utility (net income – drudgery cost)	12848	1062	-5401	-11907	-14335	-20489
Total labor, hours	2195	2096	2058	1905	1851	1931
Net income, MK	41821	28803	21926	13060	10016	6718
Purchase of maize, kg	0	143	178	172	179	23
Buy Local Maize seed, kg	12.0	10.3	8.4	3.5	1.8	1.8
Buy Improved Maize seed, kg (commercial)	0	0	1.0	4.1	5.1	6.0
Purchase commercial fertilizer, 50 kg bags	0.17	0	0	0	0	0.15
Fertilizer cost, MK	3154	2269	2160	2269	2269	3083

Table 8.4. SFH: Sensitivity analysis with intermediate access to *ganyu* employment (with subsidy access)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	**10+5**	**10+5**	**10+5**	**10+5**	**10+5**	**10+5**
Received Improved maize seed, kg (subsidized)	0	0	0	0	0	0
Received subsidized fertilizer, 50 kg bags	2	2	2	2	2	2
Land constraint, % reduction in area	**0**	**20**	**40**	**45**	**46**	**55**
Own farm size, ha	0.942	0.754	0.565	0.518	0.5087	0.424
Rented in land, ha	0	0.131	0.214	0.189	0.182	0.154
Utility (net income – drudgery cost)	7663	1730	-5329	-7626	-8188	-13297
Total labor, hours	1765	1762	1574	1489	1469	1338
Net income, MK	31084	24263	15469	11924	11049	3918
Purchase of maize, kg	0	0	78	87	90	48
Buy Local Maize seed, kg	12.0	12.0	9.9	7.9	7.3	1.8
Buy Improved Maize seed, kg (commercial)	0	0	0.7	2.0	2.3	6.1
Purchase commercial fertilizer, 50 kg bags	0.17	0.17	0	0	0	0.16
Fertilizer cost, MK	3154	3154	2629	2629	2629	3124

Tables 8.5 and 8.6 present models with low access to *ganyu* employment without and with access to two bags of subsidized fertilizer (at 64% subsidy level). In Table 8.5 we see an opposite response in the land rental market compared to the earlier models with better off-farm employment access when the land constraint is tightened. The more cash-constrained household resorts to renting out land when land access is reduced as a way to mobilize cash (a form of distress rental) and switches from local maize to improved maize to remain self-sufficient in maize production when the land constraint is tightened by more than 20%. The models become infeasible when the land constraint is tightened by more than 25%. We see that even without access to subsidies, use of fertilizer and improved maize is preferable to purchase of maize for consumption for the cash-poor and more employment-constrained household. Table 8.6 shows that with access to two bags of subsidized fertilizer the cash constraint is relaxed and the household can afford to rent in additional land when the land constraint is tightened while the incentives to intensify by purchasing improved maize seeds are somewhat reduced as access to more rented land facilitates more extensive land use while still achieving self-sufficiency in maize production.

It is important to keep in mind that these models do not incorporate any uncertainty regarding access to fertilizer subsidies, other market access opportunities or production risk. They provide an assessment of what would be the rational responses given the set of preferences, activities and constraints modeled. These models give insights into how land rental market access and *ganyu* employment access affect the incentives of typical female-headed households with varying land access in Southern Region of Malawi with the price regime and with and without fertilizer subsidies in the 2005/2006 season.

Table 8.5. SFH: Sensitivity analysis with low access to *ganyu* employment (no subsidy access)

Model	(1)	(2)	(3)
Ganyu labor access, ag. + non-ag. Person-weeks	**5+5**	**5+5**	**5+5**
Received Improved maize seed, kg (subsidized)	0	0	0
Received subsidized fertilizer, 50 kg bags	0	0	0
Land constraint, % reduction in area	**0**	**20**	**25**
Own farm size, ha	0.942	0.754	0.707
Rented in(+)/out (-) land, ha	0	-0.070	-0.127
Utility (net income – drudgery cost)	2452	-8119	-12743
Total labor, hours	1568	1264	1145
Net income, MK	22303	7677	1572
Purchase of maize, kg	0	0	0
Buy Local Maize seed, kg	12.04	5.71	1.81
Buy Improved Maize seed, kg (commercial)	0	0	6.14
Purchase commercial fertilizer, 50 kg bags	2.17	2.17	2.22
Fertilizer cost, MK	6994	6978	7121

Table 8.6. SFH: Sensitivity analysis with low access to *ganyu* employment (and fertilizer subsidy access)

Model	(1)	(2)	(3)	(4)
Ganyu labor access, ag. + non-ag. Person-weeks	**5+5**	**5+5**	**5+5**	**5+5**
Received Improved maize seed, kg (subsidized)	0	0	0	0
Received subsidized fertilizer, 50 kg bags	2	2	2	2
Land constraint, % reduction in area	**0**	**20**	**25**	**40**
Own farm size, ha	0.942	0.754	0.707	0.565
Rented in(+)/out (-) land, ha	0	0.128	0.108	0.031
Utility (net income – drudgery cost)	6357	187	-2082	-11086
Total labor, hours	1565	1499	1421	1161
Net income, MK	26117	19201	15813	3430
Purchase of maize, kg	0	0	0	0
Buy Local Maize seed, kg	12.6	12.0	10.1	1.8
Buy Improved Maize seed, kg (commercial)	0	0.04	1.2	6.4
Purchase commercial fertilizer, 50 kg bags	0.28	0.18	0.20	0.25
Fertilizer cost, MK	3478	3156	3215	3390

8.1.2. Male-headed land-poor households (SMHLP)

From Table 3.1 we see that land-poor households on average have a farm size of 0.61 ha while they are relatively labor-rich. The models in Table 8.7 assess the effects of reducing access to *ganyu* employment for a household that does not have access to additional land through the land rental market. The household has access to input subsidies in form of 2 bags of fertilizer and 2 kg improved maize seed. The model became infeasible when the *ganyu* labor access was reduced below 13+12 weeks of *ganyu* employment showing the high dependency on such employment for these households even though they have access to a standard input package. Even with input access the household still relies on purchasing a substantial amount of maize for its own consumption.

Table 8.7. SMHLP: Sensitivity to *ganyu* labor access

Model	(1)	(2)	(3)	(4)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**14+14**	**13+13**	**13+12**
Received Improved maize seed, kg (subsidized)	2	2	2	2
Received subsidized fertilizer, 50 kg bags	2	2	2	2
Utility (net income – drudgery cost)	-13681	-15173	-17200	-18399
Total labor, hours	1958	1884	1808	1768
Net income, MK	10796	8372	5400	3701
Purchase of maize, kg	686	598	511	490
Buy Local Maize seed, kg	5.62	3.82	2.35	2.35
Buy Improved maize seed, kg (commercial)	0.04	1.84	3.31	3.31

Table 8.7 shows that the land-poor household without access to additional land through the land rental market to a limited extent is able to respond to reduced access to *ganyu* employment by

intensifying its production. Total labor hours are therefore reduced and so is net income and utility. With reduced access to *ganyu* employment the household is less able to demand maize for consumption from the market and ensures its maize need by increasing its demand for improved maize seed by buying improved maize seed from the market at commercial price (assuming it is available). At the same time the household reduces its production of local maize.

In Table 8.8 we assess the effect of reduced access to subsidized maize seeds while keeping the access to subsidized fertilizer constant at two bags.

Table 8.8. SMHLP: Sensitivity to varying access to improved maize seeds

Model	(1)	(2)	(3)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**
Received Improved maize seed, kg (subsidized)	2	1	0
Received subsidized fertilizer, 50 kg bags	2	2	2
Utility (net income – drudgery cost)	-13681	-14139	-14596
Total labor, hours	1958	1959	1961
Net income, MK	10796	10354	9913
Purchase of maize, kg	686	666	646
Buy Local Maize seed, kg	5.62	5.21	4.8
Buy Improved maize seed, kg (commercial)	0.04	1.46	2.87

Surprisingly, we see that reduced free access to improved seed reduces the purchase of maize for consumption. We see a strong crowding out effect of commercial improved maize seed when free improved seeds are offered. Reduced access to free improved seeds triggers demand for improved seeds at commercial price in a way that reduces the net deficit maize production. While this seems like a perverse response it is perfectly rational given the constraints that the household faces. The household saves on cash resources by intensifying its maize production when seeds become more expensive.

What happens if we open for participation in the land rental market but at a high land rental price? This is assessed in Table 8.9. The land renting out price is set 3x the observed price in Central Malawi and the land renting in price is 50% higher than the renting out price. This gives a renting out price of MK 21900/ha and a renting in price of MK 32850/ha, assuming a market with fairly high fixed transaction cost. The results of opening this market with otherwise the same assumptions as in the previous table, are presented in Table 8.9.

We see that the household is willing to rent in extra land at the high price in the land rental market and the household is willing to rent in more land when access to free improved maize seed is increasing. The land rental market access improves self-sufficiency in maize production because about 300 kg less maize is purchased from the market as compared to the previous models. The better land access through the land rental market stimulates an increase in the production of local maize more than it stimulates the production of improved maize. The effect of varying the access to free improved maize seeds had a similar effect on the demand for commercial improved maize seeds as in the previous table. The crowding out effect is very strong, given that there is access to commercial seed.

Table 8.9. SMHLP: Sensitivity to access to improved maize seeds, with land rental market

Model	(1)	(2)	(3)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**
Received Improved maize seed, kg (subsidized)	2	1	0
Received subsidized fertilizer, 50 kg bags	2	2	2
Land rental price*	**3x1.5**	**3x1.5**	**3x1.5**
Utility (net income – drudgery cost)	-11676	-12312	-12947
Total labor, hours	2269	2246	2223
Net income, MK	17144	16154	15164
Land rented in, ha	**0.245**	**0.223**	**0.207**
Purchase of maize, kg	360	363	366
Buy Local Maize seed, kg	8.92	8.2	7.48
Buy Improved maize seed, kg (commercial)	0.43	1.86	3.29

Note: Land rental price* refers to the renting out price in Central region as base and a markup for renting in price due to transaction costs in the market. 1x1.5 implies that the renting out price is set at the base price we recorded in Central region and 1.5 indicates a 50% markup for the renting in price. 3x1.5 indicates that the renting out price is three times the base price and with additional 50% markup for the renting in price, meaning that both prices have been trippled.

8.1.3. Male-headed land-rich households (SMHLR)

This is the wealthiest household group in terms of land in our sample in Southern Region. On average they own 1.37 ha of land. We assume that this household group is less dependent on *ganyu* employment. We vary the access to agricultural and non-agricultural *ganyu* employment from no access to 5 + 5 person-weeks and to 15 + 15 person-weeks in a year. We assume 20% storage loss from the production like in the other models. We keep the land rental market open with renting out price that is three times the observed price in Central Malawi and with an additional 50% markup for renting in land. However, we do not think it is likely that this household group will rent in additional land. On the contrary this group may be a potential source of land in the land rental market, given that they are relatively land-rich compared to other households in the area. Table 8.10 presents results from models with no or limited access to *ganyu* employment while Table 8.11 presents results from models with better access to such employment. With each labor market access level we look at the effect of access to subsidized fertilizer and improved maize seed assuming that these are available also at commercial price. This allows us to assess the extent of crowding out of commercial demand, *ceteris paribus.*

Table 8.10 shows that the land-rich household without access to off-farm employment obtains cash by renting out part of its land for purchase of farm inputs. With access to subsidized fertilizer the cash need is reduced and less land is rented out but total fertilizer use is not changed and the same amount of local maize seeds is demanded in both models. We also see that total labor used is increased substantially as more of the land is cultivated by the household although it prefers to produce other crops than maize and achieves about a 50% increase in its net income and a substantial higher level of utility.

With some access to off-farm employment (5 + 5 weeks) the household no longer rents out any land as the off-farm employment generates sufficient cash for the purchase of farm inputs. More household labor is used both on farm and off-farm and net income and utility levels are higher without fertilizer subsidy access with 10 weeks of such employment than for the household with access to two bags of subsidized

Table 8.10. SMHLR: Models with limited access to *ganyu* employment

Model	(1)	(2)	(3)	(4)
Ganyu labor access, ag. + non-ag. Person-weeks	**0+0**	**0+0**	**5+5**	**5+5**
Received Improved maize seed, kg (subsidized)	0	0	0	0
Received subsidized fertilizer, 50 kg bags	0	2	0	2
Rented in(+)/out (-) land, ha	-0.297	-0.085	0	0
Utility (net income – drudgery cost)	7540	13106	14905	18745
Total labor, hours	1324	1564	2051	2051
Net income, MK	24269	32971	40832	44672
Purchase of maize, kg	0	0	0	0
Buy Local Maize seed, kg	12.5	12.5	12.5	12.5
Buy Improved Maize seed, kg (commercial)	0	0	0	0
Purchase commercial fertilizer, 50 kg bags	2.06	0.06	2.06	0.06
Fertilizer cost, MK	6991	3151	6991	3151

fertilizer but no access to off-farm employment. Fertilizer used and maize production does not change with these differences in access to employment and subsidized inputs. The last model in Table 8.10 shows the household with some access both to off-farm employment and subsidized fertilizer. This reduces the input costs of the household and increases the net income and utility but otherwise has no effect on production. This means that access to subsidy crowds out an equivalent amount of commercially demanded fertilizer. Overall, we see that access to subsidized fertilizer had the strongest effect on the more cash-poor household that does not have access to *ganyu* employment. Relatively wealthier and more cash-rich households do not need to go for sub-optimal strategies to generate the necessary cash to purchase farm inputs. However, we should also note that the observed *ganyu* wage rates in our study area are favorable enough to also make relatively more land-rich households better off, given the relatively low average agricultural productivity that was calibrated into the models from our data.

Table 8.11 illustrates the response of the male-headed land-rich household with even better access to off-farm employment. It also illustrates the effect of higher storage losses, comparing a 30% storage loss with the baseline 20% storage loss. This gives an assessment of the relative importance of reducing post-harvest losses through better storage methods. In this case it is also assumed that the households know the level of storage loss and rationally adjust the production to meet the consumption needs. Finally, we add a scenario where it is assumed that there is an inefficiency loss related to access to subsidized inputs such that productivity is 10% lower in production activities where subsidized fertilizer is used. We have empirical basis for this scenario although we do not know for sure why we observe such lower fertilizer use efficiency for subsidized fertilizer than for commercial fertilizer. One reason may be that subsidized fertilizers arrive too late to give optimal returns. Another could be that households do not know till very late whether they will receive such subsidized inputs and that may affect their production planning.

Table 8.11. SMHLR: With good access to *ganyu* employment, varying storage loss (%) and subsidized fertilizer use efficiency

Model	(1)	(2)	(3)	(4)	(5)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**	**15+15**	**15+15**
Received Improved maize seed, kg (subsidized)	0	0	0	0	0
Received subsidized fertilizer, 50 kg bags	0	2	0	2	2
Storage loss, %	**20**	**20**	**30**	**30**	**30**
Subsidized fertilizer use efficiency	**100**	**100**	**100**	**100**	**90**
Utility (net income – drudgery cost)	21355	25195	16027	19867	15686
Total labor, hours	2683	2683	2640	2640	2640
Net income, MK	56632	60472	50765	54605	50424
Purchase of maize, kg	0	0	0	0	0
Buy Local Maize seed, kg	12.5	12.5	14.3	14.3	14.3
Buy Improved Maize seed, kg (commercial)	0	0	0	0	0
Purchase commercial fertilizer, 50 kg bags	2.06	0.06	2.42	0.42	2.66
Fertilizer cost, MK	6991	3151	8062	4222	8402

Table 8.11 shows that the main effect of access to subsidized fertilizer in this household group with good land access is that input costs are reduced and net income is equivalently increased while production is unaffected as subsidized fertilizer crowds out an equivalent quantity of commercial fertilizer.

With an increase in the level of storage loss, and assuming that this is known by the household in advance, causes the household to increase its production accordingly to meet its subsistence requirements. The relatively land-rich and cash-rich household has no problem with this. It increases its demand for maize seeds and commercial fertilizer to produce enough maize for its subsistence requirement. Access to subsidized fertilizer has a similar effect as in the previous models; an equivalent amount of commercial fertilizer (100 kg) is crowded out and production is unaffected.

The last scenario with subsidized input use being associated with fertilizer use inefficiency results in no crowding out of commercial fertilizer. Rather than waiting for uncertain subsidized fertilizer that cannot be applied in an efficient way the household purchases commercial fertilizer.

Let us now revisit the cash-poor but land-rich household and assess how higher storage loss and subsidized fertilizer use inefficiency affects this household. The simulation results are presented in Table 8.12.

Comparing Tables 8.12 and 8.10 we see that an increase in storage loss from 20 to 30% causes the household to rent out additional land to generate sufficient cash to purchase inputs. With access to subsidized fertilizer that is used efficiently, the household is able to reduce the rented out area by about 0.25 ha, more than the reduction with lower storage loss (Table 8.10) and the household prefers to grow more local maize rather than a bit of improved maize. Commercial demand for fertilizer is crowded out about 1:1 by subsidized fertilizer but the cash saved allows the household to farm more of the land itself thus reducing the supply of land to the land rental market while household labor use is increased by close to 300 hours in a year.

Table 8.12. SMHLR: Without access to *ganyu* employment, with high storage loss (30%), and without and with subsidized fertilizer use inefficiency (10% lower production efficiency)

Model	(1)	(2)	(3)	(4)
Ganyu labor access, ag. + non-ag. Person-weeks	**0+0**	**0+0**	**0+0**	**0+0**
Received Improved maize seed, kg (subsidized)	0	0	0	0
Received subsidized fertilizer, 50 kg bags	**0**	**2**	**0**	**2**
Storage loss, %	30	30	30	30
Subsidized fertilizer use efficiency	**100**	**100**	**90**	**90**
Rented in(+)/out (-) land, ha	-0.435	-0.188	-0.463	-0.341
Utility (net income – drudgery cost)	125	7481	-1178	120
Total labor, hours	1177	1462	1144	1288
Net income, MK	15017	26180	13271	16574
Purchase of maize, kg	0	0	0	0
Buy Local Maize seed, kg	11.3	14.3	10.4	12.2
Buy Improved Maize seed, kg (commercial)	1.9	0	2.4	2.4
Purchase commercial fertilizer, 50 kg bags	2.45	0.42	2.69	1.1
Fertilizer cost, MK	8156	4222	8476	5751

With a 10% lower subsidized fertilizer use efficiency, assuming that output is reduced by 10% in activities where subsidized fertilizer is used on top of 30% storage loss, the household rents out more land both without and with access to subsidized fertilizer.

The reason we see a response, comparing models (1) and (3) in Table 8.12 also for households without direct access to subsidized fertilizer, is that we have assumed that they have limited access to subsidized inputs through the informal market for such inputs. This has been calibrated into the models based on our survey data. We see that the welfare effect of access to subsidized fertilizer is substantially reduced when the efficiency of utilization is lower. The benefits of the program are therefore very sensitive to imperfections such as late delivery of inputs. The reduction in area rented out is much smaller than when subsidized fertilizer can be utilized efficiently, e.g. because it has arrived on time and the household knows that it will receive the subsidized fertilizer when optimal input decisions are made. Another implication we see is that the subsidized fertilizer to a smaller extent crowds out commercial demand for fertilizer.

8.2. Central Region

Land access is better and farm sizes larger in Central Region because of lower population densities. Tobacco is also more commonly grown as a cash crop. Lower pressure on the land also leads to lower land rental prices than in the South. The need for *ganyu* employment and access to such employment may be lower in the Central Region and may also be more seasonal and linked to the demand for labor in peak seasons in agriculture. In the following models we explore the effects of varying access to *ganyu* employment (including seasonality in demand), varying farm size (land constraint adjustments), varying the rental price for land, and the access to subsidized fertilizer and improved seeds.

8.2.1. Female-headed households (CFH)

In the first four models in Table 8.13 we have used the low rental price for land (based on observed data) and vary the access to *ganyu* employment and land access. We see that increased access to *ganyu* employment leads to an increase in land area rented in but does not change the demand for farm inputs for maize production or tobacco production. A tightening of the land constraint by 20 and 40% leads to further increase in area rented in but also now without affecting demand for fertilizer and maize seeds.

The next six models (models (5) to (10)) have set the land rental price at the double of the first models and access to *ganyu* employment is limited to agricultural *ganyu* in the agricultural season. These adjustments essentially lead to an elimination of interest in renting in land. With a 20% reduction in owned farm size, only local maize is grown and only a small amount of fertilizer is purchased for tobacco production. Access to two bags of subsidized fertilizer for this household leads to some adoption of improved maize seed, crowding out of most of the commercial demand for fertilizer for maize and a crowding in of demand for fertilizer for tobacco. The subsidy access leads to a substantial mobilization of household labor for tobacco production and increases net income by as much as 180%. Provision of two kg of improved maize seed to the household crowds out demand for commercial improved maize seed and crowds in additional purchase of fertilizer for tobacco production. A further tightening of the land constraint leads to an increase in the demand for improved maize seed while demand for local maize seed is reduced and demand for fertilizer for tobacco is reduced. Without access to subsidized fertilizer and improved maize seeds the more land constrained household model requires additional access to *ganyu* employment (increase from 10 to 15 weeks) not to become infeasible and then demands more commercial fertilizer for maize and more improved seed while demand for fertilizer for tobacco production is reduced. Provision of two bags of subsidized fertilizer for this household with better *ganyu* access but poorer land access, improved net income by about 120%.

None of the models above result in purchase of maize for consumption. The relatively labor-rich household prefers to use cash to increase its tobacco production and to rent in additional land if available at a reasonable price. Access to subsidized inputs for maize production therefore has quite surprising effects in form of stimulation of tobacco production rather than maize production.

8.2.2. Male-headed and land-poor households (CMHLP)

We find that male-headed land-poor households are unable to make their ends meet without access to off-farm employment of at least 15-20 person-weeks per year given the relative prices, market and technologies and taste preferences in 2005/06. Table 8.14 presents model results with variation in access to off-farm employment and access to subsidized inputs for maize production. To some extent they are able to rent in additional land and prefer to grow improved maize on their limited land area. Surprisingly, with access to subsidized fertilizer we find that rather than intensifying maize production they prefer to expand their tobacco production and purchase part of their maize for consumption. This tendency grows even stronger with provision of free improved maize seeds in addition to subsidized fertilizer. Apparently using fertilizer on tobacco was more profitable at that time although it also required more working hours but the extra drudgery of work did not discourage this response. With lower access to off-farm employment (models 4 and 5 in Table 8.14) households are more cash-poor and less able to purchase fertilizer for tobacco production. This causes a switch to more subsistence oriented maize production with more improved maize seed.

Table 8.13. Female-headed household in Central Region (CFH): Sensitivity to access to land, varying land rental price, varying access to *ganyu* employment, and varying access to subsidized inputs.

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ganyu labor access, ag. + non-ag. Person-weeks	**10+10**	**15+15**	**15+15**	**15+15**	**10+0**	**10+0**	**10+0**	**10+0**	**15+0**	**15+0**
Land constraint, % reduction in area	**0**	**0**	**20**	**40**	**20**	**20**	**20**	**40**	**40**	**40**
Received Improved maize seed, kg (subsidized)	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**0**	**0**
Received subsidized fertilizer, 50 kg bags	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**2**	**0**	**2**
Land rental price*	**1x1.5**	**1x1.5**	**1x1.5**	**1x1.5**	**2x1.5**	**2x1.5**	**2x1.5**	**2x1.5**	**2x1.5**	**2x1.5**
Own farm size, ha	1.39	1.39	1.114	0.835	1.114	1.114	1.114	0.835	0.835	0.835
Rented in land, ha	0.162	0.341	0.396	0.451	0	0	-0.018	0	0	0
Utility (net income – drudgery cost)	25915	30663	24294	17925	-5428	15705	16917	-5184	-8954	4668
Total labor, hours	3527	3877	3693	3509	1949	2889	2934	2203	2141	2790
Net income, MK	74708	84475	75592	66710	20248	56521	58306	23692	20753	43701
Purchase of maize, kg	0	0	0	0	0	0	0	0	0	0
Buy Local Maize seed, kg	16.9	16.9	16,9	16.9	15.8	14.4	13.7	4.8	3.1	3.1
Buy Improved Maize seed, kg (commercial)	0	0	0	0	0	1.5	0	5.0	8.7	8.7
Purchase fertilizer maize, 50 kg bags	3.1	3.1	3.1	3.1	2.9	1.2	1.2	1.2	3.3	1.3
Purchase fertilizer tobacco, 50 kg bags	1.5	1.5	1.5	1.5	0.2	1.8	1.9	1.1	0.7	1.9
Fertilizer cost, MK	14441	14441	14441	14441	9941	11501	11975	9567	12506	12223

Note: Land rental price* refers to the renting out price in Central region as base and a markup for renting in price due to transaction costs in the market. 1x1.5 implies that the renting out price is set at the base price we recorded in Central region and 1.5 indicates a 50% markup for the renting in price. 2x1.5 indicates that the renting out price is twice the base price and with additional 50% markup for the renting in price, meaning that both prices have been doubled. All models assume 20% storage loss.

Table 8.14. CMHLP: With varying access to off-farm income and input subsidies

Model	(1)	(2)	(3)	(4)	(5)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**15+15**	**15+5**	**15+5**
Received Improved maize seed, kg (subsidized)	**0**	**0**	**2**	**0**	**2**
Received subsidized fertilizer, 50 kg bags	**0**	**2**	**2**	**2**	**2**
Land rental price*	**2x1.5**	**2x1.5**	**2x1.5**	**2x1.5**	**2x1.5**
Own farm size, ha	0.779	0.779	0.779	0.779	0.779
Rented in land, ha	0.160	0.076	0.066	0	0
Utility (net income – drudgery cost)	-7662	2450	3751	-11967	-9064
Total labor, hours	3035	3448	3491	2344	2520
Net income, MK	36778	53615	55751	22177	27971
Purchase of maize, kg	0	167	188	0	0
Buy Local Maize seed, kg	0.8	0.8	0.8	0.8	0.8
Buy Improved Maize seed, kg (commercial)	11.8	10.5	8.3	11.8	9.8
Purchase fertilizer maize, 50 kg bags	2.5	0.1	0	0.5	0.5
Purchase fertilizer tobacco, 50 kg bags	0.15	1.8	1.9	0.4	0.7
Fertilizer cost, MK	13148	10691	10881	8740	7876

Note: Land rental price* refers to the renting out price in Central region as base and a markup for renting in price due to transaction costs in the market. 1x1.5 implies that the renting out price is set at the base price we recorded in Central region and 1.5 indicates a 50% markup for the renting in price. 2x1.5 indicates that the renting out price is twice the base price and with additional 50% markup for the renting in price, meaning that both prices have been doubled.

Table 8.15. CMHLP: With intermediate access to off-farm income and varying access to input subsidies

Model	(1)	(2)	(3)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+10**	**15+10**	**15+10**
Received Improved maize seed, kg (subsidized)	**0**	**0**	**2**
Received subsidized fertilizer, 50 kg bags	**0**	**2**	**2**
Land rental price	**2x1.5**	**2x1.5**	**2x1.5**
Own farm size, ha	0.779	0.779	0.779
Rented in land, ha	0.130	0.160	0.160
Utility (net income – drudgery cost)	-21253	-2374	-602
Total labor, hours	2170	3151	3246
Net income, MK	9791	44779	48309
Purchase of maize, kg	0	0	0
Buy Local Maize seed, kg	0.8	0.8	0.8
Buy Improved Maize seed, kg (commercial)	11.3	11.8	9.8
Purchase fertilizer maize, 50 kg bags	2.6	0.5	0.5
Purchase fertilizer tobacco, 50 kg bags	0	1.4	1.6
Fertilizer cost, MK	10481	10867	11409

Table 8.15 provides simulation results with intermediate access to off-farm employment and varying access to subsidized inputs for maize production. We see that access to two bags of fertilizer for maize production does not increase fertilizer use on maize but stimulates tobacco production and causes net income to increase by 350% while total labor hours are increased almost 50%. Additional access to improved maize seeds pushes further in the same direction rather than stimulating maize production.

8.2.3. Male-headed land-rich households (CMHLR)

We see from Table 8.16 that land-rich households with close to two ha of land do not need supplementary *ganyu* employment. They are even in a position to rent out part of their land. At renting out price that is double of what we observed the household prefers to rent out 0.85 ha of its land and this does not change with varying access to input subsidies. If we reduced the land rental price to half, the household still rents out land but the area rented out is reduced from 0.85 ha to 0.72 ha when there is no access to input subsidies. The land-rich household appears not to have incentive to adopt improved maize. Access to subsidized fertilizer on the other hand stimulates tobacco production as the purchased amount of commercial fertilizer for tobacco production is increased. Provision of free seeds of improved maize does not lead to more intensified maize production. Additional labor is rather preferred invested in tobacco production given the relative prices in 2005/06.

Table 8.16. CMHLR: With no access to off-farm income and varying access to input subsidies

Model	(1)	(2)	(3)	(4)	(5)
Ganyu labor access, ag. + non-ag. Person-weeks	**0+0**	**0+0**	**0+0**	**0+0**	**0+0**
Received Improved maize seed, kg (subsidized)	**0**	**0**	**2**	**0**	**0**
Received subsidized fertilizer, 50 kg bags	**0**	**2**	**2**	**0**	**2**
Land rental price	**2x1.5**	**2x1.5**	**2x1.5**	**1x1.5**	**1x1.5**
Own farm size, ha	1.974	1.974	1.974	1.974	1.974
Rented in (+) / out (-) land, ha	-0.852	-0.852	-0.852	-0.724	-0.758
Utility (net income – drudgery cost)	34190	39365	39365	10916	23599
Total labor, hours	2659	2816	2816	1764	2300
Net income, MK	69820	77056	77056	33637	54610
Purchase of maize, kg	0	0	0	0	0
Buy Local Maize seed, kg	14.1	14.1	14.1	15.2	15.9
Buy Improved Maize seed, kg (commercial)	0	0	0	0	0
Purchase commercial fertilizer maize, 50 kg bags	0.5	0	0	0.18	0
Purchase commercial fertilizer tobacco, 50 kg bags	2.1	2.5	2.5	0.08	1.1
Fertilizer cost, MK	13419	12626	12626	6200	8310

8.3. Summary of findings

We have assessed how important variation in household characteristics and particularly varying access to land, captured by a typology of household categories, and how these household types respond to variation in own farm size, variation in land rental market characteristics, variation in access to off-farm employment (*ganyu*), and variation in access to subsidized inputs for maize production in Central and Southern Regions of Malawi. In addition we have also run some simulations to assess the impacts of variation in post-harvest losses and inefficiency in utilization of subsidized fertilizer. We have used observed prices in the 2005/06 season and the characteristics and levels of input subsidies in this year in these models.

The findings demonstrate that household responses are sensitive to the variation in household and market characteristics. The simulations also demonstrate that a "one-size fits all" subsidy policy that we have explored the impacts of, has very different impacts on different household categories. Like has been shown by several econometric studies, we find that access to subsidized fertilizer has a tendency to crowd out commercial demand for fertilizer with our models. Our models also demonstrate that such access may facilitate more land renting and tobacco production through relaxation of the cash constraint, thus actually crowding in demand for fertilizer for tobacco production. Access to subsidized improved maize seeds also often leads to crowding out of commercial demand for such seeds and households with more abundant land are less likely to demand such improved seeds. Improved maize seeds thus appear more attractive for more land-poor households that are in need of intensifying land use to be more self-sufficient in maize production. Land-poor households also critically depend on access to off-farm (*ganyu*) employment and may use cash from such employment to expand their own production through intensification or renting in additional land or to purchase additional maize for consumption. Tobacco production was an attractive way of intensifying land use in Central Malawi in 2005/06. Less favorable tobacco prices in the following years has reduced the attractiveness of this alternative. Provision of subsidies for tobacco production contributed to overproduction of tobacco and a fall in tobacco prices in 2008/09.

The optimization models used in this study are based on observed data and rely on strict assumptions about rational responses given preferences, resource constraints, technologies available and market opportunities and constraints, no risk and full information about prices and market opportunities. Even under such favorable conditions the models have identified quite a few "perverse" and apparent "irrational" responses that nevertheless are rational responses given the complex multi-dimensional set of constraints that households face. Economic intuition or beliefs about effects of fairly simple policy interventions such as provision of input subsidies are therefore insufficient to give a good guidance regarding the likely success and impacts of such interventions. Context matters and household heterogeneity leads to diverse and surprising direct and indirect effects of such a policy intervention. The fact that this type of intervention is very costly also makes a case for more careful analysis of its impacts and this modeling effort has been a step in this direction.

The models above have not investigated the effects of changes in relative prices such as the price changes associated with the international financial crisis that hit in 2008/09 and caused fertilizer and fuel prices to increase sharply, the fall in tobacco prices, or the potential general equilibrium effects of the large-scale input subsidy program. The models have also not been used to assess alternative input subsidy designs. The developed models can serve as good starting points for starting expansion into such analyses. The advantage of the use of such models over econometric analyses of survey data is that the models allow strict application of *ceteris paribus* assumptions while panel data analyses suffer from a lot of endogeneity problems, spill-over effects and unobserved heterogeneity that tends to be correlated with treatment variables such as targeted input subsidies. Pervasive market imperfections cause non-separability of production and consumption decisions of households rendering it very hard or impossible to identify valid instruments for prediction of many of the endogenous variables.

9. Effects of price shocks and subsidy policy adjustments

In this chapter we will investigate the impacts of the most important price shocks that took place in 2008/09 in form of increased fertilizer prices and reduced tobacco prices. At the same time the fertilizer subsidy level had been increased to 90%. The combination of high fuel and fertilizer prices and large scale of the subsidy program in 2008/09 made the subsidy program extremely expensive in that year and made it necessary to find ways to reduce the costs of the program. We assess the effect of the increase in subsidy level from 64 to 90% which took place from 2005/06 to 2008/09 and the effect of a reduction of subsidy access from two bags of fertilizer to one bag of fertilizer in combination with the price shocks.

9.1. Southern Region

9.1.1. Male-headed and land-poor household (SMHLP)

In Table 9.1 we assess the impact of increasing the fertilizer price by 25% in combination with varying access to subsidized inputs when the 2005/06 input subsidy level is maintained (at 64%). In Table 9.2 we run the same set of models after having increased the subsidy level to 90%. Increase in the subsidy represents a 40.6% increase in the cost of fertilizer subsidies. Nobody have critically assessed the difference between a 64% and a 90% subsidy in terms of costs versus benefits. We investigate alternative input packages by comparing the effects of alternatively receiving two, one and no bags of subsidized fertilizer and two kg improved maize seeds or no free seeds.

Table 9.1. SMHLP: With fertilizer price shock and varying subsidized input access

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	15+15	15+15	15+15	15+15	15+15	15+15
Land Rental Market, prices	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5
Received subsidized fertilizer, 50 kg bags	**2**	**2**	**1**	**1**	**1**	**1**
Received subsidized improved seed, kg	**0**	**0**	**0**	**0**	**2**	**2**
Storage loss, %	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100
Fertilizer price, % increase	**0**	**25**	**0**	**25**	**0**	**25**
Subsidy level, %	64	64	64	64	64	64
Utility (net income – drudgery cost)	-12947	-14456	-16450	-19095	-15133	-17416
Total labor, hours	2223	2168	2113	1968	2113	1968
Net income, MK	15164	12814	9968	5506	11282	7185
Land rented in, ha	0.207	0.161	0.114	0	0.117	0
Purchase of maize, kg	366	373	362	495	415	525
Buy Local Maize seed, kg	7.5	5.8	3.6	2.3	4.8	2.4
Buy Improved Maize seed, kg (commercial)	3.3	4.3	5.8	5.3	2.6	3.3
Purchase commercial fertilizer, 50 kg bags	0	0	1.05	0.65	0.90	0.65
Fertilizer cost, MK	3323	4154	5398	5238	4957	5238

Table 9.1 shows that the fertilizer price increase causes a reduction in renting in of land and a reduction in demand for commercial fertilizer while the dependency on purchasing maize for consumption increased. This was the case whether the household received two bags of subsidized fertilizer or just one bag of subsidized fertilizer. At the same time we see an increase in the demand for improved maize and a reduction in planting of local maize with the fertilizer price increase. Receiving one bag of subsidized fertilizer rather than two bags also stimulated the demand for improved maize seeds. Provision of free improved maize seeds crowded out commercial demand for improved seeds.

Table 9.2. SMHLP: With fertilizer price shock and varying subsidized input access

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	15+15	15+15	15+15	15+15	15+15	15+15
Land Rental Market, prices	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5
Received subsidized fertilizer, 50 kg bags	**2**	**2**	**1**	**1**	**1**	**1**
Received subsidized improved seed, kg	**0**	**0**	**0**	**0**	**2**	**2**
Storage loss, %	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100
Fertilizer price, % increase	**0**	**25**	**0**	**25**	**0**	**25**
Subsidy level, %	90	90	90	90	90	90
Utility (net income – drudgery cost)	-8794	-9337	-13402	-14423	-12099	-13060
Total labor, hours	2585	2356	2113	1960	2127	2019
Net income, MK	24920	20814	13009	10080	14526	12182
Land rented in, ha	0.498	0.319	0.120	0	0.134	0.049
Purchase of maize, kg	80	350	485	653	520	627
Buy Local Maize seed, kg	13.5	11.2	6.4	5.0	7.7	6.4
Buy Improved Maize seed, kg (commercial)	1.7	1.0	3.1	2.7	0	0
Purchase commercial fertilizer, 50 kg bags	0.66	0	0.71	0.30	0.61	0.35
Fertilizer cost, MK	2892	1154	2756	1914	2449	2105

We see the effect of increasing the subsidy level from 64% to 90% by comparing tables 9.1 and 9.2. The extent of land renting is higher for the household receiving two bags of subsidized fertilizer when the subsidy is 90% compared to 64% both before and after the 25% increase in fertilizer price. With less favorable access to subsidized fertilizer the renting in of land is very limited, however, at both subsidy levels. A surprising result is that when the subsidy level for fertilizer increases the purchase of maize for consumption also increases as the household grow less improved maize and more local maize. Provision of free improved maize seeds did not change this tendency. The models became infeasible when no subsidy access was provided to this land-poor household category demonstrating its vulnerability.

9.1.2. Male-headed land-rich households (SMHLR)

The effects of a fertilizer price shock, varying access to subsidized fertilizer, and an increase in the subsidy level for the typical land-rich male-headed household group in Southern Region are presented in Table 9.3. We see that the fertilizer price increase stimulates the household to rent out more land while provision of subsidized fertilizer and an increase in the subsidy level reduces the supply of land to the rental market. None of these changes affect the maize production of the household which is self-sufficient with maize. This household is not dependent on off-farm employment as it can generate cash by renting out part of its land. The access to input subsidies crowds out the commercial demand for fertilizer. The household does not demand improved maize seeds as maize production is not sufficiently profitable to stimulate production for sale.

Table 9.3. SMHLR: With fertilizer price shock and varying subsidized input access

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	0+0	0+0	0+0	0+0	0+0	0+0
Land Rental Market, prices	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5
Received subsidized fertilizer, 50 kg bags	**0**	**0**	**1**	**2**	**0**	**2**
Received subsidized improved seed, kg	**0**	**0**	**0**	**0**	**0**	**0**
Storage loss, %	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100
Fertilizer price, % increase	**0**	**25**	**25**	**25**	**25**	**25**
Subsidy level, %	**64**	**64**	**64**	**64**	**90**	**90**
Utility (net income – drudgery cost)	7540	4980	8495	11984	6057	15649
Total labor, hours	1324	1214	1365	1515	1260	1651
Net income, MK	24269	20308	25747	31186	21975	36570
Land rented in, ha	-0.297	-0.393	-0.261	-0.128	-0.353	0
Purchase of maize, kg	0	0	0	0	0	0
Buy Local Maize seed, kg	12.5	12.5	12.5	12.5	12.5	12.5
Buy Improved Maize seed, kg (commercial)	0	0	0	0	0	0
Purchase commercial fertilizer, 50 kg bags	2.06	2.06	1.06	0.06	2.06	0.06
Fertilizer cost, MK	6991	8739	6339	3939	8003	1253

9.1.3. Female-headed households (SFH)

Models of female-headed households in Southern Region with varying access to off-farm employment, land access, subsidy level, subsidy rate after the fertilizer price shock, are presented in Table 9.4. The price shock does not lead to a change in fertilizer use or maize production for the household with good access to *ganyu* employment. With poorer access to off-farm employment the household rents out part of its land in order to maintain its fertilizer demand and rents out even more land as the land constraint is tightened. It remains self-sufficient in maize production by adopting improved maize varieties on part of its land. With further tightening of the land constraint the household starts to buy maize for consumption and the household depends on additional off-farm income for survival and starts to rent in land if such

Table 9.4. SFH: With fertilizer price shock, ganyu access, land constraint and fertilizer input access

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Ganyu labor access, ag. + non-ag. Person-weeks	**15+15**	**15+15**	**5+5**	**5+5**	**10+5**	**15+5**	**15+5**	**15+5**	**15+5**
Land Rental Market, prices	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5	3x1.5
Land constraint, % change in own land	**0**	**0**	**0**	**-10**	**-40**	**-40**	**-55**	**-55**	**-65**
Received subsidized fertilizer, 50 kg bags	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**
Received subsidized improved seed, kg	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Storage loss, %	20	20	20	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100	100	100	100
Fertilizer price, % change	**0**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
Subsidy level, %	**64**	**64**	**64**	**64**	**90**	**90**	**90**	**90**	**90**
Utility (net income – drudgery cost)	9008	7259	27	-6891	-14428	-8980	-16149	-10262	-14873
Total labor, hours	2195	2195	1494	1294	1321	1500	1337	1391	1239
Net income, MK	37981	36233	18956	9310	2529	11412	1702	8286	1470
Land rented in (+)/rented out (-), ha	0	0	-0.065	-0.139	0	0	0	0.055	0.020
Purchase of maize, kg	0	0	0	0	51	400	346	493	509
Buy Local Maize seed, kg	12.0	12.0	11.8	6.6	1.8	7.3	1.8	5.8	2.0
Buy Improved Maize seed, kg (commercial)	0	0	0.1	3.3	5.9	0	3.8	0.2	2.5
Purchase com. Fert. Maize, 50 kg bags	2.17	2.17	2.18	2.18	2.10	1.22	1.39	0	0
Fertilizer cost, MK	6994	8742	8750	8753	8042	4730	5392	538	538

land is available. Receipt of one bag of subsidized fertilizer (90% subsidy) crowds out commercial demand for fertilizer as well as improved maize and does not reduce purchase of maize for consumption.

9.2. Central Region

The simulations for Central Region include tobacco price shocks in addition to the fertilizer price shocks and the other input subsidy simulations in the previous section.

9.2.2. Male-headed land-poor households (CMHLP)

This land-poor household category also depends on access to *ganyu* employment and demands additional land in the land rental market. Even with such access as specified in the models below the models become infeasible if the household does not access any fertilizer subsidies, again demonstrating the vulnerability of land-poor households. We first simulate impacts of the fertilizer and tobacco price shocks on households with access to a "full package" of two bags of subsidized fertilizer and two kg free improved maize seeds, models (1) – (3) in Table 9.5.

Table 9.5. CMHLP: With fertilizer and tobacco price shock and varying subsidized input access

Model	(1)	(2)	(3)	(4)	(5)	(6)
Ganyu labor access, ag. + non-ag. Person-weeks	15+10	15+10	15+10	15+10	15+10	15+10
Land Rental Market, prices	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5
Received subsidized fertilizer, 50 kg bags	**2**	**2**	**2**	**2**	**1**	**1**
Received subsidized improved seed, kg	**2**	**2**	**2**	**2**	**0**	**2**
Storage loss, %	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100
Fertilizer price, % change	**0**	**25**	**25**	**25**	**25**	**25**
Tobacco price, % change	**0**	**0**	**-25**	**-25**	**-25**	**-25**
Subsidy level, %	**64**	**64**	**64**	**90**	**90**	**90**
Utility (net income – drudgery cost)	-602	-7949	-12428	-6569	-11883	-10848
Total labor, hours	3246	2790	2299	2476	2315	2346
Net income, MK	48309	32797	19069	27600	19815	21233
Land rented in, ha	0.16	0.16	0.104	0.093	0.078	0.028
Purchase of maize, kg	0	0	150	223	202	302
Buy Local Maize seed, kg	0.8	0.8	0.8	1.8	0.8	0.8
Buy Improved Maize seed, kg (commercial)	9.8	9.8	8.9	7.7	10.5	7.8
Purchase com. Fert. Maize, 50 kg bags	0.47	0.47	0.19	0	1.06	0.81
Purchase com. Fert. Tobacco, 50 kg bags	1.62	0.85	0.16	0.48	0.24	0.40
Fertilizer cost, MK	11409	11306	7684	3719	6432	6084

We see that the fertilizer price increase did not affect fertilizer demand for maize but reduced the demand for fertilizer for tobacco production. When the fertilizer price increase is combined with the tobacco price reduction, the demand for fertilizer for tobacco production is further reduced and so is the demand for fertilizer for maize and the household starts to demand maize from the market for consumption. The combined effect of both price changes through the cash constraint reduces ability of the household to rent in land and mobilize cash for farm inputs. In all cases the land-scarce household prefers to grow mostly improved maize.

Models (4) – (6) in Table 9.4 show the effect of increasing the subsidy level to 90% and reducing the access to subsidized fertilizer from two to one bag and dropping the free improved maize seed package as alternative “input packages”. Quite surprisingly, the increase in the subsidy level increases tobacco production rather than maize production as commercial demand for fertilizer for tobacco increases while it is reduced for maize. A reduction in access to subsidized inputs from two bags to one bag stimulates commercial demand for fertilizer and seeds for production of improved maize. The free seed package seems to do more harm than good as it crowds out commercial demand for improved seed. This shows that the production effects of modification of the input subsidy package can be quite unpredictable and depend on the effect through the cash constraint where there are important trade-offs between input purchase for future consumption, food purchase for current consumption and drudgery of work in the peak agricultural season. Land scarcity in combination with cash scarcity and limited access to off-farm employment make these households extremely vulnerable to shocks.

9.2.2. Male-headed land-rich households (CMHLR)

Land-rich male-headed households in Cental Region have tobacco as an important cash crop but may also produce maize and rent out land to more land-poor households. In Table 9.6 below we have assessed the impact of the fertilizer and tobacco price shocks while we assume no access to input subsidies and no access to or participation in off-farm employment activities.

In the baseline model before the price shock the household rents out 0.85 ha of its land, produces tobacco and local maize as main crops. Most of the fertilizer is applied on the tobacco while about half a bag only is applied on the maize. After the 25% increase in the fertilizer price, land renting out and maize production is unaffected but the tobacco production and fertilizer purchase for tobacco is reduced by about 25%, leading to less than 10% increase in total fertilizer cost. The additional tobacco price shock leads to a further reduction in tobacco production while land renting out is reduced and local maize is produced more extensively (on more land with less fertilizer) to meet the household food needs. This allows a reduction in total fertilizer cost. This household category thus appears much more robust to these price shocks than the land-poor household category as it does not depend on input subsidies or access to off-farm employment to tackle the shocks.

Table 9.6. CMHLR: With fertilizer and tobacco price shock

Model	(1)	(2)	(3)
Ganyu labor access, ag. + non-ag. Person-weeks	0+0	0+0	0+0
Land Rental Market, prices	2x1.5	2x1.5	2x1.5
Received subsidized fertilizer, 50 kg bags	0	0	0
Received subsidized improved seed, kg	0	0	0
Storage loss, %	20	20	20
Subsidized fertilizer use efficiency	100	100	100
Fertilizer price, % change	**0**	**25**	**25**
Tobacco price, % change	**0**	**0**	**-25**
Subsidy level, %	64	64	64
Utility (net income – drudgery cost)	34190	26645	18020
Total labor, hours	2659	2425	2253
Net income, MK	69820	59220	47928
Land rented in (+)/rented out (-), ha	-0.852	-0.852	-0.725
Purchase of maize, kg	0	0	0
Buy Local Maize seed, kg	14.1	14.1	17.2
Buy Improved Maize seed, kg (commercial)	0	0	0
Purchase com. Fert. Maize, 50 kg bags	0.52	0.52	0.49
Purchase com. Fert. Tobacco, 50 kg bags	2.14	1.57	0.97
Fertilizer cost, MK	13419	14518	12148

9.2.3. Female-headed households (CFH)

For female-headed households in the Central Region we demonstrate the effects of fertilizer and tobacco price shocks, variation in subsidy levels and access, and variation in land access (own farm size). We start with a fairly restricted access to *ganyu* employment of 10 person-weeks of agricultural *ganyu* per year, access to two bags of subsidized fertilizer and 64% subsidy level, and with average own farm size for the group based on our survey findings. The land rental price is kept constant throughout the simulations and so are the storage loss (20%) and fertilizer use efficiency assumptions (same efficiency of subsidized and commercial fertilizer). The model results are presented in Table 9.7.

The fertilizer price increase primarily affects the tobacco production through reduced demand for fertilizer for tobacco while commercial demand for fertilizer for maize is unaffected and so is land renting. The household rents out 0.22 ha of land in both the first two model simulations. With the 25% reduction in tobacco price in combination with the fertilizer price increase, the tobacco production and demand for fertilizer for tobacco are further reduced while maize production still is unaffected and the household has stopped renting out land, indicating a more extensive land use as total labor hours are also reduced.

An increase in the subsidy level from 64 to 90% for the household with access to two bags of subsidized fertilizer causes the household to rent in 0.13 ha of land while reducing fertilizer demand for tobacco but without affecting the seed demand for maize production. A reduction in access to subsidized fertilizer from two to one and zero bags causes the household to stop renting in land and even to rent out land when no subsidized fertilizer is received, while increasing the commercial demand for fertilizer for maize to compensate for the reduction in subsidy access. The reduction from one to zero bags of subsidized fertilizer in addition required an increase in the access to *ganyu* employment for the model not to become infeasible. These changes implied that fertilizer use on maize is unchanged but at the same time there is a reduction in fertilizer use on tobacco. The cash constraint thus causes changes in the land rental market and in tobacco production rather than in maize production.

A reduction in land access by reducing own farm size by 20, 40 and 50% is presented in models (7) – (10). While the household model without access to subsidies still is feasible with a 20% reduction in farm size, it becomes infeasible with further farm size reduction without either providing subsidized inputs or more access to off-farm employment. With access to one bag of subsidized maize, the farm size may be reduced by 50% without the model becoming infeasible. The reduction if farm size results in a switch from local maize to improved maize to facilitate self-sufficiency in maize production on a smaller farm size while the household first rents in more additional land that becomes less feasible as the land constraint is further tightened and land use intensification requires more fertilizer and improved maize as the optimal response. With 50% reduction in farm size and doubling of access to subsidized fertilizer from one to two bags, the household can again afford to rent in more land and grow more local maize and less improved maize with less purchase of additional fertilizer at full commercial price. Participation in the land rental market therefore opens for less intensive maize production.

Table 9.7. CFH: With fertilizer and tobacco price shock and varying subsidized input access

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ganyu labor access, ag. + non-ag. Person-weeks	10+0	10+0	10+0	10+0	10+0	15+0	15+0	15+0	15+0	15+0
Land Rental Market, prices	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5	2x1.5
Land constraint, % change in own land	**0**	**0**	**0**	**0**	**0**	**0**	**-20**	**-40**	**-50**	**-50**
Received subsidized fertilizer, 50 kg bags	**2**	**2**	**2**	**2**	**1**	**0**	**0**	**1**	**1**	**2**
Received subsidized improved seed, kg	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Storage loss, %	20	20	20	20	20	20	20	20	20	20
Subsidized fertilizer use efficiency	100	100	100	100	100	100	100	100	100	100
Fertilizer price, % change	**0**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
Tobacco price, % change	**0**	**0**	**-25**	**-25**	**-25**	**-25**	**-25**	**-25**	**-25**	**-25**
Subsidy level, %	**64**	**64**	**64**	**90**	**90**	**90**	**90**	**90**	**90**	**90**
Utility (net income – drudgery cost)	24127	18604	11244	14098	9798	3305	-1828	-8992	-23611	-7969
Total labor, hours	3048	2910	2755	2811	2639	2023	2153	1940	1685	1967
Net income, MK	66939	59689	49426	52984	46189	29996	28293	18206	0	19557
Land rented in (+)/rented out (-), ha	-0.219	-0.219	0.005	0.132	0	-0.116	0.060	0.198	0.097	0.360
Purchase of maize, kg	0	0	0	0	0	0	0	0	0	0
Buy Local Maize seed, kg	16.8	16.8	16.8	16.8	16.8	16.8	16.8	11.1	3.8	12.1
Buy Improved Maize seed, kg (commercial)	0	0	0	0	0	0	0	3.6	7.4	3.0
Purchase com. Fert. Maize, 50 kg bags	1.13	1.13	1.13	1.13	2.13	3.13	3.13	2.19	2.31	1.18
Purchase com. Fert. Tobacco, 50 kg bags	2.17	1.78	0.99	0.85	0.80	0	0.08	0	0	0
Fertilizer cost, MK	12600	14250	11294	8417	11602	11968	12257	8822	9290	5411

10. Final discussion and conclusions

The key findings from the household models represent rational responses given typical characteristics of smallholder farm households in Central and Southern Malawi given the agro-ecological, technology, market and household characteristics after the input subsidy program was implemented from 2005. We have modeled the situation in 2005/06 and included important changes that took place in the following years up to 2008/09 such as the most important price shocks and changes in the subsidy program. This was a period with fairly stable weather conditions and our models reflect this stability and predictable technology responses. We leave climate risk responses and climate change to future work.

Our key findings are consistent with recent econometric studies that the input subsidy program crowds out commercial demand for fertilizer for maize production. An important benefit from this kind of household modeling exercise is that it allows for strict implementation of *ceteris paribus* assumptions as well as allowing substantial variation in these *ceteris paribus* assumptions as part of a comprehensive sensitivity analysis. We have implemented such robustness assessments to variation in access to labor and land rental market access, land rental market prices, land endowments, post-harvest losses, and efficiency of utilization of subsidized fertilizers for key household types in Central and Southern Regions of Malawi. This gives us confidence in the key findings we summarize below as being of relevance for future policy design in the country.

We do not claim that real households respond exactly like the models predict for several reasons. Real households may not always behave in a rational way or they may have less information or different information than what has been used in these models. Every household also has unique characteristics that lead to unique responses. Models like those used in this analysis are always gross simplifications of reality but given the careful calibration we have gone through, utilizing survey data collected through several survey rounds of the same households, give confidence that the models pick up important aggregate rational responses of typical household groups in the study areas. Such models can never become perfect and the results of simulations must always be interpreted with caution but can nevertheless give interesting, important and sometimes surprising results that can help broaden our economic intuition and understanding of behavior and behavioral responses to policies and shocks.

Some of the key insights from the simulations in the previous chapters are summarized below:

a). Land-poor households are much more vulnerable to price shocks and limited market access than more land-rich households. The share of land-poor households is growing by the day due to population growth and represents one of the biggest future challenges.

b) Access to subsidized inputs can be a safety net for land-poor households that otherwise may come into a destitute situation because of failure to access off-farm employment or to access land through the land rental market.

c) Provision of free seeds of improved maize as part of the subsidy program crowds out commercial demand for improved maize seeds for land-poor households. It is better to ensure availability of improved maize seeds at local market outlets than to provide the seeds for free. Households that are convinced about the benefits of such seeds are able to mobilize the limited cash required to purchase these seeds.

d) Access to subsidized fertilizer is in most cases crowding out commercial demand for fertilizer for maize production but can also crowd in demand for fertilizer for tobacco production. Access to subsidized fertilizer can also stimulate demand for land through the land rental market and/or reduce the supply of land through the land rental market. These potential additional effects have been ignored in earlier econometric studies.

e) Land-rich households are less vulnerable and can do ok without access to subsidized inputs. The subsidy program has aimed to target households with land without considering the farm size. The models indicate that one way of scaling down the subsidy program could be to target only households with farm sizes below one ha or even smaller cut-off point than that. The problem may, however, be that no official reliable record for farm size exists and the family size per unit of land also matters.

f) The challenge that a growing group of near landless or landless do not get access to input subsidies while they are the most vulnerable ones that are most in need if they cannot access alternative employment, may point towards alternative employment creation as a more efficient mechanism to reach the poor and needy than the input subsidy program. The design of such an alternative poverty targeting strategy goes beyond the objectives of this report.

g) Access to *ganyu* employment is crucial for land-poor households who cannot make a living only from farming when the farm size is getting very small. To some extent they may subsist on smaller farms if they can afford to buy fertilizer and improved seeds and do not have access to additional land through the land rental market and cannot get additional *ganyu* employment. Better access to *ganyu* employment induces purchase of maize for consumption and relaxes the incentives to intensify own production *ceteris paribus*.

h) The going prices and transaction costs in relation to selling of crops also contribute to the sluggish supply response for maize and contribute also to the limited maize production response to access to fertilizer and seed subsidies.

i) The tobacco price shock in form of a reduction of the tobacco price by 25% also reduced the profitability of tobacco production and reduced the fertilizer use on tobacco and possibly also on maize because the household becomes more cash-poor. This price shock may also reduce participation in the land rental market.

j) The fertilizer price shock did not affect maize production much because this production is driven by subsistence needs more than profitability of production. There was, however, a stronger effect on tobacco production which was reduced due to reduced profitability and the effect through the cash constraint.

The models developed may be used for further simulations of various kinds. Such simulations may focus on specific changes in agricultural technologies, relative price changes, direct and indirect impacts of input subsidies by inclusion of general equilibrium effects in e.g. maize prices and wage rates. Further extensions could include risk such as weather shocks (droughts) and alternative policy responses to such shocks. This would require further expansion of these simple models and could be implemented in a variety of different ways using different software.

References

Alwang, J., and Siegel, P. B. (1999). Labor shortages on small landholdings in Malawi: Implications for policy reforms. *World Development* 27(8): 1461-1475.

Binswanger, H. P. and Rosenzweig, M. R. (1986). Behavioural and Material Determinants of Production Relations in Agriculture. *Journal of Development Studies* 22, 503-539.

Chibwana, C., Fisher, M. and Shively, G. (2012). Cropland Allocation Effects of Agricultural Input Subsidies in Malawi. *World Development* 40(1), 124-133.

Chibwana, C., Jumbe, C. B. L. and Shively, G. (2013). Agricultural subsidies and forest clearing in Malawi. *Environmental Conservation* 40.01 (2013): 60-70.

Chirwa, E. W., and Dorward, A. (2013) "The Evaluation of the 2008/09 Malawi Agricultural Input Subsidy Programme: Lessons from Implementation. Unpublished report. London: School of Oriental and African Studies.

de Groote, H., Doss, C., Lyimo, S. D., Mwangi, W. and Alemu, D. (2002). Adoption of Maize Technologies in East Africa – What Happened to Africa's Emerging Maize Revolution? Paper presented at the FASID Forum V, "Green Revolution in Asia and its Transferability to Africa", Tokyo, December 8-10, 2002.

Denning, G., P. Kabembe, P. Sanchez, A. Malik, R. Flor, R. Harawa, P. Nkhoma, C. Zamba, C. Banda, C. Magombo, M. Keating, J. Wangila, and J. Sachs (2009). Input Subsdies to Improve Smallholder Maize Productivity in Malawi: Toward an African Green Revolution. Plos Biology 7, 1. www.plosbiology.org

Dorward, A. R. (2002). A Typology of Malawian Rural Households. Working Paper: Institutions and Economic Policies for Pro-Poor Agricultural Growth, July 2002. Imperial College, London; Wye Campus.

Dorward, A. R. (2003). Modelling poor farm-household livelihoods in Malawi: lessons for pro-poor policy. Wye, Ashford, UK, Centre for Development and Poverty Reduction, Department of Agricultural Sciences, Imperial College London.

Dorward, A.R. (2006). Markets and pro-poor agricultural growth: Insights from livelihood and informal rural economy models in Malawi. *Agricultural Economics* 35: 157-169.

Dorward, A., & Chirwa, E. (2011). The Malawi agricultural input subsidy programme: 2005/06 to 2008/09. *International Journal of Agricultural Sustainability* 9(1): 232-247.

Dorward, A. and Chirwa, E. (2009). The agricultural input subsidy programme 2005 to 2008: achievements and challenges. Unpublished manuscript. London: School of Oriental and African Studies.

Dorward, A., Ephraim W. Chirwa, E. W., and Rachel Slater, R. (2010). Evaluation of the 2008/9 agricultural input subsidy programme, Malawi: Report on Programme Implementation. Unpublished Report. London: School of Oriental and African Studies.

Holden, S. T. (1991). Peasants and Sustainable Development: The Chitemene region of Zambia: Theory, Evidence and Models. Unpublished PhD-dissertation. Department of Economics and Social Sciences, Agricultural University of Norway, Ås.

Holden, S. T. (1993). Peasant household modelling: Farming systems evolution and sustainability in northern Zambia. *Agricultural Economics* 9: 241-267.

Holden, S. T. (2013a). Input subsidies and demand for improved maize: Relative prices and household heterogeneity matter! CLTS Working Paper No. 6/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.

Holden, S. T. (2013b). Amazing maize in Malawi: Input subsidies, factor productivity and land use intensification. CLTS Working Paper No. 4/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.

Holden, S. T. and Lunduka, R. W. (2014). Input subsidies, cash constraints, and timing of input supply. *American Journal of Agricultural Economics* 96(1), 290-307.

Holden, S. T. and Lunduka, R. W. (2013). Who Benefit from Malawi's Input Subsidy Program? *Forum For Development Studies* 40(1): 1-25.

Holden, S. T. and Lunduka, R. W. (2010a). Too Poor to be Efficient? Impacts of the Targeted Fertilizer Subsidy Program in Malawi on Farm Plot Level Input Use, Crop Choice and Land Productivity. Report to NORAD. Department of Economics and Resource Management, Norwegian University of Life Sciences.

Holden, S. T. and Lunduka, R. W. (2010b). Impacts of the fertilizer subsidy program in Malawi: Targeting, household perceptions and preferences. Report to NORAD. Department of Economics and Resource Management, Norwegian University of Life Sciences.

Holden, S. T. and Mangisoni, J. (2013). Input subsidies and improved maize varieties in Malawi: -What can we learn from the impacts in a drought year? CLTS Working Paper No. 7/2013. Centre for Land Tenure Studies, Norwegian University of Life Sciences, Ås, Norway.

Holden, S. T., Kaarhus, R. and Lunduka, R. W. (2006). *Land policy reform: the role of land markets and women's land rights in Malawi*. Noragric, Norwegian University of Life Sciences, Ås.

Jayne, T. and Jones, S. (1997). Food Marketing and Pricing Policy in Eastern and Southern Africa: A Survey. *World Development* 25(9), 1505-1527.

Jayne, T. S., Mather, D. and Mghenyi, E. (2010). Principal Challenges Confronting Smallholder Agriculture in Sub-Saharan Africa. *World Development* 38(19), 1384-1398.

Kydd, J. (1989). Maize research in Malawi: lessons from failure. *Journal of International Development* 1, 112-144.

Lipton, M.(2007). Plant Breeding and Poverty: Can Transgenic Seeds Replicate the "Green Revolution" as a Source of Gains for the Poor? *Journal of Development Studies* 43(1), 31-62.

Lunduka, R. W. (2010). Land Rental Markets, Investment and productivity under customary land tenure systems in Malawi. Unpublished PhD-dissertation, Department of Economics and Resource Management, Norwegian University of Life Sciences, Ås, Norway.

Lunduka, R. W., Fisher, M. and Snapp, S. (2012) Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi? *Food Policy* 37(5), 504-510.

Lunduka, R. W., Ricker-Gilbert, J. and Fisher, M. (2013).What are the farm-level impacts of Malawi's farm input subsidy program? A critical review. *Agricultural Economics* 44(6), 563-579.

Mason, N. M., and Ricker-Gilbert, J. (2013). Disrupting demand for commercial seed: Input subsidies in Malawi and Zambia. *World Development* 45, 75-91.

Ministry of Agriculture and Food Security (2008). The 2007/2008 Input Subsidy Programme Review Report. An Internal Review. MoAFS, Lilongwe.

Minot, N., Smale, M., Eicher, C., Jayne, T., Kling, J., Horna, D., and Myers, R.(2007). Seed development programs in Sub-Saharan Africa: A review of experiences. Report submitted to Rockefeller Foundation, Nairobi.

Republic of Malawi and The World Bank (2006). Malawi. Poverty and Vulnerability Assessment. Investing in Our Future. Final draft. Lilongwe.

Ricker-Gilbert, J., and Jayne, T. S. (2010). "What are the Enduring Benefits of Fertilizer Subsidies on Household Well-Being? Evidence from Malawi." Working Paper, Department of Agricultural, Food and Resource Economics. Michigan State University

Ricker-Gilbert, J., Jayne, T. S. and Chirwa, E. W. (2011). "Subsidies and Crowding out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics* 93(1), 26-42.

Ruthenberg, H. (1980). *Farming Systems in the Tropics*. 3rd Edition. Clarendon Press, Oxford.

School of Oriental and African Studies (SOAS), Wadonda Consult, Overseas Development Institute and Michigan State University (2008). Evaluation of the 2006/7 Agricultural Input Supply Programme, Malawi: Final Report. London, School of Oriental and African Studies; March 2008.

Singh, I., Squire, L. and Stauss, J. (1986). *Agricultural Household Models. Extensions, Applications, and Policy.* The World Bank. John Hopkins University Press, Baltimore and London.

Smale, M. and Heisey, P. W. (1994). Maize research in Malawi revisited: an emerging success story? *Journal of International Development* 6(6), 689-706.

Smale, M., Kaunda, Z. H. W., Makina, H. L., and Mkandawire, M. M. M. K.(1993). Farmers Evaluation of Newly Released Maize Varieties in Malawi: A Comparison of Local Maize, Semi-Flint and Dent Hybrids. CIMMYT, Lilongwe, Malawi and Harare, Zimbabwe.

World Bank (2008). *World Development Report 2008*. The World Bank, Washington, D. C.

Zeller, M., Diagne, A. and Mataya, C. (1997). Market Access by Smallholder Farmers in Malawi: Implications for Technology Adoption, Agricultural Productivity, and Crop Income. FCND Discussion Paper No. 35, Food Consumption and Nutrition Division, International Food Policy Research Institute, Washington, D. C.