Norwegian University of Life Sciences (UMB)

Input Subsidies and Demand for Improved Maize: Relative Prices and Household Heterogeneity Matter!

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Centre for Land Tenure Studies Working Paper 06/13

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Relative Prices and Household Heterogeneity Matter![1]

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Abstract

This study uses simple non-separable farm household models calibrated to household, market, farming and policy context conditions in Central and Southern Malawi. The models are used to simulate how household characteristics, design and access to input subsidies affect the demand for improved maize seeds; how increasing land scarcity affects the cropping system and demand for improved maize; and how access to improved maize seeds affects household welfare with varying access to input subsidies. The model simulations demonstrate that a) there is a high risk that access to subsidized improved maize seeds can crowd out commercial demand for improved maize seeds but the effect is very sensitive to household characteristics, market characteristics and relative prices; b) increasing land scarcity increases the demand for improved maize seeds and improved maize facilitates intensification among others through intercropping of maize with legumes such as beans and pigeon peas; c) the welfare effects depend on households' ability to utilize the potential of the improved varieties by combining them with complementary inputs.

Key words: Improved maize varieties, input subsidies, impact on seed demand, land scarcity, intensification, cash constraints, household welfare.

JEL codes: Q12, Q18, Q16.

[1] This research has been financially supported by CIMMYT through the projects "*Measuring the poverty and food security impacts of improved maize in Africa: A combined Econometric and Micro-Economy-wide Modeling Approach*" and "*Identifying socioeconomic constraints to and incentives for faster technology adoption: Pathways to sustainable intensification in Eastern and Southern Africa (Adoption Pathways)*".

1. Introduction

Poverty and hunger alleviation is a core mission of the CGIAR. It is widely believed that widespread adoption of improved varieties developed by CGIAR Centers has had substantial positive impacts on the well-being of impoverished households – directly via impacts on farm profits and household food security; and indirectly via impacts on wages, product prices, and linkages to nonfarm economic activities (Kerr and Kolavilli 1999). However, the empirical evidence of this is limited and large knowledge gaps remain as to the strength of the various links from improved technologies to adoption, production, income and welfare outcomes in form of food security and improved nutrition.

Alene et al. (2009) estimated that more than one million people per year have escaped poverty through adopting improved maize varieties in West and Central Africa since 1990 and credit the work of IITA and CIMMYT for half of this impact. Pauw and Thurlow (2010) show that there can be supply-side as well as demand-side effects from higher crop yields in form of increased availability and improved purchasing power for the poor due to reduced prices.

In this study we attempt to assess the impacts from access to improved maize varieties in Malawi in the context of a large-scale input subsidy program where one of the challenges is to disentangle the effects from access to subsidized inputs from that of access to improved maize technologies. With up to 90% subsidy provided for restricted amounts of basal and top dressing fertilizers, the impacts of improved maize technology also become highly dependent on the access to subsidized inputs. The analysis is complicated by the facts that a) improved seeds of maize and legumes may also be provided with the subsidized fertilizers at no extra cost; b) the subsidized inputs are targeted towards poor smallholder farm households but targeting errors are substantial (Dorward and Chirwa 2011; Holden and Lunduka 2013); c) leakage of subsidized inputs from the official targeting system has resulted in secondary markets for subsidy vouchers and fertilizers (Holden and Lunduka 2013; Holden and Mangisoni 2013); d) the large-scale input subsidy program leads to crowding out of the demand for commercial fertilizer (Dorward and Chirwa 2008; Ricker-Gilbert and Jayne 2011); e) the availability of improved maize seeds is limited such that observed use of improved maize may not reflect the true demand; f) the input subsidy stimulates production and demand for labor in agriculture which may have resulted in higher wage rates and lower maize prices (Ricker-Gilbert and Jayne 2013a, b?); and g) maize is the main food crop in Malawi and is vulnerable to droughts and this contributes to household and national food insecurity. Holden and Lunduka (2013) found that about 60% of the households in their sample from Central and Southern Malawi were net buyers of maize even after the input subsidy program had been introduced at a broad scale and this was based on analyses in years with good rainfall.

Impact assessment is further complicated by rural factor market imperfections, climate risk, and unobservable and observable smallholder household heterogeneity where the majority of rural households in Malawi are net buyers of maize. It would be a suicide exercise to econometrically try to estimate unbiased impacts from improved maize while attempting to control for all the endogenous variables related to the issues explained above as these are likely to be correlated with unobservable household, community, location and time-varying factors. This is a first step towards handling several but not all of the challenging issues stated above through a household modeling approach where facilitating *ceteris paribus* testing of key hypotheses under varying assumptions about household characteristics, technology characteristics, market access characteristics and policy parameters.

The approach is here therefore to use non-separable household models that are calibrated to the conditions facing different aggregate categories of household types derived from a random sample of households from a rural household survey in six districts in Central and Southern Malawi where the large majority of the population in the country is situated. This allows us to simulate impacts based on *ceteris paribus* assumptions, while sensitivity analysis is done by varying these *ceteris paribus* assumptions. The analysis builds on and is integrated with econometric analysis of farm household and farm plot level panel data covering the period 2005/06, 2006/07 and 2008/09 which gives a three year panel data and provides a good basis for identifying reasonable *ceteris paribus* assumptions and experimental variables for simulations. The simulations have focused on three important issues; a) How household characteristics, design and access to input subsidies can affect the demand for improved maize seeds; b) How increasing land scarcity affects the cropping system and demand for improved maize; and c) How access to improved maize seeds affects household welfare/utility with varying access to input subsidies and the sensitivity of these welfare effects to the cash constraint and to food preferences for cassava. The models presented here have not included risk and general equilibrium effects related to the input subsidy program. These issues are left for the follow up work.

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 thereby enhancing household food security in a very cost-effective way.

2. Literature Review

2.1 Poverty and food security in Malawi

Malawi has one of the highest population densities in Sub-Saharan Africa, is among the poorest countries and with an inequality index (Gini) of 0.38. Close to 90% of the population is rural and derives most of its income from rain-fed agriculture and is therefore being highly vulnerable to rainfall variability. RoM and World Bank (2006) estimated that 52% of the population in Malawi lives below the poverty line with 22% being classified as ultra-poor. The poverty is most severe in rural areas and particularly in Southern region where the population density is highest and the largest share of the population lives. The Southern rural region has 40.4% of the total population and 49.7% of the poor while the Central rural region has 38.1% of the population and 33.9% of the poor.

About 50% of the child population is stunted and 22% are severely stunted (RoM and World Bank 2006). Insufficient consumption of food in form of calories is most common in rural areas and in the Southern region. Cereals constitute two thirds of energy consumption and maize represents 93% of the cereal consumption (ibid.). Population growth remains high and particularly so among the poorest segments of the population with average number of children in the poorest decile being 3.5 against 0.9 in the richest decile. The strong seasonality in agriculture related to the uni-modal rainfall with a five months growing season leads to widespread underemployment during most of the year while labor-poor households in particular may face labor shortages in peak seasons, especially during planting time in December/January (Alwang and Siegel 1999). The seasonality in production also leads to seasonal variation in calorie availability and seasonal food shortages. Food shortages at household level coincide with high food prices in the market. There is a tendency that households sell food crops at harvest time at low prices to obtain cash for other needs but then they are forced to buy more expensive food later.

Female-headed households are 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). The most important cash crop, tobacco, is grown by 19% of the male-headed households and 7% of the female-headed households demonstrating the stronger subsistence orientation of female-headed households (ibid.). Our survey data also revealed that although vulnerable female-headed households should have been given priority in the allocation of input subsidies under the Farm Input Subsidy Program in Malawi, the probability that they accessed subsidized inputs was substantially lower than that of male-headed households and they also received smaller amounts in case they received any subsidized inputs (Dorward and Chirwa 2011; Holden and Lunduka 2010b; 2013). Because of the heaviest burden in household chores women have less time for income-generating activities than men, the gender-division of labor is therefore an important driver of gender differences in welfare and access to resources and services. Frequent and widespread shocks contribute to vulnerability and the persistence of poverty but also to a large share of the population "jumping" up and down across the poverty line from year to year. Droughts and large rises in food prices are among the most severe (covariate) shocks while illness and death of family members are the most severe idiosyncratic shocks (RoM and World Bank 2006).

Mussa and Pauw (2011) show a sharp decline in poverty rates over the FISP implementation period from 2005 to 2009 with a reduction from 52 to 39% being below the poverty line and a reduction from 22 to 15% for the ultra-poor. Based on the fact that 85% of the population lives in rural areas and poverty being more common in rural areas they estimated that 96% of the poor live in rural areas. The reduction in urban poverty was from 25% in 2004 to 14% in 2009 comparing to a reduction from 56% to 43% in the same period in rural areas. They attribute a large share of this poverty reduction to the input subsidy program (FISP), even in the urban poverty reduction although FISP targeted rural households. They explain this as three possible effects; first a price reduction effect for maize benefiting urban consumers; second, as a growth in urban industries; and third, as a measurement error due to use of imputed rather than real consumption expenditure data. Mussa and Pauw (2011) emphasize that it is not known how much of this poverty reduction is due to growth and how much is due to redistribution, or how much is due to growth in specific sectors or regions or migration between these. We may add that it is not well known how much of the poverty reduction was due to FISP, how much was due to the fertilizer component of FISP, and how much was due to the improved maize seed component and the adoption of improved maize seeds more widely. Based on our household and farm plot panel data we investigate these issues more in detail by combining econometric analyses and household farm modeling for different categories of farmers.

2.3 Impacts of the input subsidy program

Ricker-Gilbert and Jayne (2011) estimated that one kg of subsidized fertilizer crowded out 0.22 kg of commercial fertilizer. They also indicated that the crowding out effect was stronger for wealthier farmers and in areas with better market access. Mason and Ricker-Gilbert (2013) assess the effects of access to subsidized inputs on commercial demand for improved maize seeds in Malawi and Zambia. They used reduced form estimation of two-year panel data from Malawi (2006/07 and 2008/09) and estimated that one kg of subsidized (free) maize seed reduced the commercial purchase of improved maize by 0.58 kg in Malawi and by 0.49 kg in Zambia. They found limited correlation between access to subsidized fertilizer and subsidized improved maize seeds varying from 26% in 2006/07 to 44% in 2008/09 for the probabilities of getting and only 6% in 2006/07 and 4% in 2008/09 for quantities received. On average 38.6% of the households received subsidized seeds in these two years in Malawi and they received on average 5.7kg. The maize seed packs that were distributed for free in these years were 2kg packs for hybrid maize and 4 kg packs for OPV seeds. They found evidence that districts where the ruling party had won the last election received significantly more subsidized inputs, 1.66 kg extra improved seeds and 13.2 kg extra fertilizer per household.

Holden (2013), using farm plot level panel data for three years (2005/06, 2006/07 and 2008/09) estimated that only half of the farm plots in Central and Southern Malawi that received subsidized fertilizer were planted with improved maize seeds and that yields on plots planted with improved seed were 323kg/ha higher than on plots planted with local maize after having controlled for the difference in fertilizer use and household and land characteristics. Expanding the seed component of the subsidy program to ensure that subsidized fertilizer are combined with improved maize seeds was therefore suggested as one way to enhance the efficiency of the program. The study also found that fertilizer subsidies resulted in land use intensification and a reduction in maize areas, releasing areas for other crops. Holden and Lunduka (2012) found that input subsidies did not crowd out the use of organic manures in Malawi, but rather the opposite, organic manure and inorganic fertilizers were more used as complements than as substitutes.

Lunduka, Fisher and Snapp (2012) studied adoption of improved maize seed in Mulanje district in Southern Malawi and found limited adoption of improved maize varieties. Adoption depended on access to improved seeds through the input subsidy program as the share of improved seeds out of total seed used increased with access to subsidized seed. The subsidized seed therefore crowded out local maize rather than own demand for commercial seed. The share of improved maize also decreased at the expense of local maize with increasing distance to nearest market town, indicating that access to improved maize seeds may be a constraint. Household preferences for local maize due to its easy storage, high flour-to-grain ration and good taste were attributes associated with higher shares of local maize in total seed demand while emphasis on high yields favored hybrid maize and early maturity favored OPV varieties. Cash constraints may explain limited adoption of improved maize as poor households were having a larger share of local maize and the high response to the cheep source of improved maize seed through the subsidy program.

2.4 Rural market characteristics in Malawi

The credit system in Malawi collapsed in 1992-94 when droughts coincided with election promises that lead to high default rates (Zeller, Diagne and Mataya 1998). Credit has since then not been a major device for promotion of food crop production in the country.

Dorward et al. (2003) state that there have been large reductions in real wages from 1980 to the mid 1990s. They also emphasize the high importance of non-price constraints such as poor infrastructure and limited development of the private sector after withdrawal of the state from marketing activities and from provision of financial resources. Goldberg (2011) find that the elasticity of employment is 0.15-0.17 and not significantly different for men and women.

Ricker-Gilbert (2011, chapter 2, PhD-dissertation) found the following labor responses to fertilizer subsidy access: a) Each additional kilogram of subsidized fertilizer acquired by a household causes the average household to supply 9.6% fewer days in the off-farm agricultural labor market; b) The average household that receives subsidized fertilizer only reduces *ganyu*[2] supply by 2.5 days on average. HE therefore concludes that this reduction in labor supply has a limited effect on household income; c) A one kilogram increase in the amount of subsidized fertilizer received on average by households in a community boosts off-farm wage by 0.2%. This implies a 10% increase in the wage if households on average receive one 50 kg bag of fertilizer.

2.5 Earlier household modeling studies in Malawi

Alwang and Siegel (1999) developed a linear programming model to study and explain labor shortages in smallholder agriculture in Southern Malawi. They assessed the multiple constraints that households face in form of land, seasonal labor, cash, food security and subsistence requirements, and limited credit access. They demonstrate why this context can lead to households being “too poor to be efficient” (Holden and Binswanger 1998). Access to off-farm *ganyu* labor is important for households with limited land access who are deficit producers of staple food but this also limits labor availability for agricultural production at peak seasons. They conclude that multiple constraints need to be addressed to enhance rural welfare, including improved access to credit and commodity markets. Provision of free inputs and improved technologies only help in the short run, more holistic solutions are required in the longer run. They also recommend that agricultural research and extension should focus on

[22] *Ganyu* is the local term for informal off-farm employment.

crop rotations and labor-intensive farming systems that require few purchased inputs and spread labor demands more evenly over the year.

Dorward et al. (2004) combined farm household models and a CGE-model for Malawi to assess the potential for pro-poor agricultural growth strategies in the country. They modeled households as expected utility maximizers using a linear expenditure system with constrained resource use and production opportunities in four periods. Market imperfections were captured by a reduction in farm-gate prices, by price uncertainty in food markets, with transaction costs in the labor market for unskilled labor, and no access to credit (missing credit market). They found that own-farm income accounted for less than 50% of income especially for poorer households. Wage rates and maize prices were critically important for real incomes of poor households. Strong interactions were found between maize prices and wage rates, maize production, income and welfare. They used the models to assess 12 different policy scenarios including; universal input subsidies at 10 and 20% levels, universal small input packages with free fertilizer and seed for 0.1 ha, targeted small input packages with free fertilizer and seed for 0.1 ha for poor male and female-headed households, reduction in marketing costs, consumer subsidy on maize, universal cash transfer at beginning of the rainy season, and targeted cash transfer at beginning of the rainy season.

They emphasized growth that could help raise real wage rates, technological change that could directly impact the labor productivity in smallholder agriculture, the need to expand non-agricultural activities as complementary to agricultural growth, and the need for structural change to open for new tradable non-agricultural growth drivers. Transaction costs and liquidity constraints were considered as primary obstacles to create promote market development and growth.

3. Household classification for household modeling

A classification of the rural population in Malawi into more uniform groups can be useful if household characteristics show substantial variation and this variation has important implications for how these households behave as producers and/or as consumers and if also the welfare implications such as poverty levels show large variation. This may for example imply that the impact of access to improved seeds will vary between a land-poor and a land-rich household, a male-headed and a female-headed household, a net seller of maize and a net buyer of maize, etc. Land scarcity and poverty are more severe in Southern Malawi than in Central Malawi in general. We have therefore decided to classify households by region, sex of household head, and by land availability for the larger group of male-headed households. This gives six household groups as is shown in Table 1 by basic household characteristics for the 2005/06 baseline survey from two districts in Central Malawi (Kasungu and Lilongwe) and four districts in Southern Malawi (Chiradzulu, Machinga, Thyolo, and Zomba). These groups and their characteristics are used as a basis for household modeling where the household models are aimed to represent these groups based on their average or median characteristics. Additional simulations are used to further assess the sensitivity of responses to certain intra-group variation such as farm size.

Table 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 2 provides an overview of access to and use of subsidized inputs, improved maize seeds, and expenditure and use of various production inputs. These are also used as a basis for calibrating models, identifying reasonable *ceteris paribus* assumptions as well as selecting and scaling simulation variables.

Table 2. 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
Manure quantity (kg)	1906	2986	2599	439	201	462
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.

4. Household model construction

Households are assumed to maximize utility subject to a set of resource constraints, market access and prices, and preferences. Market imperfections and seasonality are important characteristics to model and causing production and consumption decisions to be non-separable. Table A2 gives an overview of the resource characteristics of the household groups in terms of land availability, livestock endowment, and male and female labor endowment. Table A2 gives average access to input subsidies and input use, costs and *ganju* wage rate in 2005/06.

4.1. Household production

The household survey production data are used to calibrate the production activities by region. There were some systematic differences between the Central and Southern regions in terms of what crops and crop combinations (intercropping activities) that were grown. This distinction is also kept in the models. The crop production activities were as shown in Table 3. We see that some of the intercropping activities were found in Southern region only. They were therefore included only in the models for the Southern region.

Table 3. Crop production activities in Central and Southern Malawi included in household models

Mono-crop ping activities	Intercropping activities Comment	
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		
Rice		

Maize yields were calibrated based on the analysis of farm plot data for maize for three production seasons with good rainfall. 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, propensity score matching methods were used by grouping plot level data into intervals of fertilizer use intensity and by matching on observable plot characteristics. The results of this exercise are presented in Table A1 in the Appendix. There were too few observations with OPV maize to keep it as a separate category so OPV maize was lumped together with the HYV maize and jointly called improved maize. The results are also summarized in Figure A1 in the Appendix. It can be seen that the fertilizer response was fairly linear in fertilizer use intensity with higher yields for improved maize than for local maize. For the model we smoothed the yields into linear functions as shown in Figure A1. 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 activities are specified in Tables A2, A3 and A4 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 among others. Our study did not include detailed labor data collection by crop and season which is a very time-consuming task. The labor tasks were split across 11 time periods of varying length from half a month to three months. Tables A5 and A6 show the specification of cassava, sweet potato, tobacco, groundnut and pigeon pea activities where labor is split by time periods instead of by tasks. Table A7 gives the 2005/06 and 2006/07 crop prices while Table A8 gives the prices used in the models.

For subsidized maize activities we assumed a penalty of 10% lower yield due less efficient fertilizer allocation (late delivery & less optimal use) based on our econometric analysis (Holden and Lunduka 2010a). We have not included tables for the maize activities with subsidized fertilizer. They are available from the author upon request.

4.2. Market imperfections in the models

Market imperfections in Malawi are caused by the basic production relations of tropical agriculture (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 rationed provisions of subsidized fertilizers and seeds, the informal market for fertilizer that is created by leakages of fertilizers from the official subsidy distribution system, 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. More specifically;

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 specified based on observed access to this market
c) Restricted access to off-farm employment in form of agricultural and non-agricultural *ganyu* labor of seasonal character at going seasonal wage rates
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) It is assumed that there is no land market such that the household land constraint is binding. Although this is a restrictive assumption for individual households, local land renting activity is a zero-sum game. A binding land constraint is therefore assumed to be appropriate at household group level.

Table A11 presents the shadow wages and *ganyu* wages used in the models. We assume that up to 50% of *ganyu* income for agricultural work can be used to relax the cash constraint in agricultural production and up to 30% other non-farm *ganyu* income can be used to relax the cash constraint in agricultural production (Holden and Lunduka forthcoming). Buying prices for major food crops are assumed to be 10% higher than the going market prices. A loss of 20% is assumed for consumed crops.

4.3. Household preferences

Households were assumed first to satisfy their basic food requirements and taste preferences for food and other goods. They were assumed to be drudgery averse and drudgery aversion to increase with amount of time households had to work in each time period (Chayanovian specification). Their utility function became a net income function after satisfaction of basic needs and deduction for disutility of labor across time periods. This is the same specification as used by Holden (1991; 1993) except that I have ignored risk in these models. Based on observed production and consumption data, minimum and maximum consumption levels were set for crops like maize, beans, pigeon peas, cassava and sweet potato. Some simulations involved exclusion or limited inclusion of cassava as a staple food crop.

4.4. Household composition, nutrition requirements and labor availability
The archetype households that are modeled are specified in Table A11 with family compositions that include full members based on median figures from our survey sample data.

4.5. Simulations
Base models were developed first and tested for their performance related to observed data in terms of technology choice and input use. The models were sensitive to the severity of the cash constraint as cash availability in the early rainy season is important for input purchases and this also affects the benefits that can be obtained from access to fertilizers and improved maize seeds, including subsidized fertilizers and seeds. The multiple constraint nature of the models revealed highly non-linear responses in many cases and highly variable responses by different household types to changes in the same basic experimental variables. The responses in maize seed demand by type and source of maize seeds are explored first with varying access to subsidized fertilizer for the different household categories. This also serves to complement the findings of Mason and Ricker-Gilbert (2013) that access to subsidized improved maize seeds to a large extent crowds out the demand for commercial maize seeds and the findings of Lunduka, Fisher and Snapp (2012) who found that cash constraints, availability of seeds, and taste preferences also affected seed demand. The following models reveal the importance of multiple constraints faced by heterogeneous household types that can lead to diverse outcomes with crowding out in some cases and no crowding out in other cases.

5. Household model simulation results
Key findings of the simulation models 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 effects of tightening the land constraint on demand for alternative maize seeds and the cropping system. Finally, the third section looks at the welfare (net income/utility) implications of the alternative policy options for selected household types.

5.1. Demand for maize seed simulations
Figure 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).

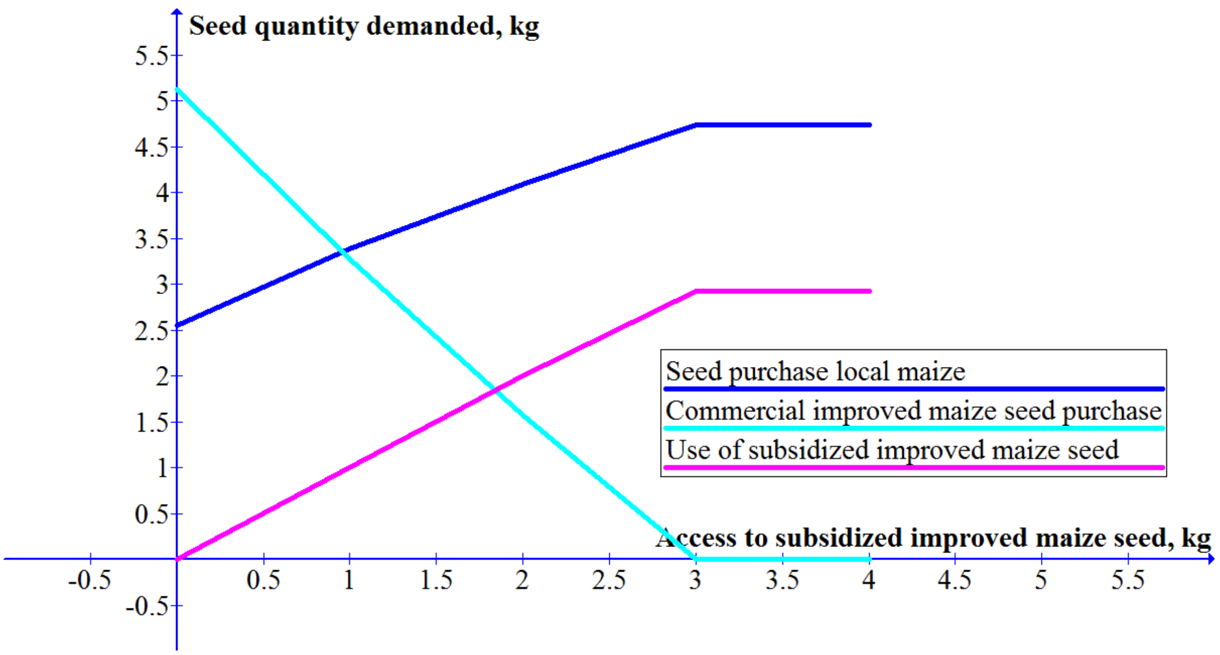

Figure 1. Improved maize seed experiment: Maize seed demand for land-poor male-headed household with good access to *ganyu* employment

Figure 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 are similar to for the previous household, with access to more than 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.

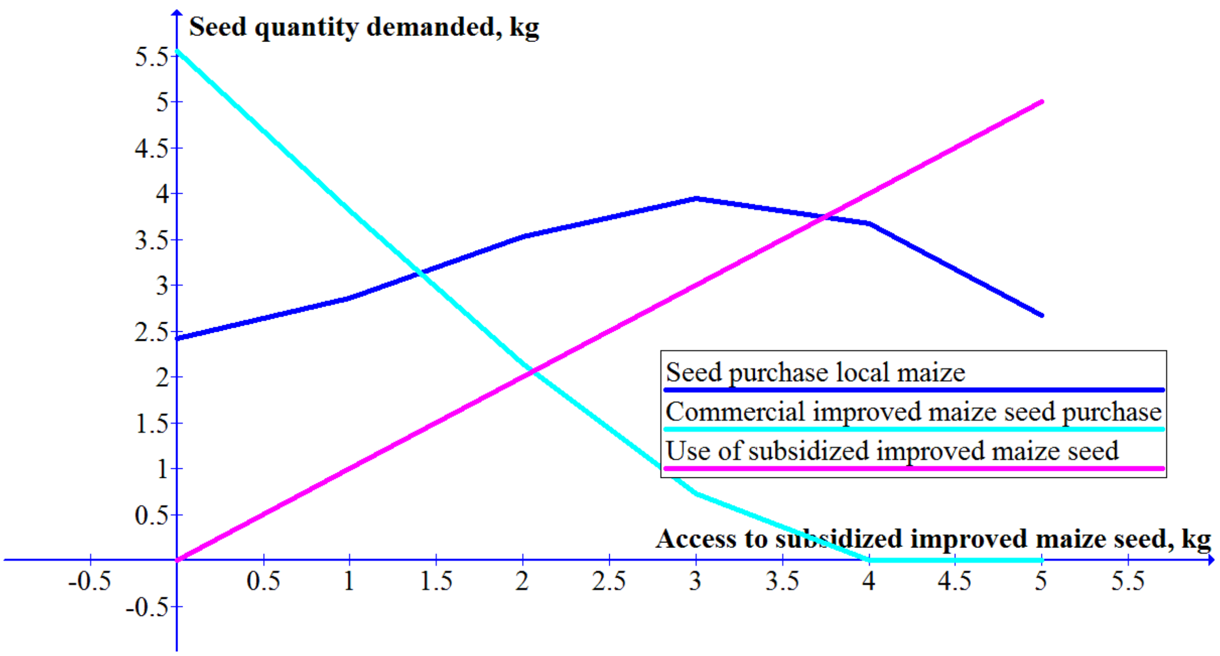

Figure 2. Improved maize seed experiment: Maize seed demand for land-poor male headed household with limited access to *ganyu* employment

Figure 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.

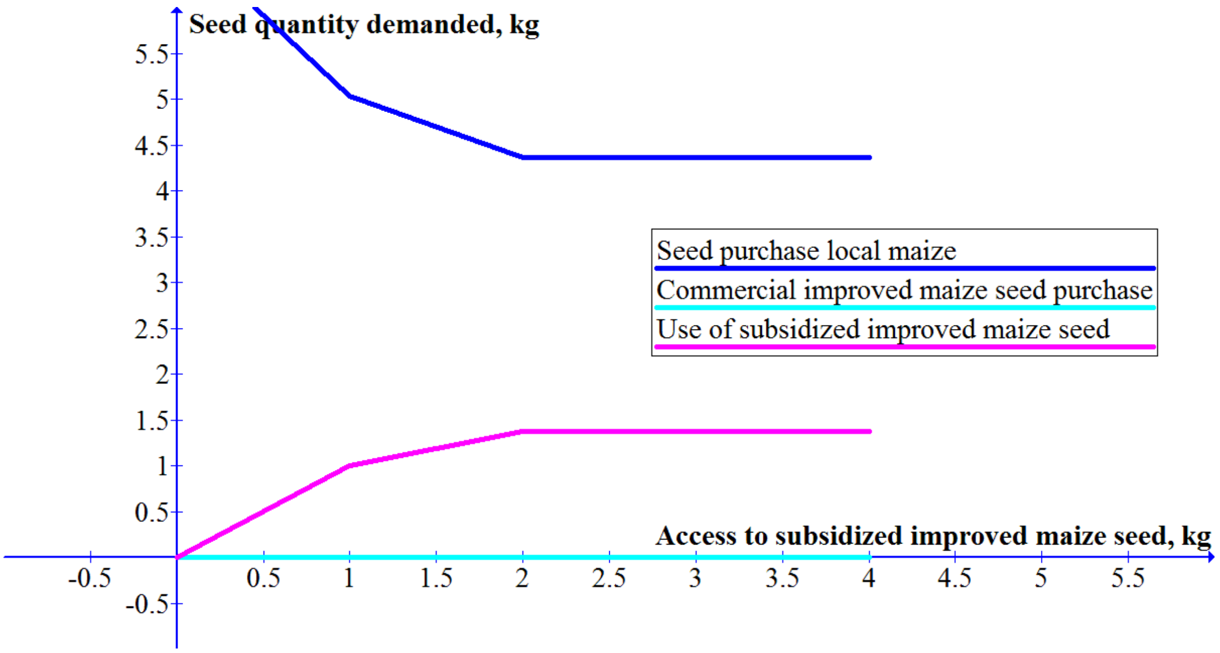

Figure 3. Improved maize seed experiment: Maize seed demand for land-rich household when improved maize seeds are subsidized (150 MK/kg), while commercial price is 500 MK/kg and local maize costs 120 MK/kg.

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 4 makes one change in the model from Figure 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.

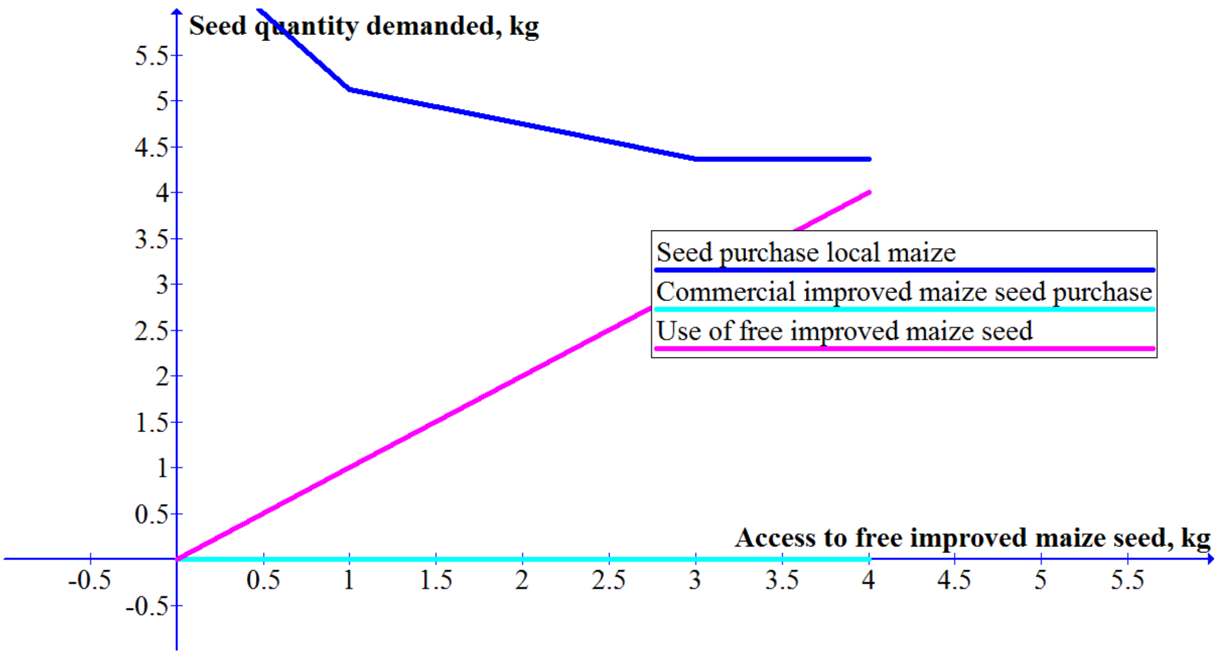

Figure 4. Improved maize seed experiment: Demand for maize seeds by land-rich household in southern Malawi with access to free seeds of improved maize.

Figure 5 illustrates the case of a female-headed household in Southern Malawi, having 0.94 ha of land (Table 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.

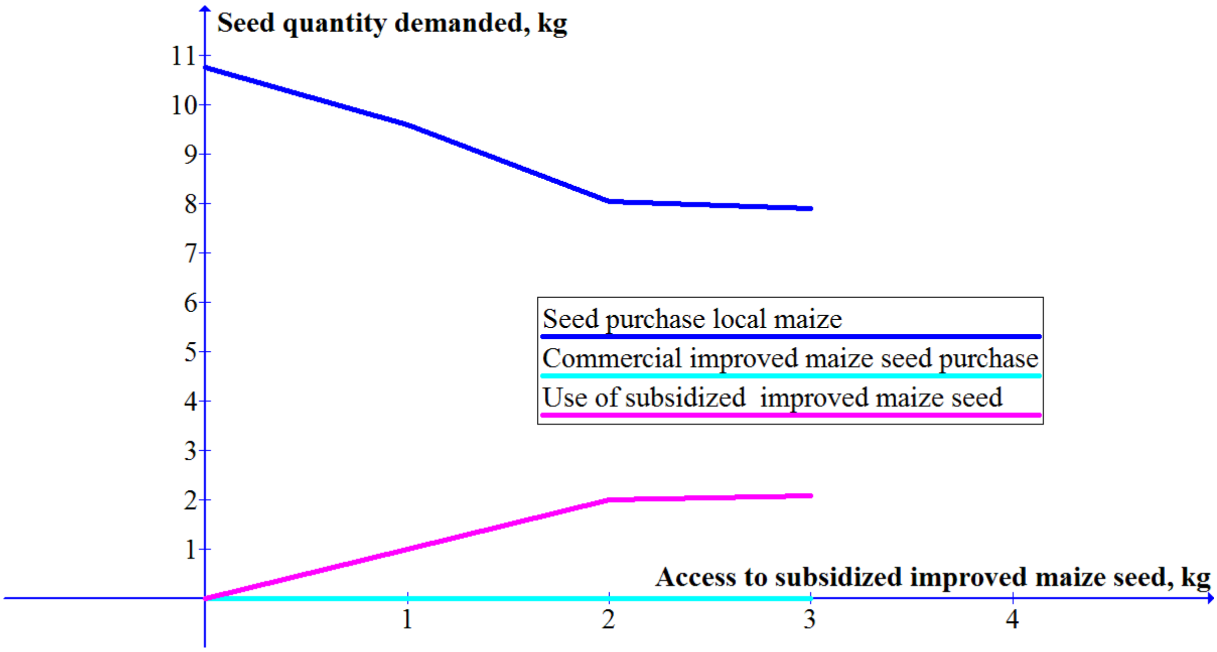

Figure 5. Improved maize seed experiment: Demand for maize seeds for female-headed household in Southern Malawi without access for subsidized fertilizer but with varying access to improved maize seeds at subsidized price (150 MK/kg).

Figure 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 for improved maize seed at commercial price remains zero throughout.

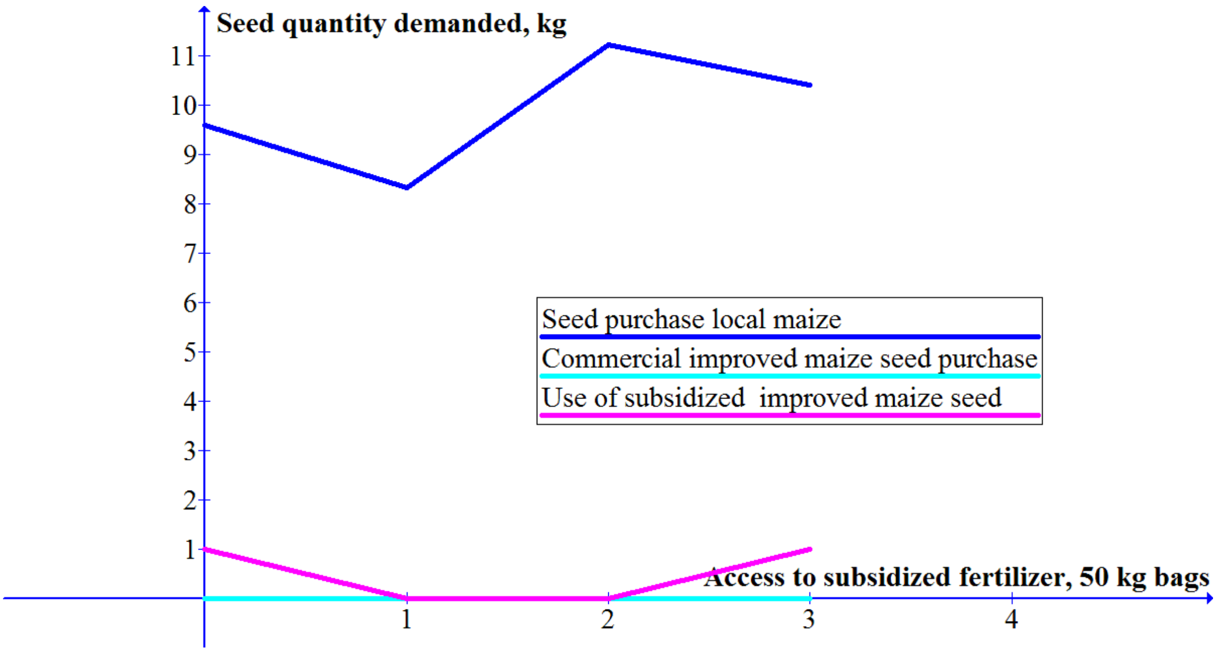

Figure 6. Subsidized fertilizer experiment: Demand for maize seeds for female-headed household in southern Malawi with varying access to subsidized fertilizer (from 0 to 3 bags) and access to 1 kg subsidized improved maize seed (farm size 0.94 ha).

5.2. 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. 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.

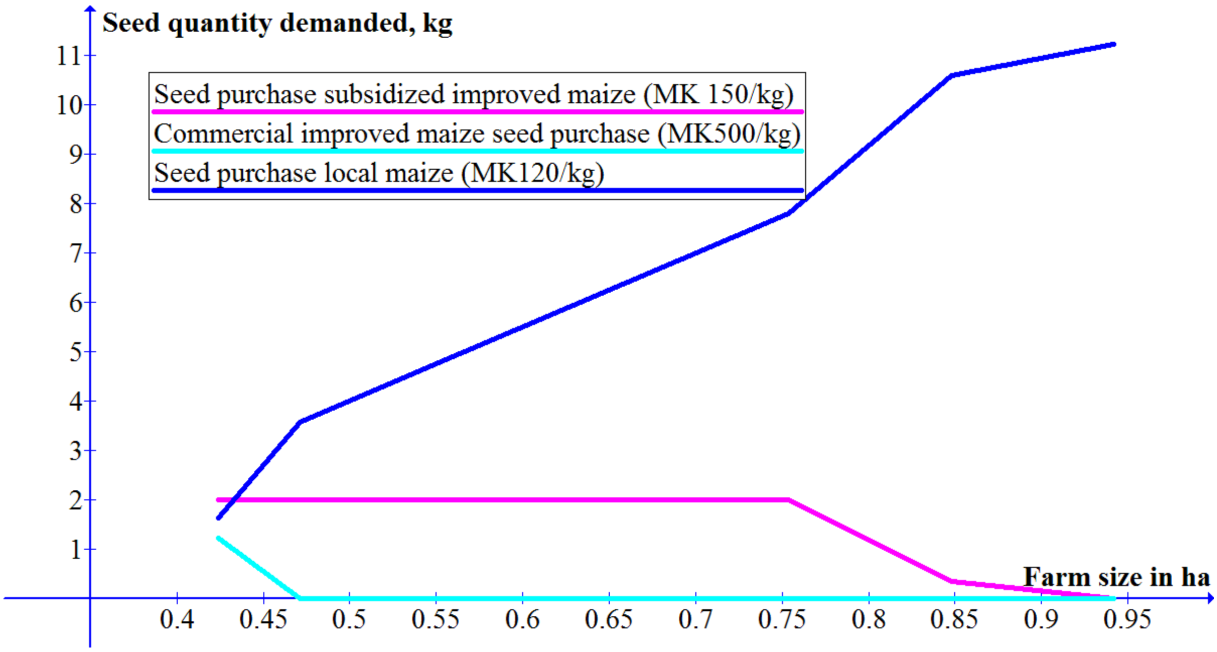

Figure 7. Land constraint experiment: Demand for maize seeds for female-headed household in southern Malawi with access to two bags of subsidized fertilizer and 2 kg improved maize seed when we vary (reduce) the farm size

Figure 8 provides additional insights into the cropping system changes in 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.

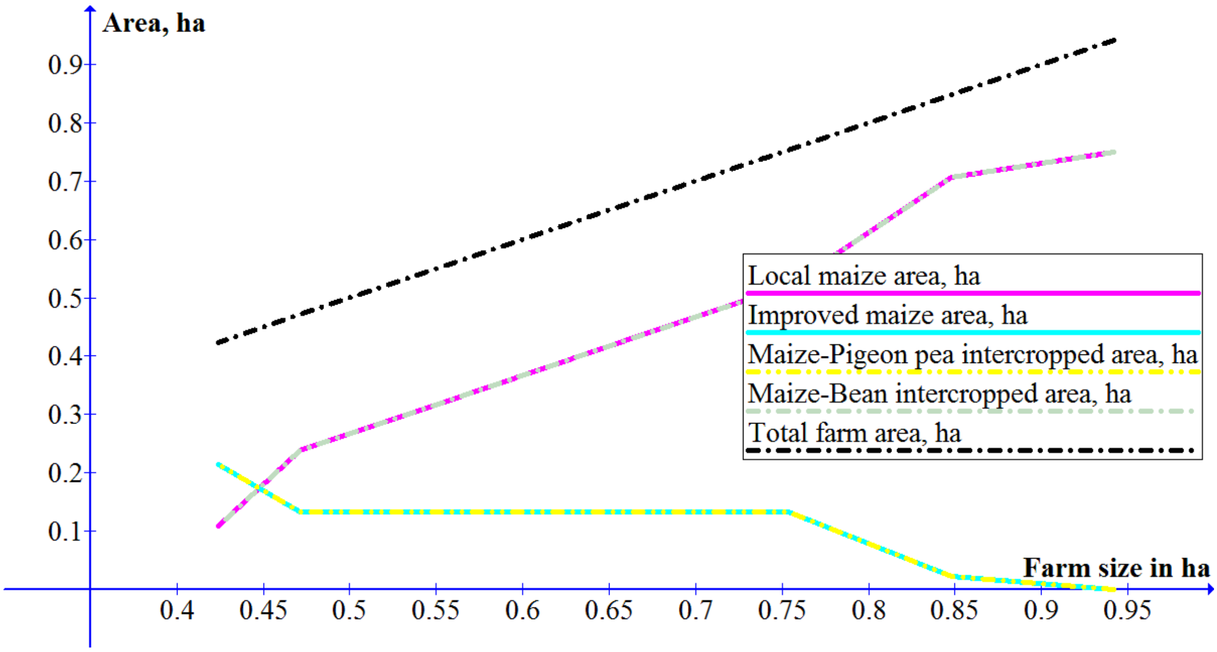

Figure 8. Land constraint experiment: Maize area by type of maize and intercropping for female-headed household in southern

Figure 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.

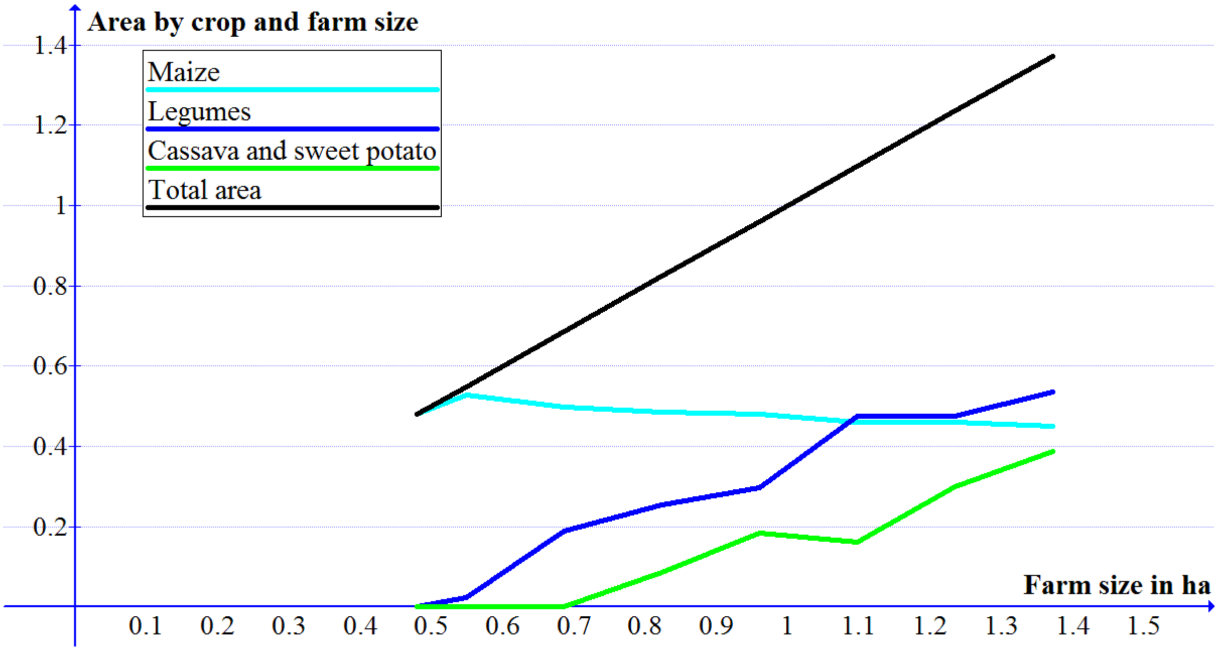

Figure 9. Land constraint experiment: Effect of shrinking farm size on area of maize, legumes and root and tubers for land-rich household in Southern Malawi.

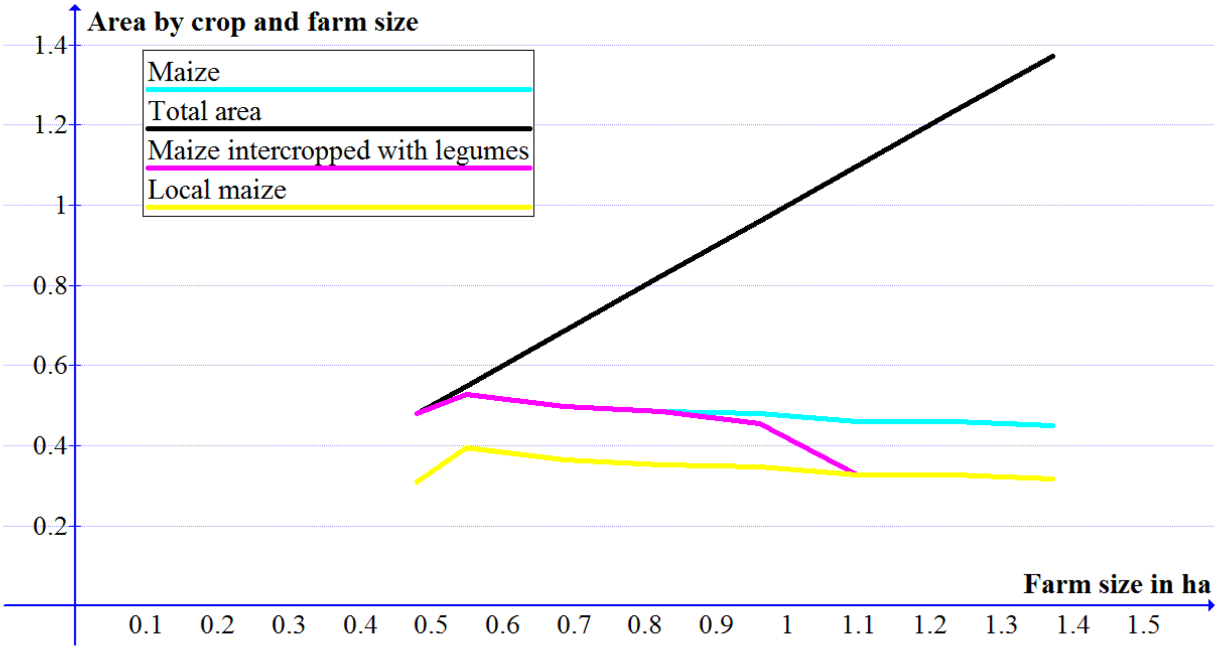

Figure 10. Simulation of maize type and intercropping with shrinking farm size for household in Southern Malawi

5.3. 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 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 measured in net income units in the figure. We see that relatively small adjustments in cash availability at planting time have large impact on output and utility.

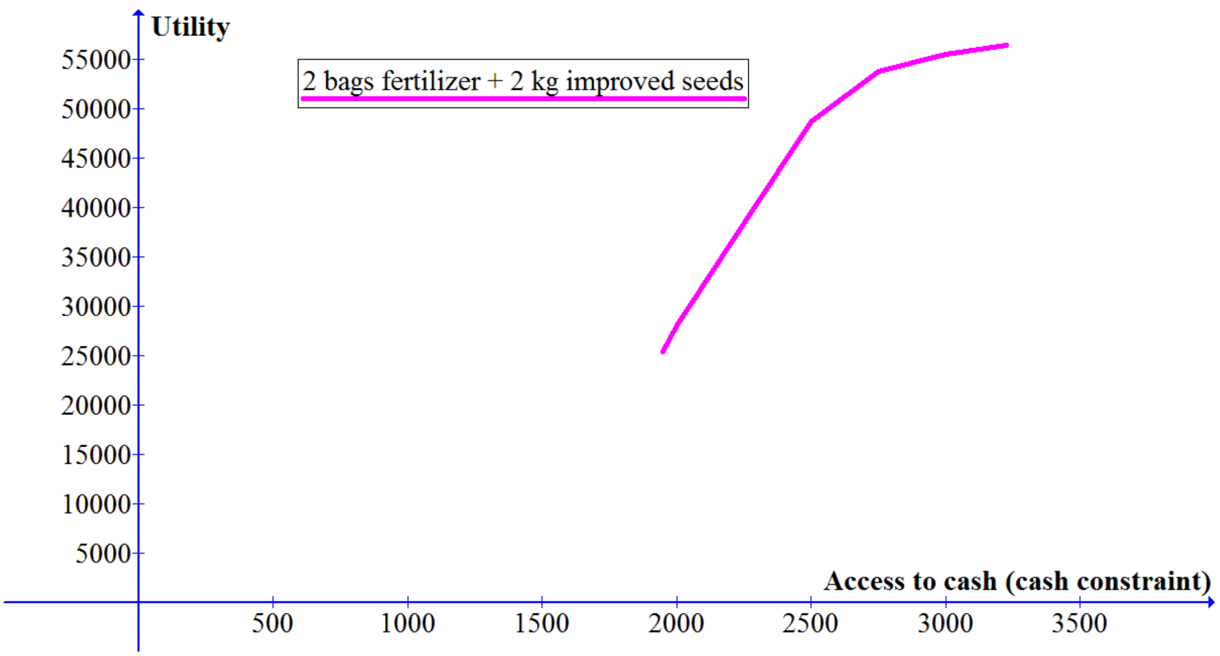

Figure 11. Impact of variation in cash constraint on utility of female-headed household in central Malawi from access to subsidized fertilizer and improved seeds

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 (In press) used choice experiments to demonstrate the impact of this cash constraint and the timing of input supply on the ability to buy inputs.

Figure 12 demonstrates that for a severely cash-constrained household a higher level of subsidy for improved maize seeds can increase the benefit of access to such seeds because scarce cash can be used for complementary inputs that also increase the returns from the improved seeds.

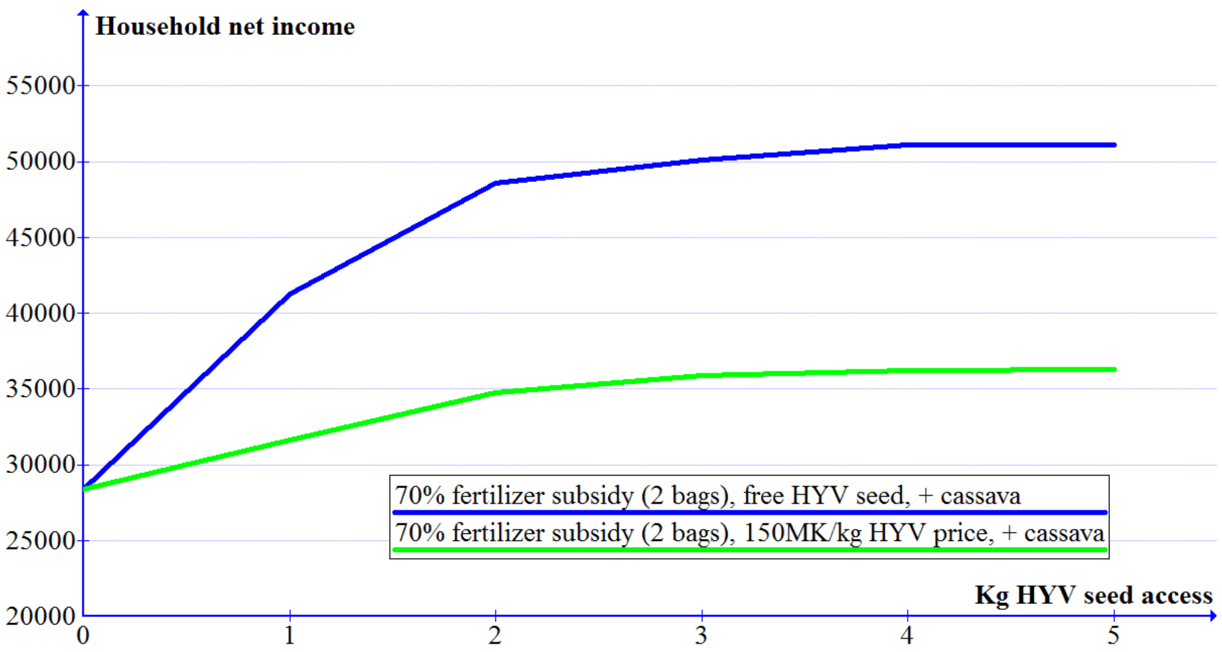

Figure 12. Effect of access to free seeds of improved maize for cash-constrained land-rich household with access to subsidized fertilizer (2 bags) in Southern Malawi.

Figure 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 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.

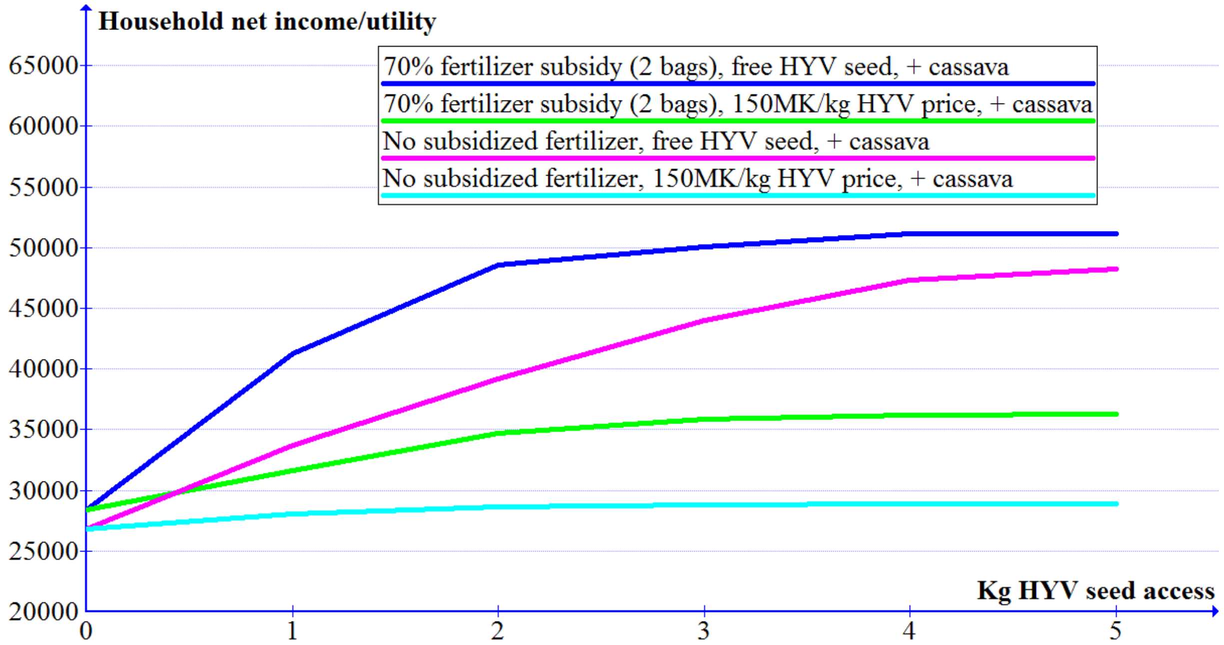

Figure 13. Effect of access to free or cheap improved maize seeds and subsidized fertilizer (2 bags) for cash-constrained land-rich household in Southern Malawi

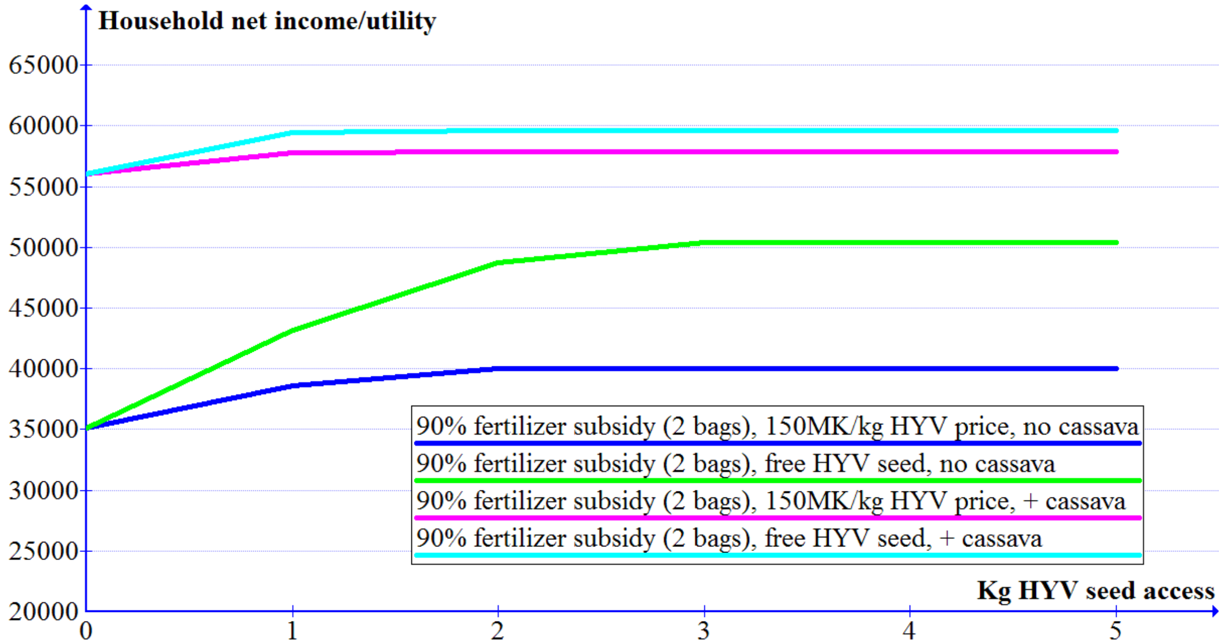

Figure 14. Simulation of the effect of improved maize seed access (free or at subsidized price) for land-rich household in Southern Malawi with and without cassava as a supplementary food crop.

6. Conclusion

The paper 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, and leakage and access to fertilizers through secondary markets. 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 also 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 and the severity of the welfare benefits from such access are also very sensitive to the severity of the cash constraint. 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 types of 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. Important policy lessons. 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.

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Appendix

Table A1. 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.

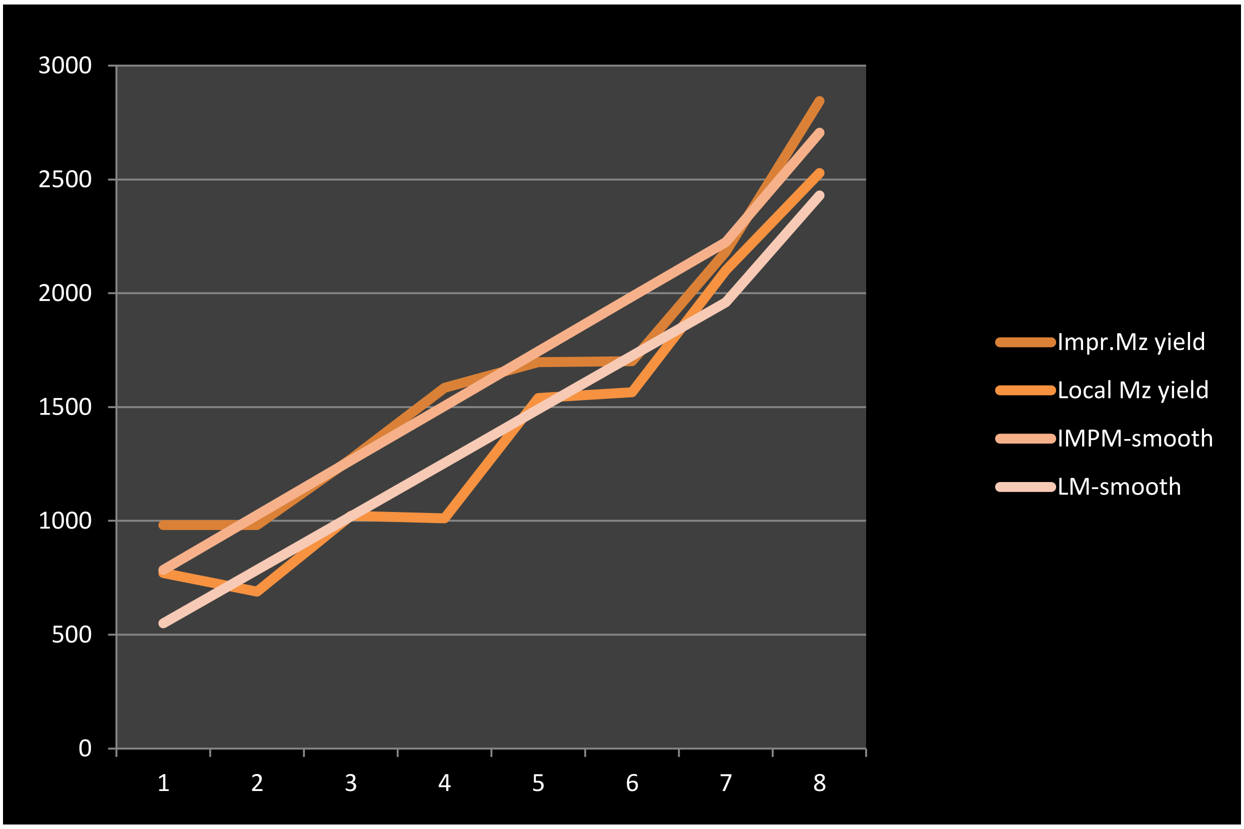

Figure A1. Maize production functions from propensity score matching at different fertilizer intensity ranges (before and after smoothing)

Table A2. 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

Table A3. 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

Table A4. 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

Table A5. 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
Maize/fertilizer ratio									3.2	3.2

Table A6. 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

Table A7. Observed prices for inputs and crops in 2005/06 and 2006/07

PRICES USED IN THE MODELS (2005/06 PRICES)			
INPUTS	UNIT KG	Subs. price	Commercial
FERTILIZER (23-21, Urea)	50	950	3000
Fetilizer (D-comp., CAN)	50	1400	3000
MAIZE SEED, OPV	3	150	500
MAIZE LOCAL	3		120
PIGEON PEA	3	0	150
BEAN	3		150
GROUNDNUT	3	0	150
	Local prices in 2007		
Crops	MWK/kg	MK/100kg	
Hybrid maize (HYV)	20	2000	
OPV	20	2000	
Local Maize	20	2000	
Groundnuts	70	7000	
Tobacco	180	18000	
Cassava	30	1500	
Sweet Potato	30	1500	
Rice	50	5000	
Beans	122	12200	

Table A8. Prices used in the models

Producer Price	MWK/100kg
Beans, dry	9981.508
Cassava	2639.998
Groundnuts, with shell	5548.204
Maize	2689.959
Pigeon peas	6327.845
Sweet potatoes	2700
Tobacco, unmanufactured	12931.79

Table A9. 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

Table A10. 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

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

Table A11. 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						
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
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	0.1038	0.1256	0.22628	0.0582	0.1508	0.3450
Maize fertilizer subsidy access, 50 kg bags	0.65205	0.97032	0.91098	0.46000	1.03385	1.24054

Table A12. Poverty line estimates for Malawi

Measure	MK/person & year
2005 Poverty line	16165
2005 Ultra poverty line	10029
2004: 1 US$/day equivalent	11051

Source: RoM and World Bank (2006, p.10). Based on 1993 PPP conversion factor 1.5221 updated by using Malawi CPI inflation rates from 1993 to 2004.