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Economy-wide effects of input subsidies in Malawi: Market imperfections and household heterogeneity

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Abstract

The potential benefits of providing subsidized inputs to farm-households in developing countries may reach well beyond the targeted households. More specifically, increased food production and demand for rural labor may benefit poor households through lower food prices and higher rural wages. However, two recent studies of a large input subsidy program in Malawi find that these effects are smaller than expected based on anecdotal evidence and previous studies using simulation models. In this paper we provide a potential explanation for this finding by using six farm-household programming models to show how market imperfections limit households' ability to take advantage of cheaper inputs. Our findings suggest that input subsidy programs could be combined with improved market infrastructure and market access in order to increase non-beneficiary households' benefits from input subsidies.

Keywords: Input subsidies, Malawi, Farm-household models

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1 Introduction

Over the past years there has been renewed emphasis on input subsidies as a tool to increase agricultural productivity and food security in developing countries. In 2011, input subsidy programs were in place in 10 African countries, providing inputs such as fertilizer and improved seeds at highly subsidized prices to rural households (Jayne and Rashid, 2013). Malawi's Farm Input Subsidy Program (FISP) is at the forefront of this trend, and has been praised as a model program that could inspire other African countries to replicate its success (Jayne and Rashid, 2013). The program was introduced in 2005, and has since then grown considerably to become a large-scale, national subsidy program. For instance, in 2008/09, 202 000 metric tons of fertilizer were distributed to about 65 percent of rural households[1] at about 10 percent of the commercial price of fertilizer (Dorward and Chirwa, 2011). Contrary to previous, smaller-scale subsidy programs, the goal of the current program is to increase national food security, as well as vulnerable households' food security (Dorward and Chirwa, 2011), through increased access to fertilizer and improved seeds for targeted households, allowing them to boost maize production and increase household incomes (Denning et al., 2009). Due to the large scale of the program, it is also expected to generate economy-wide impacts that affect non-beneficiary households through indirect effects on maize prices and rural wages (Dorward and Chirwa, 2011). Increased maize production may lead to lower maize prices, which would benefit the majority of poor households in Malawi who are net food buyers (Ricker-Gilbert, 2014). Increased maize production may also decrease the off-farm labor supply of poorer subsidy beneficiary households,[2] and increase the demand for on-farm labor among less poor subsidy recipients, leading to an increase in rural wage rates, also benefiting poorer households (Dorward et al., 2008; Ricker-Gilbert, 2014).

Ricker-Gilbert (2014) and Ricker-Gilbert et al. (2013) are the first to quantify these indirect effects empirically and they find that there are relatively small general equilibrium effects from the input subsidy program in Malawi. Specifically, Ricker-Gilbert (2014) estimates that an average increase in access to subsidized fertilizer by 10 kg per household in a community increases the median wage in that community by 1.4 percent.[3] Ricker-Gilbert et al. (2013) find that doubling the amount of subsidized fertilizer in the program only reduces the maize price by 1.2 - 2.5 percent.

[1] The program aimed to provide a package of two 50 kg bags of fertilizer and a bag of improved seeds to targeted households. Targeting was based on land access and poverty/vulnerability (Dorward and Chirwa, 2011).

[2] For instance through increased demand for on-farm work to increase maize production, or through decreased need for off-farm income to cover food deficits.

[3] 10 kg is about 17 percent of the average amount received per household in 2006-2009.

On the other hand, Dorward et al. (2008) simulate access to 50 kg of fertilizer with a 70 percent subsidy and 2 kg of free improved maize seeds for all households, using farm-household models, and find 20-30 percent higher wages and about 25 percent lower maize prices. Similarly, economy-wide impacts estimated using a computable general equilibrium model of Malawi indicate significant spillover effects to non-recipients due to lower maize prices and higher rural wages (Arndt et al., 2013). Qualitative evidence from interviews with recipients also suggest large impacts of the subsidy program at the household level, which were expected to lead to significant economy-wide effects of the subsidy program (Dorward et al., 2008; Chirwa et al., 2011). Dorward and Chirwa (2013) support this, claiming that the indirect effects of the program in terms of reducing poverty could be larger than the direct effects. Similarly, Denning et al. (2009) interpret observed price declines in Malawi during the first years of the program as being caused by the program, and thus evidence of the positive effects of input subsidies on net maize consumers.

We are interested in understanding why the empirically observed general equilibrium effects of the Malawi Farm Input Subsidy Program seem to have been lower than expected, based on previous simulation studies and anecdotal evidence. In particular, we are interested in potential explanations for what appears to be only a modest maize price decrease and a moderate increase in rural wage rates, despite the size of the program, both in terms of the amount of fertilizer distributed and the number of households reached. Our hypothesis is that market imperfections limit households' ability to respond to the subsidy. To investigate this hypothesis, we run a series of simulations using six farm-household programming models representing typical household groups in the Central and Southern regions of Malawi. We show how a combination of market imperfections and variations in household endowments constrain households' response to the input subsidy, and how these constraints may explain why the observed economy-wide impacts of the subsidy program may be small. The contribution of the paper is thus to present potential explanations for the apparent discrepancy between the large impacts described in anecdotal evidence and the small estimated maize price and wage effects based on empirical studies.

We use the farm-household programming models to examine the maize supply response and labor supply- and demand decisions of households to varying levels of access to subsidized fertilizer. The models represent households in an environment with missing and imperfect markets, taking into account transaction costs related to input and output markets, missing land rental markets, constrained access to off-farm employment, seasonality in labor demand and informal (secondary) markets for input coupons and cheap inputs. In line with previous literature on agricultural households in environments with missing and imperfect markets, we find non-linear household supply responses to price changes and access to subsidized inputs. We also find large variations across household groups in their response to input subsidies, and that the response is sensitive to the constraints that the different household groups face as well as their endowments.

Our findings suggest that the size of general equilibrium effects of input subsidies depends on the level of market integration and the heterogeneity of household types to which the subsidy is targeted. Because of constrained market access and large transaction costs related to market participation, even large impacts at the household level may not translate into observable wage- and price effects. A possible policy implication is that input subsidies should be combined with efforts to improve access to input and output markets through investment in infrastructure and market integration in order to increase benefits for poor non-recipient households.

In the next section we present the study context and the motivation for developing the farm-household programming models that are described in detail in Section 3. The simulations and the results are presented in Section 4. We discuss the results and limitations to the analysis in Section 5, and Section 6 concludes the paper.

2 Study context

Malawi is among the poorest and most densely populated countries in Sub-Saharan Africa (World Bank, 2014). Poverty is most severe in rural areas, and particularly in the more populous Southern region where the population density is highest.[4] The majority of the population lives in rural areas and produces maize, which is the most important crop in terms of both production and consumption.[5] Female-headed households are more likely to be poor than male-headed households, with 57 percent of female-headed against 49 percent of the male-headed households living below the poverty line in 2011 (National Statistical Office, 2012). Tobacco, the most important cash crop in Malawi, is cultivated on about 10 percent of male-headed plots, compared to about 3 percent of female-headed plots (National Statistical Office, 2012), which demonstrates the stronger subsistence orientation of female-headed households.

[4]The Southern rural region has about 38 percent of the total population and 63 percent of the poor while the Central rural region has about 36 percent of the population and 49 percent of the poor (National Statistical Office, 2012).

[5]Cereals constitute two thirds of energy consumption and maize represents 93 percent of the cereal consumption World Bank (2007).

Agricultural production in Malawi is strongly seasonal, due to predominately rain-fed agriculture and a single rainy season between November and April.[6] This leads to widespread underemployment during the lean season, while labor-poor households in particular may face labor shortages in peak seasons, especially during planting time in December/January (Wodon and Beegle, 2006). Supplying informal farm labor (*Ganyu*[7]) is an important source of cash income for poor households, and is mainly done out of necessity when food stocks have run out (Whiteside, 2000). Whiteside (2000) also notes that there is a potential conflict between doing *Ganyu* and own farm production, since the time when food stocks normally run out coincides with peak labor demand.

Only a small share of Malawian households have access to formal credit (Diagne and Zeller, 2001), and in 2010/11 about 8 percent of households borrowed for production purposes, and less than half of these from formal lenders (National Statistical Office, 2012). The seasonality in production combined with imperfect credit markets also leads to seasonal food shortages that coincide with high food prices (Ellis and Manda, 2012). Households often sell food crops at harvest time at low prices to obtain cash for other needs, and buy food when stocks run out and food prices are higher before the next harvest (World Bank, 2007). In addition to large seasonal variation in food prices, in particular maize prices, crop markets are characterized by large transaction costs (Jayne et al., 2010).

The land sales and rental markets in Malawi are restricted. Holden et al. (2006) report large transaction costs related to land sales (almost 70 percent of the price), and our survey reveals that there are few sales transactions in the land market among the respondents. The land rental market is somewhat more active, but often influenced by traditional norms for land borrowing that contribute to high transaction costs (Holden et al., 2006). Our survey data indicates that the land rental market is less active in the Southern region where land is scarcer.

2.1 The Farm Input Subsidy Program (FISP)

Input subsidies have been present in Malawi since the 1970s, but were removed in the 1980s under the Structural Adjustment Programs of the World Bank (Harrigan, 2003). In the late 1990s, subsidies were reintroduced under the Starter Pack program, consisting of universal distribution of a small pack of fertilizer and maize and legume seeds (Harrigan, 2008). The program was since scaled

[6] A seasonal calendar of a typical agricultural year is shown in the appendix.

[7] *Ganyu* is often piecework such as weeding or ridging that is paid in kind or in cash. It is traditionally seen as a social obligation for farmers with sufficient food stocks to provide food for work (Whiteside, 2000).

down after donor critique, but following a particularly poor maize harvest in 2004/05, a large-scale input subsidy program, later known as the FISP, was introduced (Holden and Lunduka, 2012). The program aims to target about 50 percent of farmers to receive vouchers that can be exchanged for fertilizer and improved maize seeds (Dorward and Chirwa, 2011).[8] The composition of subsidized inputs has varied over the years of the program, including subsidies for tobacco fertilizer and legume seeds in addition to the "standard" package of two vouchers for 50 kg bags of fertilizer and a voucher for 2 kg of improved maize seeds (Dorward and Chirwa, 2011).

Several studies have assessed the farm-level impacts of the subsidy program in Malawi, including impacts on fertilizer use and displacement of commercial fertilizer purchases (Ricker-Gilbert et al., 2011), cropland allocation (Chibwana et al., 2012),[9] use of organic manure (Holden and Lunduka, 2012), seasonal demand for fertilizer (Holden and Lunduka, 2014), targeting (Holden and Lunduka, 2013) and welfare effects of access to improved maize seed (Bezu et al., 2014). Lunduka et al. (2013) summarize empirical studies of farm-level impacts of the FISP, and conclude that impacts on maize production and yields were small but statistically significant, and that better off households benefited more than poorer households.

Fewer studies have assessed the economy-wide effects of the subsidy program, including the indirect impacts on non-recipient households through maize prices and wages. Dorward et al. (2008) report results from focus group interviews that indicate strong indirect effects of the subsidy program in 2005/06. A combination of good rains and access to subsidized inputs is said to have turned net buyers of maize to become net sellers, resulting in lower maize prices. The seasonal labor surplus when maize stocks normally run out switched to a labor deficit situation where workers became wage setters, leading to higher *Ganyu* wages. Likewise, Chirwa et al. (2011) find decreasing maize prices and increasing *Ganyu* wage rates from 2009 to 2010, leading to an average increase in maize purchasing power by 47 percent, which is supported by statements from focus group interviews. They conclude that this is suggestive evidence of strong indirect impacts of the subsidy program.

Dorward et al. (2008) simulate direct and indirect impacts of the subsidy program in a set of household models, representing household groups in two areas of the Central and Southern regions

[8] The targeting rules have been unclear and subject to local adjustments, and the number of rural households has been debated due to a large discrepancy between the population census data and the household rosters used by the subsidy program (Holden and Lunduka, 2013).

[9] Chibwana et al. (2012) investigate the impact of the FISP on the allocation of land to crop types in Kasungu and Machinga districts through a two-step instrumental variables approach. They find that recipient households on average allocated respectively 16 percent and 46 percent more land to maize and tobacco, and that they allocated less land to other crops.

of Malawi. They find that the poorer households benefit from selling their input vouchers to obtain cash,[10] while less poor households replaced at least some regular fertilizer purchases with subsidized fertilizer. The authors also use these models combined with a partial equilibrium model of the rural economy to simulate the maize price- and wage changes resulting from a universal subsidy, where all households have access to one bag of fertilizer at 70 percent subsidy, and 2 kg of free seeds. They find that the supply of labor from poorer households contracts, because of increased maize production and income from reselling fertilizer, and that there is a small increase in labor demand from land-rich households who have saved input expenses by replacing commercial fertilizer purchases with subsidized fertilizer. The tighter labor market implies 20-30 percent higher wages and increased maize production reduces maize prices by just over 25 percent.

Arndt et al. (2013) investigate impacts of the farm input subsidy program in a computable general equilibrium model of Malawi. They simulate access to the full package of subsidized inputs (2 kg of improved seeds and 100 kg fertilizer) for half of farmers in 2005/06, and find that maize prices decrease as maize supply increases, due to marketing and demand constraints (i.e. export constraints and inelastic domestic demand). The real maize price index decreases by between 2.6 and 4.3 percent, depending on how the subsidy is financed, and the average farm wage increases by about 7 percent. They conclude that the indirect effects of the subsidy constitute as much as two-fifths of total benefits from the subsidy. [11]

Ricker-Gilbert et al. (2013) investigate the impact of input subsidies in Zambia and Malawi on maize prices, using market- and district level panel data. They use price-data from two seasons each year from 2000 to 2011 from 72 markets in 26 districts in Malawi, and estimate the average impact of access to subsidized fertilizer on the maize price using the Arellano-Bond estimator. They estimate the same model using district level data from Zambia. Their results indicate statistically insignificant, or significant but very small effects on maize prices in both countries; doubling the amount of fertilizer to a district decreases maize prices in the district by on average 1.2-1.6 percent. The authors conclude that there is minimal effect of input subsidies on maize prices, and that there is little evidence supporting the claim that large-scale subsidy programs may have large poverty-reducing effects for non-targeted households through reduced food prices. They also conclude that the results are as expected based on previous empirical findings of significant displacement of com-

[10]This finding is not supported by their survey data, where there is little reselling of vouchers, nor by the survey data in Holden and Lunduka (2013) or household fertilizer demand experiments in Holden and Lunduka (2014).

[11]Benefits are measures as change in total real absorption (private and public consumption and investment).

mercial fertilizer purchases, and small household level increases in maize production in response to subsidies, combined with increasing integration of domestic maize markets with international markets.

Ricker-Gilbert (2014) examines the wage and employment effects of the subsidy program. He uses three waves of nationally representative survey data from 2003, 2006 and 2008 from Malawi, and estimates the labor supply and demand decisions of households, controlling for household fixed effects, and a community-level wage equation, controlling for community-level fixed effects. On average, receiving 100 kg more of subsidized fertilizer (i.e. two more vouchers, or doubling the standard package) reduces the number of days of *Ganyu* labor supplied by a household by about 3 days. The author concludes that this is in line with previous empirical findings of small, but significant increases in maize production and welfare for recipient households, and that the reduction in labor supply could be due to a relaxed credit constraint. Ricker-Gilbert (2014)'s findings also suggest a small positive impact of subsidy receipt on the probability of hiring labor. This falls in line with the community level wage results, which show a small, positive effect of increasing household level access to subsidies on the community wage rate. Giving each household access to 10 kg more fertilizer on average increases the wage by 1.4 percent. The author also notes that although there has been a large increase in real wages over the three years of the panel survey, a relatively small share of this increase can be attributed to the subsidy program.

The discrepancy between the findings of the two empirical studies and the predicted economy-wide impacts based on anecdotal evidence and partial- and general equilibrium models requires further investigation. In particular, it is necessary to investigate potential causal mechanisms underlying the indirect impacts of the FISP.

3 Model description

In order to investigate household-level responses to an input subsidy program in a setting with imperfect and missing rural markets, we use a set of partial equilibrium linear programming household models that represent six typical household groups in Malawi. We attempt to take into account important characteristics of rural Malawian households, first by creating a household typology based on survey data, and secondly, by incorporating the constraints we expect to be relevant for household response to an input subsidy.

Table 1: Basic characteristics of household groups

	Southern districts			Central districts		
		Male-headed			Male-headed	
	Female -headed	Land -poor	Land -rich	Female -headed	Land -poor	Land -rich
Share of households in sample (percent)	16	20	22	10	8	24
Land owned (ha)	0.94	0.61	1.37	1.39	0.78	1.97
Household size (median)	4	6	4	5	6	5
Per capita owned land (ha)	0.27	0.10	0.44	0.35	0.13	0.41
Household labor (adult equivalents)	2.6	3.0	2.8	3.2	3.2	3.1
Male labor/ha	2.2	3.5	2.8	1.1	2.8	1.2
Female labor/ha	2.9	2.8	2.1	2.0	2.6	0.9
Share receiving subsidized inputs	0.43	0.53	0.49	0.27	0.54	0.50
Subsidized fertilizer received (kg)	32.6	48.5	45.5	23.0	51.7	62.0
Total fertilizer use (kg)	59	82	114	87	88	153

Adult equivalence weights: male=1, female=0.8 and child younger than 16=0.5

Children younger than 8 are not included.

Source: 2005/06 survey

3.1 Household typology

We base our models on three rounds of survey data collected in 2006, 2007 and 2009. The panel survey covers a random sample of rural households in two districts in Central Malawi (Kasungu and Lilongwe) and four districts in Southern Malawi (Chiradzulu, Machinga, Thyolo, and Zomba), as shown in Figure A2. The sampling strategy and survey design is described in detail in Lunduka (2009). The households differ in their access to land and household labor, and a significant share are female-headed. We categorize households by region, sex of household head, and by land availability for the larger group of male-headed households. More specifically, households with less than median land owned per household member are categorized as land-poor, while those with more than median land available per household member are categorized as land-rich. This categorization of households captures land scarcity when consumption needs and labor scarcity are taken into account. This gives us six household groups, with summary statistics of basic characteristics described in Table 1.

3.2 Mathematical representation

Households are assumed to maximize utility subject to a set of technology and resource constraints. We build on Holden (1993) who models household utility as a weighted income-leisure goal in a Chayanovian (drudgery averse peasant) spirit (Chayanov, 1966). We assume that households derive

utility from what can be seen as a hierarchical utility function, with basic food needs at the first level of preferences, and net income at the second level. The model does not explicitly account for consumption of other goods and non-staple foods, beyond the basic food needs, and we therefore assume that households maximize net income available to purchase such goods. This net income is then weighted against the disutility of labor (drudgery aversion) to reach a "subjective equilibrium" (Nakajima, 1986), capturing the trade-off between labor and leisure. Drudgery is assumed to be increasing in total time use within each seasonal time period. Basic household taste preferences for foods, and subsistence requirements in terms of calories and protein, are captured by a set of separate constraints. Drudgery aversion is captured by seasonal constraints on labor availability and labor requirements across production activities, reflecting the timing of crop production as well as seasonal labor shortages and surpluses. The model is essentially static, but it is time-recursive in the sense that input decisions and initial liquidity constraints affect production decisions. The seasonal disaggregation allows us to take into account missing credit markets, as input purchases must take place before the revenue from crop sales is realized. The model is "non-separable", in line with previous literature on agricultural households with market imperfections (see for instance Singh et al. (1986)), since production decisions are affected by food needs, drudgery aversion and constrained access to cash, seasonal employment and subsidized inputs.
The expression to be maximized is:

$$\sum_{i=1}^{N}(p_i^c q_i^c + p_i^s q_i^s - \mathbf{p^x x_i}) + w^m(l^s - l^h) - \sum_{t=1}^{T} w_t^f (l_t^f + l_t^s) \tag{1}$$

where q_i^c is the amount consumed of crop i, p_i^c is the price at which consumption is valued, q_i^s is the quantity sold, p_i^s is the sales price of crop i, and $\mathbf{p^x}$ is a vector of input prices for the vector of purchased inputs, $\mathbf{x}$. Consumption is valued at a price below the sales price, i.e. $p_i^c < p_i^s$ to reflect a higher weight in the utility function on cash income than on consumption of staple crops, once subsistence constraints are satisfied. w^m is the market wage of labor, l^s is the total amount of labor supplied off-farm and l^h is the amount of labor hired. There are $T = 11$ sub-seasons in the agricultural year described in the model, and the total labor supply of the household in each sub-season, t, is the sum of labor used on the farm, l_t^f and the labor supplied off-farm, l_t^s. w^f is the shadow wage of family labor, defined in equation (10) below.

Equation 1 is maximized subject to a number of constraints. To reflect consumption needs and preferences, we have included constraints on minimum protein and calorie consumption per household member, as well as taste preferences for minimum and maximum consumption of specific crops. A simplified[12] representation of the subsistence and taste constraints is

$$\underline{Q}_i \leq q_i^c \leq \overline{Q}_i \qquad \forall i \tag{2}$$

where $\underline{Q}_i$ is the lower bound on consumption of crop i, and $\overline{Q}_i$ is the upper bound on consumption. For each crop, the following resource balance must hold:

$$q_i + q_i^b - q_i^c - q_i^s = 0 \qquad \forall i \tag{3}$$

where total production and purchases equals the combined consumption and sales. Thus, consumption of crop i consists of consumption of own farm output, (quantity produced of crop i, q_i, minus quantity sold) and quantity purchased, q_i^b. The production technology for each crop is described by

$$q_i = F_i(l_i, \mathbf{x_i}; A_i) \qquad \forall i \tag{4}$$

where l_i is labor input, $\mathbf{x_i}$ is a vector of purchased inputs and A_i is the amount of land allocated to the production of crop i. Variation in input use and access is captured by specifying multiple activities (technology sets) for each crop. We have assumed that the amount of land available for cultivation is fixed, i.e. there is no land rental or sales market.

$$\sum_{i=1}^{N} A_i \leq \bar{A} \tag{5}$$

Total labor input in the production of crop i is the sum of family labor and hired labor in each sub-season, t:

$$l_i = \sum_{t=1}^{T} (l_{it}^f + l_{it}^h) \qquad \forall i \tag{6}$$

l^f is total family labor supplied on-farm in the production of all crops:

$$l^f = \sum_i \sum_t l_{it}^f \tag{7}$$

[12]The nutritional requirements are shown in detail in Holden (2014).

and l^h is the total amount of hired labor

$$l^h = \sum_i \sum_t l_{it}^h \tag{8}$$

Total labor supply (on-farm and off-farm) in each sub-season is constrained by the time available in each sub-season, $\bar{L}_t$:

$$l_t^f + l_t^s \leq \bar{L}_t \tag{9}$$

The shadow value of household labor is increasing in the share of total time used in each sub-season:

$$w_t^f = f\left(\frac{l_t^f + l_t^s}{\bar{L}_t}\right) \tag{10}$$

where $f'(\cdot) > 0$. There is constrained access to off-farm employment in each sub-season:

$$g_t^s \leq \bar{G}_t \tag{11}$$

and constrained access to purchased inputs, including subsidized seeds and fertilizer:

$$\sum_{i=1}^{N} \mathbf{x_i} \leq \bar{\mathbf{x}} \tag{12}$$

In addition, households face a cash constraint,

$$Y + w^m(l^s - l^h) = \sum_{i=1}^{N}(p_i^b q_i^b + \mathbf{p}^x \mathbf{x_i}) \tag{13}$$

where the amount of cash available is defined by an exogenous cash endowment, Y, and net income from labor supply (off-farm labor income net of expenses for hired labor). This covers expenses on crop purchases and purchased inputs for all crops. We assume that the purchasing price of crops is higher than the sales price, due to transaction costs. Note that income from crop sales does not enter the cash constraint, since this income is not available until after inputs and most of the food purchases are already made (see the timeline of a typical agricultural year in Figure A1). Further, to account for seasonality in off-farm employment, income from off-farm employment after the main harvest does not enter the cash constraint. The implicit assumption is thus that there is no credit market.

Table 2: Crop production activities

Monocropping activities	Intercropping activities
Improved maize varieties	Improved maize varieties + beans
Local maize	Improved maize + cassava*
Groundnuts	Improved maize + pigeon peas*
Tobacco	Local maize + beans
Cassava	Local maize + cassava*
Sweet potato	Local maize + pigeon peas*
Pigeon peas	

* Southern districts only

3.3 Model calibration

Plot level data from the household surveys is used to calibrate the production activities by region. The variation in production technologies are captured by introducing multiple activities that may produce the same crops, but vary in terms of fertilizer use, intercropping and use of subsidized inputs. Fertilizer use is varied from zero to relatively high levels, based on the observations in the survey data.[13] Maize production activities include the possibility of intercropping with beans, pigeon peas or cassava. Finally, the use of subsidized inputs was included in separate activities to account for lower fertilizer use efficiency on plots where subsidized fertilizer is used.[14] We allow for some systematic differences between the Central and Southern regions in terms of what crops and crop combinations (intercropping activities) that are grown, in line with findings from the survey data. The crop production activities are as shown in Table 2.

An important aspect of the production technologies included in the model, is that they take into account the seasonality of labor demand in the production of each crop. We divide the year into 11 sub-seasons, with more detailed disaggregation of the peak season. Households are constrained by the total amount of labor available in each sub-season, as shown by equation (9), but also timing of input purchases with respect to income from off-farm labor and crop sales, as shown by the cash constraint in equation (13). The model only explicitly includes consumption of crops that are typically both produced and consumed by the households, which includes maize, beans, groundnuts, pigeon peas, sweet potato and cassava. We further assume that storage loss implies 80 percent utilization of production when crops are consumed on-farm.[15] Any other foods or goods consumed

[13]Details of the calibration are provided in Holden (2014).

[14]Holden (2014) found significantly lower output per kg fertilizer on plots using subsidized fertilizer, which could be due to a number of factors, for instance delays in the distribution of subsidized fertilizer, or less experience with fertilizer use among farmers receiving subsidized fertilizer.

[15]This implies a modification of the resource balance in equation (3), which is omitted for simplicity. Jayne et al.

Table 3: Crop prices used in the models

Producer price	Malawi Kwacha/100 kg
Beans	9982
Cassava	2640
Groundnuts	5548
Maize	2690
Pigeon peas	6328
Sweet potatoes	2700
Tobacco	12 932

Source: 2005/06 survey

by the households are not explicitly modeled, but we interpret the surplus income maximized by the households to be spent on off-farm goods, including additional food.

Households can undertake off-farm work in the period before harvest to obtain cash, but this also reduces the amount of family labor available for work on-farm. Households may also rent in *Ganyu* labor. Based on the seasonality of the labor market in Malawi, we assume constrained access to off-farm employment, as illustrated by equation (11) in the mathematical model representation. Market access constraints also include constrained access to subsidized inputs as illustrated by equation (12), both through formal and informal channels, based on the access observed in the data.

The prices used in the model are summarized in Table 3. We include transaction costs causing price bands for crops and inputs. For crops, the basic assumption is a 10 percent mark-up on purchased crops, and a 10 percent mark-down on the price of crops sold. These marketing margins represent a lower bound on the margins found by Jayne et al. (2010). They find the ratio of farm-gate to local retail price to be as low as 45 percent in certain areas and times of the year, while farm-gate prices were on average 75 percent of local retail prices. The weight on consumption in the utility function, p^c, is set at 10 percent below the sales price, i.e. 20 percent below the prices in Table 3. We vary the transaction costs in the simulations in order to investigate the importance of these for household supply response.

The market wage, w^m, is set to 200 Malawi Kwacha per day, based on the survey data from 2005/06. The shadow wage of the household is constructed as a step-function of the share used of

(2010) report average storage losses of maize at the farm-level in Central and Southern Malawi of 14 percent.

total time available in each sub-season, representing the function in equation (10) by:

$$w_t^f = \begin{cases} 0.5w^m & \text{if } \frac{l_t^f + l_t^s}{\bar{L}_t} \leq 0.7 \\ 0.75w^m & \text{if } 0.7 < \frac{l_t^f + l_t^s}{\bar{L}_t} \leq 0.9 \\ 1.1w^m & \text{if } \frac{l_t^f + l_t^s}{\bar{L}_t} > 0.9 \end{cases} \tag{14}$$

Lastly, the data on access to subsidized inputs through informal channels is taken from the 2008/09 survey, since we do not have this information from the first survey round.

4 Simulations

We are interested in understanding why the observed general equilibrium effects of the Malawian Farm Input Subsidy Program seem to have been lower than expected, based on previous studies using simulation models and anecdotal evidence. In particular, we are interested in potential explanations for the modest maize price decrease and the limited increase in rural wage rates, despite the size of the FISP and the number of households reached. Our hypothesis is that market imperfections constrain households' ability to respond to the subsidy. To investigate this hypothesis, we run a series of simulations in the six linear programming household models described above, with and without market imperfections. We are primarily interested in the net supply of maize and off-farm labor (*Ganyu*) since these are the outcomes that will affect the maize price and the rural wage rate. We first show how the household groups' supply of maize and labor respond to changes in the maize price and the wage, keeping the amount of subsidized inputs fixed. Second, we investigate the impact of varying the access to subsidized inputs on households' supply of maize and labor. Finally, we investigate the sensitivity of these latter supply responses to market imperfections, specifically the transaction costs related to buying and selling maize, the liquidity constraint, and the missing land rental market. The simulations are summarized in Table 4.

Table 4: Simulations

Simulation	Prices	Subsidy	Market assumptions
Maize price change	-15 to 15 percent change from 2005/06 price	2005/06 level	Baseline assumption
Wage change	-15 to 15 percent change from 2005/06 wage	2005/06 level	Baseline assumption
Varying subsidy access	2005/06 level	0-4 50 kg bags of subsidized maize fertilizer	Baseline assumption
Varying subsidy access and reducing transactions costs	2005/06 level	0-4 50 kg bags of subsidized maize fertilizer	Maize market transactions costs reduced from 20 to 10 percent
Varying subsidy and access to credit market	2005/06 level	0-4 50 kg bags of subsidized maize fertilizer	Access to credit: 10 percent of income from crop sales can be used to buy inputs
Varying subsidy and access to a limited land rental market	2005/06 level	0-4 50 kg bags of subsidized maize fertilizer	Access to land rental market with transaction costs, larger transaction costs in Southern region.

4.1 Supply curves for maize and labor

To illustrate the characteristics of the six typical household groups, we vary the price of maize and labor, and look at the response in marketed surplus (which is negative for net buyers) of maize and labor for each household group. The net sale of maize is calculated as the quantity sold less the quantity purchased, i.e. $q_i^s - q_i^b$ in the mathematical model representation. Net labor supplied to the market is calculated as the amount of labor supplied less the amount of labor hired, i.e. $l^s - l^h$. The supply curves of maize and labor for each of the household groups are presented in Figures 1 and 2.[16]

[16]Southern region household groups: S FH = Female-headed, S MHLP = Male-headed land-poor, S MHLR= Male-headed land-rich. Central region household groups: C FH = Female-headed, C MHLP = Male-headed land-poor, C MHLR= Male-headed land-rich.

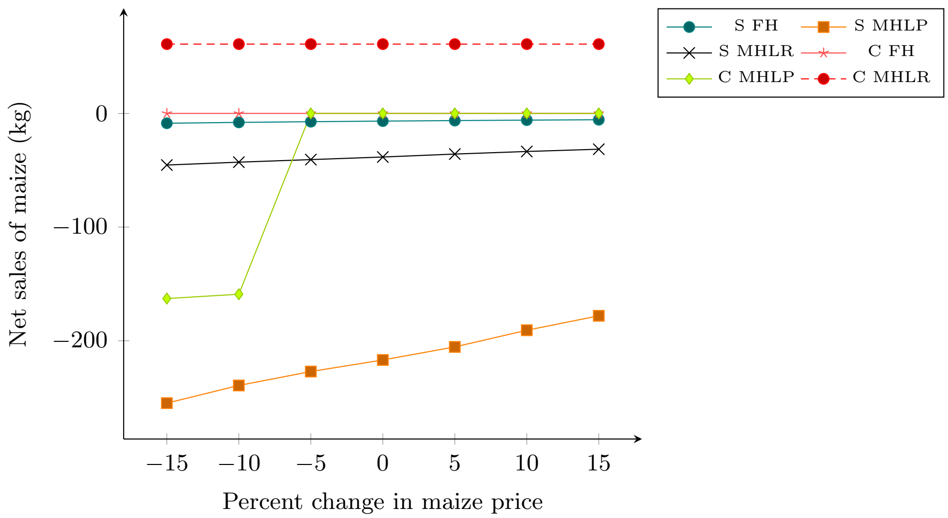

Figure 1: Effect of maize price change on net sales of maize with baseline subsidy level

In the initial situation, calibrated to the 2005/06 data (from now on called the baseline), the three household groups in the Southern region are net buyers of maize, with the largest quantity bought by the male-headed land-poor group. The female-headed group and the male-headed land-poor group in the Central region neither sell nor buy maize, and are self-sufficient. The male-headed land-rich group in this region is a net supplier of maize in the market. The amount of maize purchased by the net buying groups is decreasing in the price of maize, as expected.

As the price drops more than 5 percent below the baseline, the male-headed land-poor group in the Central region switches from self-sufficiency to becoming a net buyer of maize. None of the groups move beyond self-sufficiency and become net sellers over the price range explored in this figure. The amount of maize sold by the net selling male-headed land-rich group in the Central region does not respond to the price variation.

Figure 2 shows that there is little response in labor supply as the wage changes. All household groups except one supply as much labor as possible, under the assumption of constrained access to off-farm employment, and do not rent in any labor. The male-headed land-rich group in the Central region rents in some labor during planting and harvest, and engages in off-farm labor in the lean season. We see that this group's labor demand is decreasing in the wage, as expected, but only marginally. As the wage increases, this group also responds by marginally decreasing net maize sales. The lack of response to the wage change is in line with Goldberg (2010), who finds the labor supply in Malawi to be highly inflexible, while Ricker-Gilbert (2014) finds that a 1 percent increase

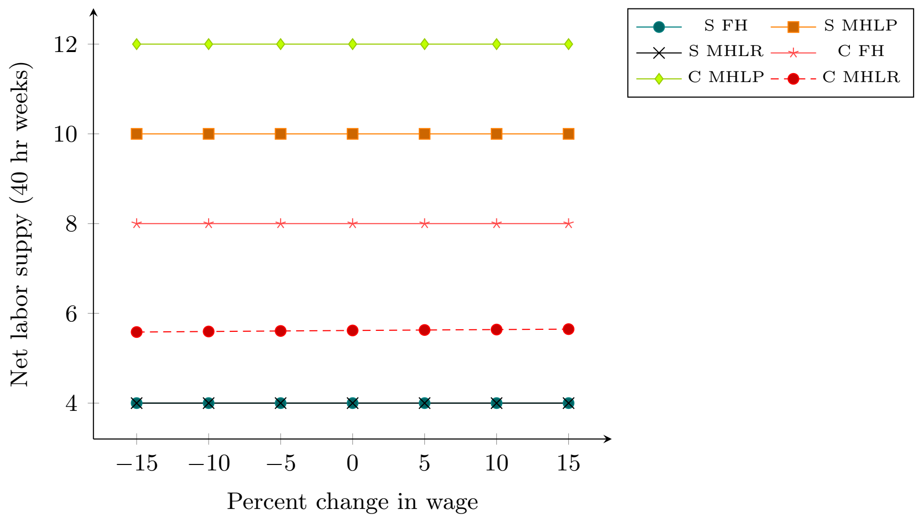

Figure 2: Effect of wage change on net supply of labor to the market with baseline subsidy level

in the median wage in a community decreases the labor supply of *Ganyu*-suppliers, indicating a backward-bending supply curve.

4.2 Effect of access to subsidized maize fertilizer

Next, we study the effect of access to subsidized maize fertilizer (50 kg bags) on the net maize sales of each of the household groups. For simplicity, we have kept access to other subsidized inputs, i.e. seeds and cheap fertilizer through informal sources, fixed at the baseline level. All prices are fixed at the 2005/06 level, not taking into account any price effects of the subsidy. We are thus focusing on the "first round" effect of altering the amount of subsidized fertilizer available to the household groups. Results are reported in Figure 3. We see that giving households the opportunity to buy one bag of subsidized maize fertilizer increases maize purchases for the three household groups in the Southern region, while the remaining household groups are unresponsive to this subsidy level. With access to more than one bag of subsidized fertilizer, both male-headed land-rich household groups and the female-headed group in the Southern region become net maize sellers. However, with 3 or more bags of fertilizer, only the male-headed land-rich group in the Central region is able to take advantage of the subsidy, increasing net sales further. The female-headed category in the Central region is unresponsive to the subsidy, and remains self-sufficient regardless of the amount of subsidized fertilizer available for purchase. Surprisingly, the male-headed land-poor group in this region moves from self-sufficiency to becoming a (marginal) net buyer as access increases beyond two bags of subsidized fertilizer.

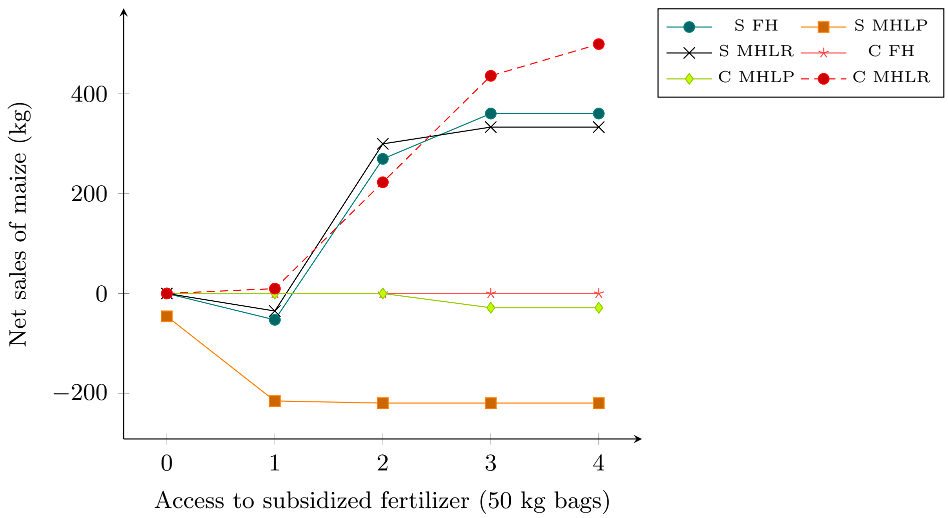

Figure 3: Effect of varying access to subsidized maize fertilizer on net sales of maize with baseline prices

The increase in maize purchases by several of the household groups requires further explanation. As discussed above, giving households access to subsidized inputs may displace commercial input purchases, and thus leave production unchanged. The subsidy would then act as a cash transfer to the targeted households. This could explain why net purchases could increase, reflecting a relaxation of the cash constraint leading to increased leisure or maize consumption (through an income effect) which is in part satisfied through purchasing maize. Further subsidy access allows households to increase maize production and move beyond self-sufficiency.

Based on Figure 4, there does not seem to be much impact of access to subsidized maize fertilizer on labor supply, and no contraction of the labor market. The land-rich household group in the Central region initially hires some labor during peak season, but with access to subsidized fertilizer it decreases its labor demand, i.e. increasing net labor supply to the market. This is despite their increasing maize supply, as they substitute fertilizer for labor in production.[17] The household group thus shifts from more labor-intensive to more fertilizer-intensive maize production. The remaining household groups continue supplying as much labor as possible to relieve their cash constraint. According to this model, these households do not reduce off-farm labor supply, or start renting in labor, rather their adjustment in labor supply is mainly through the amount of family labor employed on-farm.

To understand the mechanisms behind the supply curves above, it is necessary to look at what

[17] The technology set specification facilitates substitution between labor and land through varying the intensity of fertilizer use and choice of improved versus local maize seeds.

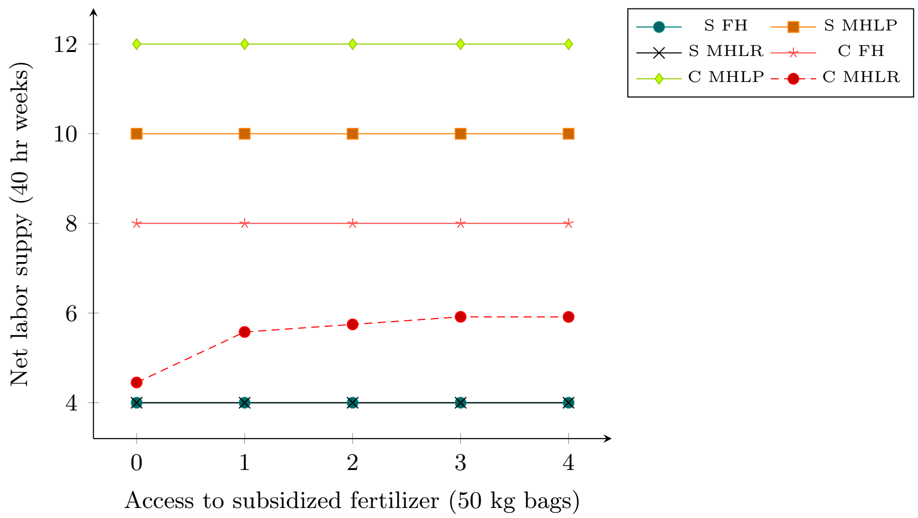

Figure 4: Effect of varying access to subsidized maize fertilizer on net labor supply to the market with baseline prices

happens to total fertilizer use and maize production for each household type. As discussed by Ricker-Gilbert et al. (2011), access to subsidized fertilizer has been found to displace commercial fertilizer purchases, and we do not expect fertilizer use to increase one-to-one with access to subsidized fertilizer.

According to the results presented in Figure 5, total fertilizer use initially decreases or stays constant for the male-headed land-poor groups, while the remaining household groups increase their total fertilizer use. Only the male-headed land-rich group in the Central region increases fertilizer use one-for-one with access to subsidized fertilizer, but not beyond access to three bags of fertilizer. Beyond access to two bags of subsidized fertilizer, there is little change in fertilizer use for the remaining household groups.

If we look at the male-headed land-poor group in the Central region as an example, the effect of access to subsidized fertilizer on relaxing the liquidity constraint of the household seems to be important. Being able to substitute increasingly more of fertilizer purchases with cheap fertilizer relaxes the liquidity constraint such that the household can focus on cash crop production. The household increasingly specializes in tobacco production with increased access to cheap fertilizer, and uses subsidized fertilizer in tobacco production.[18] Since tobacco is relatively more labor intensive than maize, this means increasing on-farm labor use. Access to more than two bags of fertilizer

[18]There is no constraint on the substitutability between fertilizer for maize and for tobacco in our model. The fertilizers distributed through the FISP can be used for tobacco production, while tobacco fertilizer is less suitable for maize.

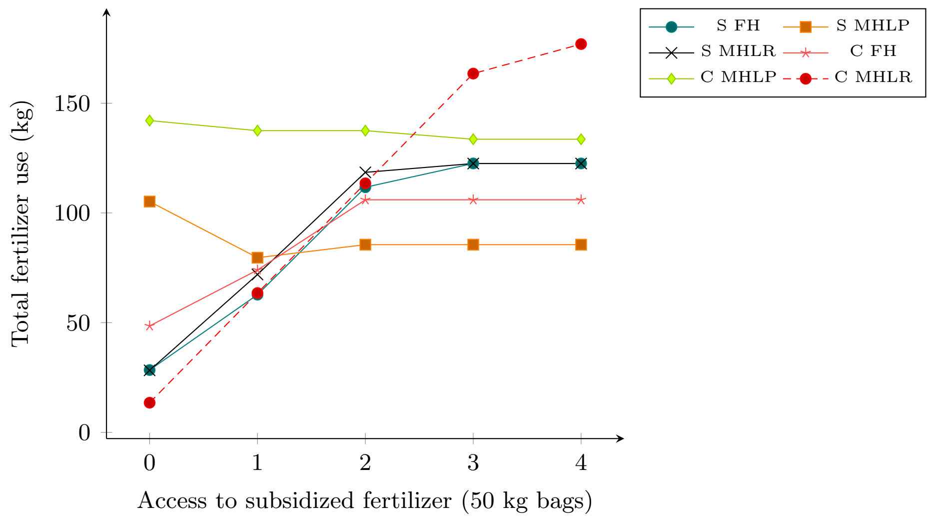

Figure 5: Effect of varying access to subsidized maize fertilizer on total fertilizer use with baseline prices

relaxes the liquidity constraint to the extent that the household can substitute its own maize with purchased maize, and thus decrease fertilizer use marginally, while increasing the area allocated to tobacco.

Looking instead at the male-headed land-poor group in the Southern region, the income effect leads to decreased labor use on-farm and substitution of maize produced on-farm with purchased maize. This response is another example of the impact of relaxing a tight cash constraint. The household spends its extra cash on increasing consumption of leisure, and purchasing maize rather than producing it on-farm with scarce resources. With access to more than one bag, net purchases increase further, but maize production also increases, as the household consumes more maize.[19]

Based on these results, it could be possible for the maize price to increase rather than decrease in response to subsidizing inputs, depending on the targeting and scale of the program. The subsidy could also have impacts on crops other than maize, for instance tobacco. We find that changing the price of fertilizer relative to other inputs, combined with a missing credit market, constrained access to off-farm labor, and transaction costs, create unexpected responses to introducing subsidized inputs for five of the six typical household groups.

[19]The utility function in the models does not give any incentive to increase food consumption beyond subsistence needs, but taste preferences may create incentives for substitution between food crops as long as minimum calorie and protein consumption is satisfied.

4.3 Effect of market imperfections on supply response

To investigate the importance of the market imperfections we have included in our models, we relax the assumptions concerning market imperfections in turn and look at the household groups' response to increased access to subsidized maize fertilizer. The figures below should thus be compared to Figures 3 and 4 above. We focus on three market imperfections that could potentially be mitigated through policy interventions, and that are likely to be important for households' response to the subsidy program: Marketing transaction costs, credit market access and a land rental market.

4.3.1 Maize transactions costs

Figure 6 shows the net supply of maize for each household group when maize transaction costs are removed.[20] The supply response of the female-headed and the male-headed land-rich groups in both regions is stronger than in the case with transaction costs. The net maize sales are larger at all levels of subsidy access, and the female-headed group in the Central region becomes a net seller of maize with access to more than two bags of subsidized fertilizer. As in the case with transaction costs, only the male-headed land-rich group is able to respond to access to more than three bags of subsidized fertilizer. For the male-headed land-poor household groups in both regions, the mechanisms behind their responses are similar to the case with transaction costs, but the lower price on purchased maize makes it possible to increase maize purchases at a lower cost.

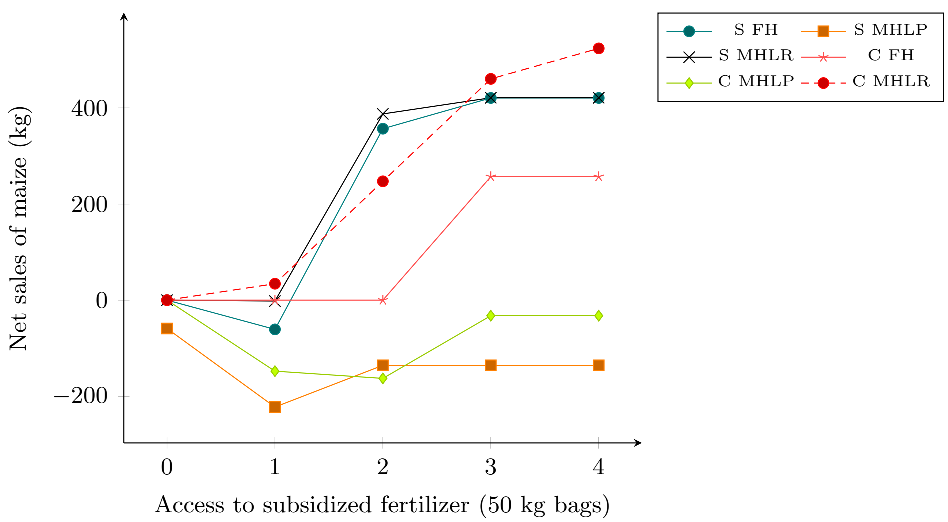

Figure 6: Net maize sales with decreased transaction costs

[20] Compared to the baseline assumption of 20 percent transaction costs.

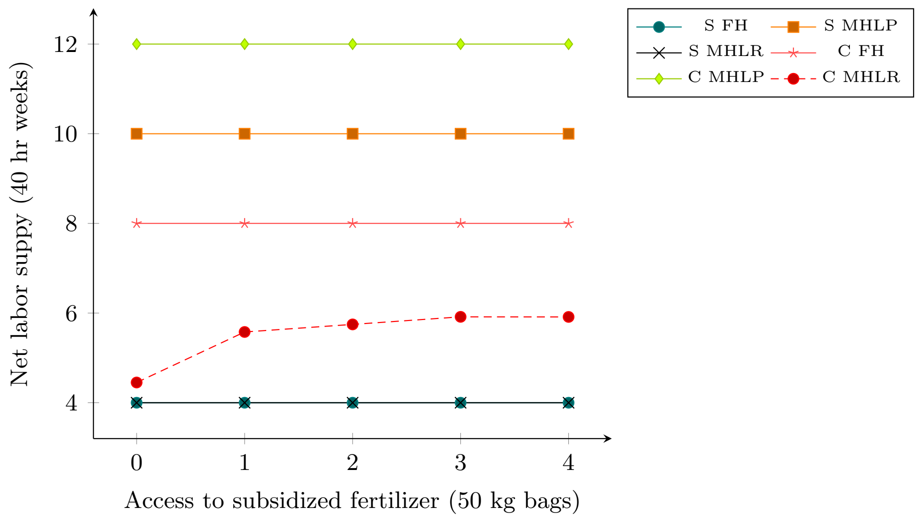

Figure 7: Net labor supply to the market with decreased transaction costs

In Figure 7 we show that there is still no contraction of the labor market in response to varying access to subsidized fertilizer, and that the male-headed land-rich group substitutes its rented in labor with subsidized fertilizer as access to cheap fertilizer increases.

4.3.2 Credit market access

In Figure 8 we show the net supply of maize from each household group with varying access to subsidized maize fertilizer after relaxing the assumption of no credit market. We now assume that households can spend up to 10 percent of their crop sales revenue from harvest time to relax their cash constraint at planting time. The response of the male-headed land-rich groups and the female-headed group in the Southern region is stronger than in the case without a credit market, and both land-rich groups are able to increase net maize sales with access to more than three bags of subsidized fertilizer. The land-poor groups and the female-headed group in the Central region, however, take advantage of access to credit by becoming net maize buyers. The male-headed land-poor group in the Southern region does so to increase maize consumption, while the land-poor group in the Central region increases tobacco production in addition to increasing maize consumption.

An interesting result from relaxing the credit constraint is that all household groups except the male-headed land-poor and the female-headed in the Southern region respond to the subsidy by decreasing their net labor supply, either by reducing their off-farm labor supply or by renting in labor in the peak-season. This is shown in Figure 9, and indicates that the household groups had to work at a high labor cost (drudgery) to meet their basic needs before the constraint was relaxed.

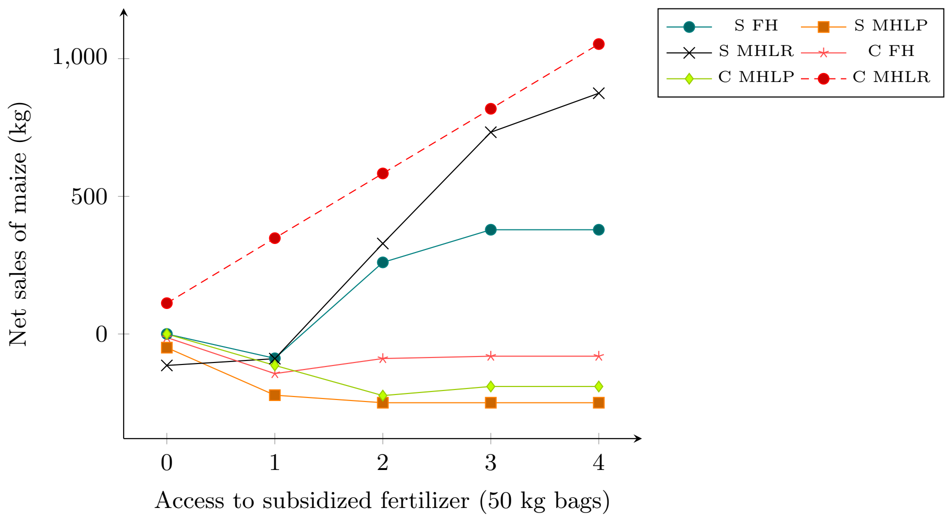

Figure 8: Net maize sales with "borrowing"

The land-rich group in the Central region rents in labor, and more so as the access to subsidized maize fertilizer increases, but it still works off-farm in the off-season.

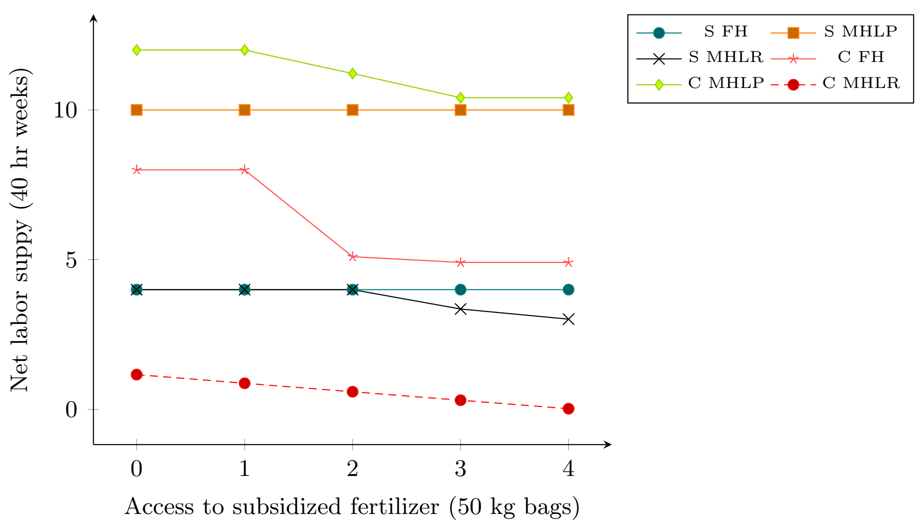

Figure 9: Net labor supply to the market with "borrowing"

4.3.3 Introducing a land rental market

As discussed above, the land rental market in Malawi is limited and largely informal. Heterogeneity in access to land, combined with seasonal labor shortages may constrain households' response to access to subsidized inputs. We relax the assumption of no land market by introducing a land rental market with transaction costs, where the land rental price and transaction costs are assumed to be

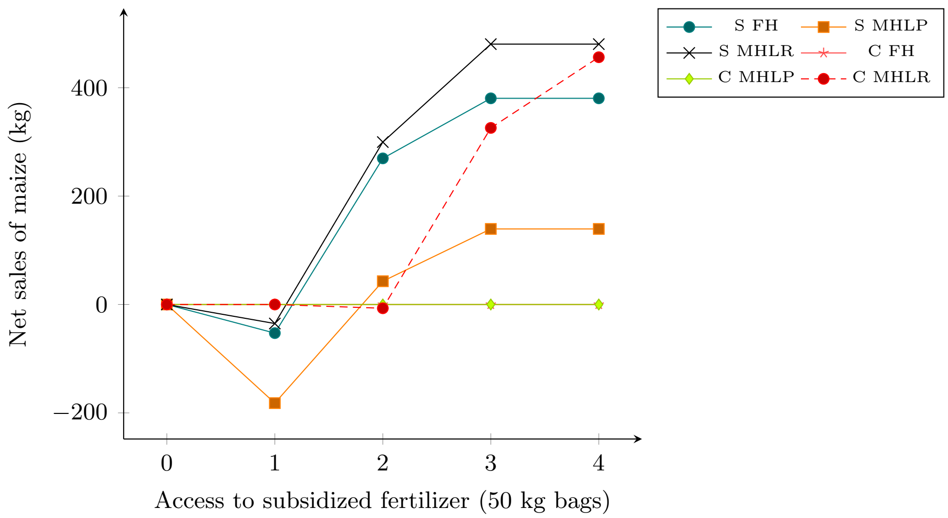

Figure 10: Net maize sales with land rental market

larger in the more land scarce Southern region than in the Central region.[21] We first investigate how this affects net maize sales. As shown in Figure 10, access to a land rental market and more than two bags of subsidized fertilizer turns all household groups, except the female-headed and male-headed land-poor groups in the Central region, into net sellers of maize. The two remaining household groups in the Central region remain self-sufficient when introducing land rental. The land-rich male-headed group in the Central region, however, is less responsive to access to subsidized fertilizer in terms of increasing maize supply when we introduce a land rental market. The household group prefers to rent out land rather than to rent in labor to cultivate their relatively large land area, given the binding cash constraint, and thus remains self sufficient with access to less than two bags of subsidized fertilizer.

Next, we look at the combined effect of land rental and subsidized fertilizer on the labor market. According to Figure 11, the labor market contracts, as the male-headed land-rich group in the Central region starts renting in labor when given access to more than one bag of fertilizer and a land rental market. A similar reduction, albeit marginal, holds for the male-headed land-poor group in the Central region when given access to more than two bags of subsidized fertilizer, but this group is instead reducing its own labor supply.

[21] The assumptions regarding transaction costs and prices in the land rental market are discussed in Holden (2014).

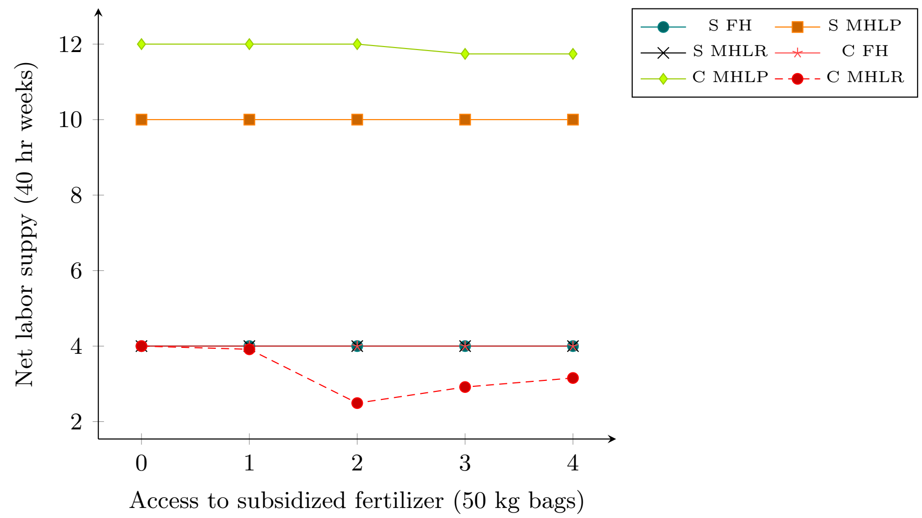

Figure 11: Net labor supply to the market with land rental market

5 Discussion

To summarize the results, both land-rich groups respond strongly to credit market access, indicating that this is an important constraint to expanding maize production for these groups. On the other hand, the land-poor in the Southern region become net sellers only when they gain access to a land rental market and have access to at least two bags of subsidized fertilizer. Relaxing the three market imperfections does not induce the land-poor household group in the Central region to become net sellers of maize, which may be due to the incentives for tobacco production, given that we have kept access to subsidized tobacco fertilizer fixed in the simulations. Both female-headed household groups respond most strongly to the incentives provided by removing transaction costs related to maize trade. For the female-headed group in the Southern region, removing transaction costs is the only measure that induces net maize sales in response to subsidy access, and only with access to more than two bags of subsidized fertilizer.

Our purpose is to investigate potential mechanisms that may explain the small empirically estimated price effects resulting from the subsidy program in Malawi. We will not attempt to aggregate our results to the market level and calculate an equilibrium price resulting from the supply responses observed in our model. That would require a more detailed model of rural markets, while we are mainly concerned with the behavior of typical household groups. However, based on the shares of the population represented by each household group we would not expect a large increase in maize supplied to the market, and thus not a large maize price decrease resulting from the program at the current levels. Likewise, our results on household net labor supply to the market suggest that the rural wage rate is unlikely to increase, they could even indicate the opposite. An important observation from our results is that the supply response of each household group is highly heterogeneous and non-linear. Moving beyond the observed level of the subsidy program, responses are even more diverse and depend on the market characteristics facing the household groups. The empirically estimated wage- and maize price impacts of the program in Ricker-Gilbert et al. (2013) and Ricker-Gilbert (2014) are estimates of the average impact of marginally increasing access to subsidized fertilizer. Based on the model results shown in this paper, extrapolating from these average marginal effects to predict wage- and price effects of a larger scale program could be problematic.

There are several limitations to using farm-household linear programming models to analyze the response to input subsidies. The models represent "average" or typical household groups, based on average characteristics of a large number of heterogeneous households in the survey data. This implies aggregating away much of the heterogeneity across actual households. It also means that it is important to create household groups that have similar characteristics in terms of responding to the input subsidy program, at the same time as being representative. We have not aggregated the behavior of our household groups to predict impacts on the rural maize and labor market. Rather, we consider each household type as an example of a Malawian rural household providing an illustration of potential limits to responding to subsidized inputs in the presence of market imperfections that are prevalent in the rural economy in Malawi.

The models are based on imperfect survey data, which was not collected for the purpose of creating these models. The data on labor supply and demand are particularly weak, as well as the data on food consumption. We have had to make simplifying assumptions, and external data sources were consulted where needed. These assumptions and sensitivity of the models with regards to them are discussed in Holden (2014).

Several assumptions are made in order to create tractable models that are sufficiently detailed to capture important household- and market characteristics, as well as detailed crop production technologies. For instance, we have not included any non-farm income sources or non-farm economic activities. The demand for non-farm foods and goods is treated as a desire to maximize cash income in the utility function of the households. Moreover, there is no uncertainty in the household models, which is obviously a simplification. Exposure to for instance weather risk and price risk is likely to affect household production decisions. For instance, according to Alwang and Siegel (1999), the risk of high maize prices induces subsistence orientation among Malawian smallholders. Incorporation of climate risk is one important area for future expansion of these models.

Nevertheless, the paper shows that this type of household models may be a useful tool to investigate the mechanisms behind results from reduced-form econometric models. Although the models are based on linear programming, they can be used to explore potential non-linear relationships derived from household heterogeneity in ways that econometric models are unable to. While the models have clear limitations in terms of predicting individual household behavior, they allow assessment of plausible responses to specific heterogeneity and to changes in exogenous factors. The results show how multiple market imperfections combined with the characteristics of typical household groups interact to create complex responses to access to subsidized farm inputs. These insights can be combined with the empirical findings on economy-wide effects of input subsidies to explain observed behavior.

6 Conclusion

We have showed in this paper that the maize and labor supply response of households to access to subsidized maize fertilizer is non-linear and dependent on heterogeneity in household groups' resource endowments and market imperfections. Depending on the targeting of the input subsidy and the amount of subsidized inputs received by households, this may explain why the observed general equilibrium effects of a large-scale subsidy program in Malawi are small. First, transaction costs related to buying and selling maize may be too large for households to participate in the market, preventing any impact of increased production on the retail price of maize. Furthermore, households may have constrained access to cash, and thus complementary inputs, preventing them from taking advantage of the subsidized inputs to increase production. Finally, subsidized inputs may serve to relax the cash constraint of households rather than increasing production. This final effect may, as we have seen, induce households to increase purchases of maize rather than supply. All these effects reduce the impact of the subsidy program on maize prices.

We find that relaxing the credit constraint and reducing transaction costs related to maize marketing could increase the supply response to input subsidies. This means that combining input subsidies with credit arrangements for smallholders, and improving infrastructure to reduce transaction costs could contribute to indirect effects that would benefit poor non-targeted households. The results also indicate that an improved land rental market could increase the supply response of some households.

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Appendix A

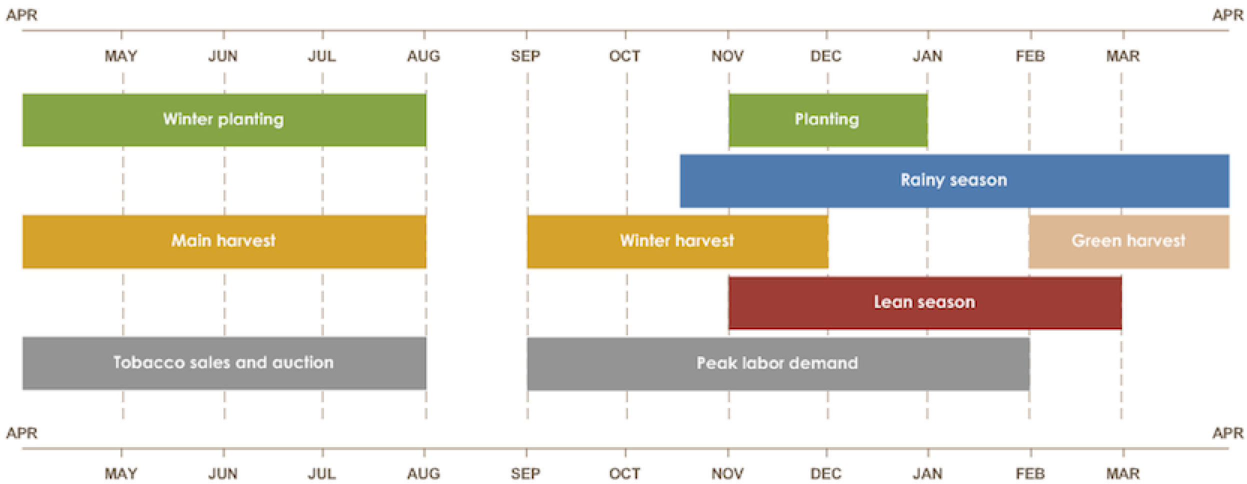

Figure A1: Timeline of typical agricultural year. Source: FEWS Net (2014)

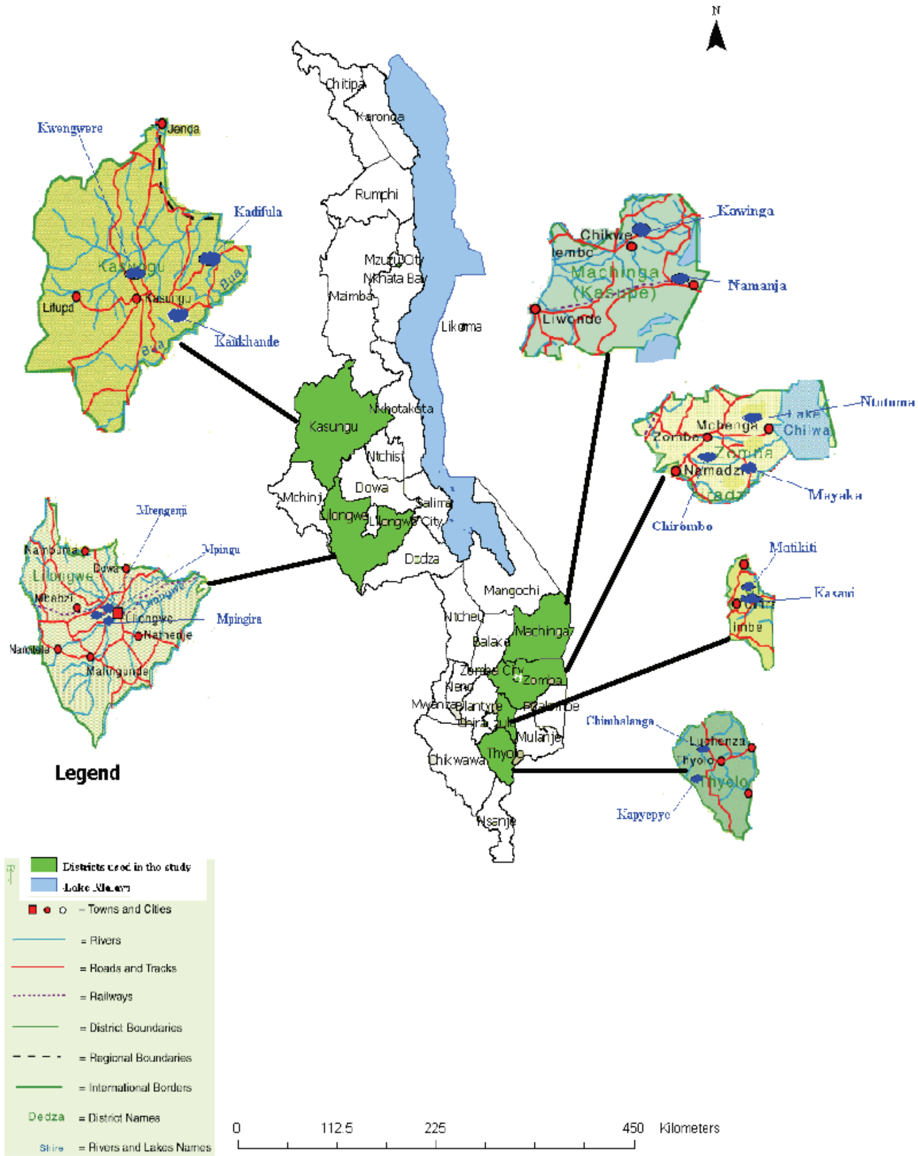

Figure A2: Districts and sites sampled in 2008/09 survey. Source: Lunduka (2009)