DETERMINANTS OF FARM HOUSEHOLDS' CROPLAND ALLOCATION AND CROP DIVERSIFICATION DECISIONS: THE ROLE OF FERTILIZER SUBSIDIES IN MALAWI.

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THE ROLE OF FERTILIZER SUBSIDIES IN MALAWI

THESIS

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Declaration

I, Duncan Eric Ndhlovu, do hereby declare that this thesis, except where duly acknowledged, is a product of my own research investigations and findings. To the best of my knowledge, this work has never been previously published or submitted to any other university for any type of academic degree.

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Duncan Eric Ndhlovu

Ås, May 2010

Dedication

To my loving wife, **Taonga** and dear son, **Sithembiso**, for their patience, understanding, love and enduring the times of my almost one year absence from home.

To my late brother, **Webster** and late sister-in-law, **Elizabeth** for setting a good foundation of my current and future academic achievements.

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Above all, I thank my God for enabling me to successfully pass through this life changing process!

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List of Acronyms and Abbreviations

ADMARC	Agricultural Development and Marketing Corporation
CAP	Common Agricultural Policy
CGE	Computable General Equilibrium
CMAAE	Collaborative Masters Program in Agricultural and Applied Economics
EPA	Extension Planning Area
FAO	Food and Agricultural Organization of the United Nations
GDP	Gross Domestic Product
GLS	Generalized Least Squares
GPS	Geographical Positioning System
IFPRI	International Food Policy Research Institute
IHS	Integrated Household Survey
NEPAD	New Partnership for African Development
NOMA	NORAD's Program for Master studies
NORAD	The Royal Norwegian Agency for Development and Cooperation
OLS	Ordinary Least Squares
PSU	Primary Sampling Unit
NSO	National Statistical Office
SAP	Structural Adjustment Policies
SID	Simpson's Index of Diversification
STATA	Data Analysis and Statistical Software
UMB	Norwegian University of Life Sciences
UN	The United Nations

Abstract

This study analyzes how fertilizer subsidies to maize production in Malawi affects farm households' crop choice, cropland allocation and crop diversification level. The analysis is based on a three-year household survey data collected in 2006, 2007 and 2009 from six districts across Malawi; two of the districts are in the central region while four districts are in the southern region. Crop choice and cropland allocation patterns are examined using the generalized least square (GLS) model within which the control function approach is applied to control for endogeneity arising from having access to fertilizer subsidy. In this study, the access to fertilizer is used as a binary endogenous regressor in the crop choice/cropland allocation and crop diversification equations. The Simpson's index of crop diversification is used as the dependent variable in the assessment of the relationship between farm households' access to fertilizer subsidy and crop diversification level. This relationship is analyzed using the treatment effect model in order to overcome the endogeneity problem. Model estimations are based on pooled panel data. Empirical results indicate that farm households' cropland allocation patterns and the subsequent crop diversification levels are sensitive to fertilizer subsidy program. In particular, the results showed that farm households' access to fertilizer subsidy is associated with a decrease in the cropland allocation to maize and pulses while there is an increase in cropland allocation to ground nuts, roots-tubers and tobacco. In terms of crop diversification, the study findings suggest that farm households' access to fertilizer subsidies promote crop diversification. The results illustrate that fertilizer subsidies to maize positively contribute to promoting farm households' crop diversification levels through intensified maize production. This has implications for household welfare; crop diversification enhances stability of household incomes through the mitigation of price and crop production risks and shocks.

Key words: fertilizer subsidy, cropland allocation, crop diversification, Malawi

CHAPTER ONE

1.0 Introduction

Fertilizer subsidy programs are again[1] taking stage in many African countries mainly to challenge the food shortage problems arising from declining soil productivity, erratic weather and high population growth (Minot and Benson, 2009). Malawi is one of such countries that have possibly drawn a global attention for successfully implementing its innovative input subsidy program for the past four consecutive crop growing seasons. The program is particularly hailed for the resulting surplus staple food crop production levels, some of which has been exported to neighboring countries (Denning *et al.*, 2009).

Literature indicates that agricultural support programs such as fertilizer subsidies that are directly linked to farmers' production of specific crops, not only affect total production, land use, labour use and other inputs' use, but also distort the mix of crops grown (Westcott and Young, 2004). Farmers that benefit from such program support tend to switch to crops with higher benefit resulting from the received program support, especially when there is no room to expand their total planted area (Di Falco and Perrings, 2005; Vavra and Colman, 2003). This illustrates that at both policy and farm household level, the composition and the level of crop production are of crucial concern (Ali, 1990). Therefore studies on the impact of subsidies on crop production must reflect not only crop productivity changes but also farmers' crop switching behaviors as these may have implications for crop yield and production levels, crop market supply response, crop diversification, food security and poverty.

Agricultural subsidies play an important role in farm households' crop production strategies by relaxing some of the production constraints, risks and market imperfections or failures (Chavas and Holt, 1990; Duffy *et al.,* 1994). Financial assistance to farm households in the form of subsidies directly affects their production decisions mainly through inputs, cropland and labor resource allocation (Di Falco and Perrings, 2005; Westcott and Young, 2004).

[1] Fertilizer subsidies were a common and major element in the agricultural development policy strategies in the 1960's-70's but were phased out in the 1980's-90's as part of the Structural Adjustment Policies (SAPs).

However, past studies on the impact of fertilizer subsidy programs in Malawi have not been extended to analyzing farm households' behavior response in terms of crop choice and cropland allocation decisions. This response behavior can vary across regions, reflecting differences in agro-ecological zones, resource constraints and the functioning of markets. Empirical findings also indicate that there are gender differentials in farm productivities which can also be accounted for in terms of farmers cropping pattern responses to the fertilizer subsidy support (Smale and Heisey, 1994; Udry *et al.*, 1995).

This study is motivated by two opposing theoretical arguments regarding how farm households' cropping patterns respond to fertilizer subsidies. On one hand, it is argued that crop specific subsidies provide farm households' an incentive to grow the most supported crop (s) which lead to a reduction in crop diversification. In order to manage the risk and ensure profitability, farmers increase cropland allocation to the subsidized crop (s) and reduce the cropland allocated to the substitute crops (Di Falco and Perrings, 2005; Chavas and Holt, 1990; Westcott and Young, 2004; Ellis, 1992). Thus, this leads to specialisation in the supported crop (s) instead of crop diversification. On the other hand, fertilizer subsidies might promote cropland intensification of the supported crops. Through higher yields, the same amount of produce can be obtained from a smaller area. This outcome enables farm households to re-allocate the uncultivated cropland to other crops thereby promoting crop diversification (Smale, 1995).

This dilemma therefore necessitates a deeper understanding of farmers' crop switching behavior which is not only important for policy planning, but also for those interested in evaluating input subsidy programs. This is because crop switching patterns account for spatial and inter-temporal variations in crop yields and revenue. This in turn, has implications for household food security and welfare (Kurukulasuriya and Mendelson, 2008; Nkonya *et al.*, 2004). Hence, effective measurement of the impact of the agricultural input subsidy programs on crop yields, production levels, supply response, food security and poverty reduction requires critical understanding of farm households' decision on crop choices and cropland allocation and crop diversification (Guyomard *et al.,* 1996; Mendola, 2007).

This study therefore seeks to provide an empirical analysis of the role of fertilizer subsidies on farm households' cropping decisions including crop diversification. The main objective of the study is to investigate the role of the fertilizer subsidy program on farm households' crop choice, cropland allocation and crop diversification. Specifically, the study aims to 1) assess how fertilizer subsidies to maize affect crop diversification at farm household level; 2) investigate how fertilizer subsidies to maize affect cropland allocation to other major crops such ground nuts, tobacco and root-tuber crops; 3) assess gender and regional differences in crop diversification with respect to farm households' participation in the fertilizer subsidy program.

The rest of this paper proceeds as follows: chapter two provides the background sections followed by chapter three which outlines the theoretical framework and literature review. Chapter four provides the study methodology followed by chapters five and six which discuss the empirical results and conclusions respectively.

CHAPTER TWO

2.0 Background

2.1 Malawi's smallholder context of crop production

Malawi's path to economic growth and development follows a strategy of smallholder-led agricultural development. Approximately 90 percent of all households derive their livelihoods from farming. Therefore improvements in smallholder productivity imply increased agricultural development. The agriculture system has a bi-modal structure comprising smallholder farmers and large scale estate holders and it heavily depends on rain-fed agriculture. The smallholder sector contributes 75 percent of the total agricultural production while estates account for the remaining 25 percent. However, the smallholder agriculture is characterized by maize-dominated production systems with low productivity and stagnant yields. Increasing productivity and diversifying into high-value crops have been identified to be the key steps to improving the performance of smallholder agriculture in Malawi (Malawi Government and World Bank, 2006).

Smallholders in Malawi can be classified as semi-commercial peasant farmers that grow crops largely for home consumption (Smale, 1995). Usually farmers sell their maize at low prices during harvest time. However, they fail to buy it when they need it later in the season mainly because the market cannot provide or the price becomes unaffordable. The large scale estates focus on the growing of high value cash crops for export including tobacco, tea, sugar, coffee and macademia nuts (Orr and Orr, 2002). Table 1 shows percentage of smallholder farm households cultivating different crops at national and regional levels.

Table 1: Percentage of farm households cultivating different crops

Crops grown	National	Central region	Southern region
Maize	97	97	99
Other cereals	24	14	33
Roots/tubers	36	35	32
Cassava	21	11	24
Pulses	68	70	69
Ground nuts	38	53	25
Beans	23	34	13
Pigeon peas	27	3	54
Tobacco	15	25	6
Vegetables	36	40	33

Source: Malawi Government and World Bank (2006)

Maize is the staple food, it is grown by 97 percent of farm households and it takes about 90 percent of the cropped area. The need to secure household food requirements limit farm households' efforts to diversify into high value cash crops and/or other micro enterprises. In addition, most farm households put their priority in the production for subsistence food needs which reflects lack of confidence in the rural markets because they are either missing or imperfect Malawi Government and World Bank (2006).

Other major staple foods[2] include roots and tubers comprising mainly cassava (21 percent of farm households) and sweet potato. FAO (2004) indicates that cassava is becoming the second most important alternative staple. Other minor cereals include sorghum, millet and rice. Vegetables and pulses[3] are also main food crops. Tobacco (mainly burley tobacco), is the

[2] Cassava, sorghum and potatoes act as bridging crops in times of shortages in maize production and supply. Cassava acreage and production are reported to be increasing since late 1990s (FAO, 2004)
[3] These crops mainly include pigeon peas, beans and ground nuts.

male dominated crop[4], the country's main cash crop accounting for 30 percent of GDP and 70 percent of exports earnings. Tobacco is a competitor crop with maize for labor and land resources and it requires crop rotation to prevent plant insect pests and disease infestation and/or build up (Orr, 2000).

There are important boundaries between male and females within the household, in terms of who makes crop cultivation decisions. Women mainly grow crops for home consumption while men cultivate at least some cash crops in addition. In terms of decision making on crop production activities, women hold decision making power in female-headed households only. In male headed households, men make almost all decisions especially for the cultivation of cash crops and vegetables. Women's role in this case is largely limited to crops that do not require fertilizers and purchased seed (Malawi Government and World Bank, 2006).

Access to farm inputs, especially fertilizer has been identified as the most constraining factor for improving smallholder productivity. To overcome this challenge, the government decided to implement fertilizer subsidy targeting poor smallholder farmers. Since the implementation of the fertilizer subsidy program started over the past four years, Malawi has made remarkably positive shifts in the performance of smallholder agriculture particularly in the maize sector. The sector has registered substantial improvement in maize production[5], attributable to the success of agricultural input subsidy program initiated in 2005/2006 crop growing season which coincided with good rains (Denning *et al.*, 2009).

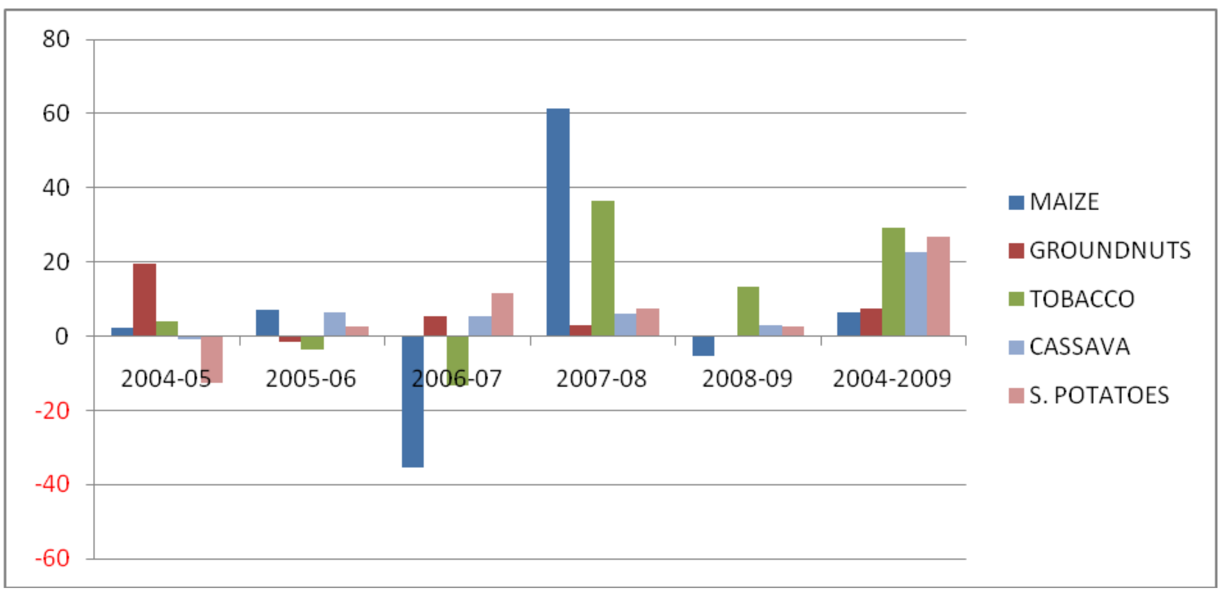
However, the dominance of maize in the cropping pattern still remains the major concern for agricultural policy in Malawi as it implies lack of diversification. This situation does not only narrow the economic base of farm households but it renders the whole agriculture sector

[4] 19 percent of male headed households grow tobacco while only 7 percent of female headed household grow it (Malawi Government and World Bank, 2006).

[5] According to the Ministry of Agriculture and Food Security crop estimates, maize production was 2.7 million metric tonnes in 2006, 3.4 million tonnes in 2007, 2.9 million metric tonnes in 2008 and 3.9 million metric tonnes in 2009.

vulnerable to economic and weather shocks which have become very recurrent. Crop diversification is therefore viewed as a key priority in achieving growth in the sector (Malawi Government, 2006b). This is evidenced from the following quote from the national food security policy: “Government shall put in place distinctly targeted agricultural input subsidies to enhance growth and food diversification for the poor farmers that can still not afford agriculture inputs after exhausting all economic levers” (ibid). Chirwa (2009) argues that unacceptably large numbers of the poor will continue to be exposed to hunger or worse, unless farmers have access to improved inputs for both food production and diversification.

Figure 1 presents a national trend on cropland percentage changes between 2004 and 2009; possibly suggesting that the incentives offered by the agricultural programs influence farm households behavioral responses.



Source: Own computation from Ministry of Agriculture and Food Security crop estimates figures

Figure 1: Distribution of annual crop area percentage change for major crops from 2004 to 2009

Considering 2004-2005 as the baseline year, figure 1 illustrates that there is no consistent pattern in cropland changes. However, in overall terms (2004-2009) tobacco is registering the highest cropland change with a total increase of 28 percent, while maize has the lowest percentage increase, followed by ground nuts. Cassava (23 percent) and sweet potato (27 percent) area changes may suggest that these two crops are competing for cropland with tobacco.

In 2005/2006, the year when the fertilizer subsidy program was initiated, there was a small increase in cropland allocated to maize (7 percent), cassava (6 percent) and sweet potato (3 percent); but a decrease was registered for tobacco (-4 percent)and ground nuts (-1 percent). 2006/2007 surprisingly registered a negative percentage change in the cropland allocation to maize and tobacco, while 2007/2008 has the highest percentage cropland increment for maize and tobacco.

The cropland allocation trend indicate access to fertilizer subsidies in one growing season result into a supply shock which may possibly reduce crop production in the following year. Therefore, understanding the basis of individual crop-yield performance is essential for determining the linkages and trade-offs between input subsidies and crop production. However, such relationships may not be fully explained at national level without understanding the underlying farmers' crop choice and cropland allocation behavior.

2.2 An overview of the fertilizer subsidy program

Recently, the role of agricultural input subsidy programs in stimulating economic growth and addressing food insecurity and poverty challenges has re-emerged as an important agricultural policy debate. The re-emergence of this policy debate partly supports the need to urgently respond to the crisis posed by the dramatic increases in world food and fertilizer prices in 2007 and 2008. Land shortage due to population pressure, declining soil fertility and lack of purchasing power to access farm inputs, especially fertilizers, are the main explanations for low agricultural productivity. Programs for promoting fertilizer and fertilizer subsidies are therefore among the top list of options for government and donors (Minde *et al.*, 2008).

The Malawi's fertilizer subsidy program has become a model for its successful implementation for past four consecutive crop growing seasons. The program was initiated in 2005/2006 crop growing season following a bad crop harvest in 2004/2005 crop season. The main objective of the program is to improve smallholder land and labor productivity, food and cash crop production and reducing vulnerability to food insecurity and hunger (Dorward *et al.*, 2008). The program is being implemented within the green revolution strategy, an approach advocated by both African union under the NEPAD's Common African Agricultural Development Program and the UN's African green revolution (Sanchez *et al.*, 2009). The program is being implemented through the distribution of vouchers of which the targeted beneficiary farm households use to redeem the subsidized input at designated farm input retails shops.

The program is aimed at reaching the poor smallholder farmers who would not otherwise be able to purchase fertilizer at the commercial price. Allocation of coupons starts at regional level, then at district level and finally at an Extension Planning Area (EPA) level. Each targeted household is intended to receive two coupons (worth 100 kg of fertilizers), one for basal and the other for top dressing at the subsidized rate[6]. In addition, each beneficiary household was also allowed to buy hybrid maize seed up to a maximum of 2 kilograms at a subsidized price. Table 2 provides details of program package and the scale of implementation.

[6] The subsidized rates per 50 kilogram bag of fertilizer were MK950 in 2005/06, MK900 in 2006/07, MK800 in 2007/08 and MK500 in 2008/09. Farmers paid at least 20 percent of the total cost.

Table 2: Program package and scale of implementation

Year	Input	Package	Targets
2005/2006	120,000 metric tons of maize fertilizer	2 x 50 kg bag	1.2 million
2006/2007	150,000 metric tons of maize fertilizer	2 x 50 kg bag	1.5 million
	4,000 metric tons of maize seed	1 x 2 kg pack	1.5 million
2007/2008	150,000 metric tons of maize fertilizer	2 x 50 kg bag	1.5 million
	4,000 metric tons of maize seed	1 x 2 kg pack	1.5 million
2008/2009	150,000 metric tons of maize fertilizer	2 x 50 kg bag	1.5 million
	4,000 metric tons of maize seed	1 x 2 kg pack	1.5 million

Source: Mwale (2009)

The process of targeting households to access the subsidized fertilizers is complex partly because the targeting criteria are not explicit enough. Hence it leaves room for manipulation by those who administer it. The targeting of beneficiary households is based on a combination of poverty/vulnerability and productivity indicator which include: the poorest and most vulnerable households such widows, elderly, orphans and disabled; households with access to land, households with access to cash and capable of adopting and utilizing technology (Dorward *et al*., 2008).

The prominence of Malawi's fertilizer subsidy program has attracted a lot of interest and need for impact studies in order to quantify the outcomes. However, studies that have been done so far concentrate their focus on crop productivity, household income (Denning *et al*., 2009; Ricker-Gilbert *et al*., 2009) and impacts of the demand for commercial fertilizer (Ricker Gilbert and Jayne 2009). At policy level, in order to realize the program objectives of improving food and cash crop productivity and the reduction in food insecurity, there is need to understand underlying causal influences of the subsidy program on farm household behavior regarding crop choice and cropland allocation.

2.3 Research questions

The background provided in the foregoing chapters motivates the following research key questions:

i. Does fertilizer subsidy to maize negatively influence farm households' decisions to grow other crops such as ground nuts, root/tubers, tobacco and pulses?

ii. Does fertilizer subsidy to maize affect cropland allocation to maize, ground nuts, root/tubers, tobacco and pulses?

iii. Are there systematic gender and regional differentials in the farm households' crop diversification with respect to farm households' participation in the fertilizer subsidy program?

CHAPTER THREE

3.0 Literature Review and Theoretical Framework

3.1 Farm households' decision making environment and context

The basic economic theory of farm production and management in any given locality simply revolves around farm household decisions regarding what to produce, how much to produce and how to produce (Ellis, 1993). Essentially, these decisions necessitate crop choices and cropland allocation and have implications for farm household's crop diversification level (Nkonya *et al.,* 2004). Such decisions are relatively simple for farmers when they follow a particular crop rotation plan. However, for many smallholder farmers in Malawi, crop rotation has become more difficult to practise due to population pressure on land which has resulted into smaller land sizes, land fragmentation and the need for mixed cropping (Malawi Government, 2003).

Farm households will typically make crop choice and cropland allocation decisions simultaneously (Hua and Hite, 2005). These decisions can be influenced not only by farm household characteristics but also government policies such as fertilizer subsidy program (Di Falco and Perrings, 2005; Westcott and Young, 2004; Wu and Brorsen, 1995). In turn, crop choice and cropland allocation decisions not only determine agricultural production levels, but also affect land resource conditions, crop diversification, levels of farm income and household food security and welfare. These decisions have therefore become current issues of concern for both rural people and policy makers (Wu *et al*., 2008; Malawi Government and World Bank, 2006; Hua and Hite, 2005).

Farm households make crop choice and cropland allocation decisions within their own production risk and uncertainty management strategies, income diversification strategies and market access constraints (Zeller *et al.*, 1998; Babcock *et al.*, 1987; Chavas and Holt, 1990; Collender and Zilberman, 1985; Pender *et al.,* 2004). Therefore agricultural support programs in the form of fertilizer subsidies help to relax some of these constraints while offering economic and financial incentives that also influence farmers' crop choices and land allocation (Chembezi and Womack, 1992; Duffy *et al.*, 1994; McDonald & Sumner, 2003; Rashid *et al.,* 2004). This study therefore considers these household decisions, conditional on their participation in the fertilizer subsidy program.

3.2 The Crop Choice and Cropland Allocation Framework (The Random Utility Model)

In modeling crop choice and cropland allocation decisions in a developing country like Malawi, production and consumption decisions become inseparably linked through shadow prices. This is due to pervasive imperfections in the factor and commodity markets. This situation is perpetuated when most farm households are semi-subsistence (de Janvry *et al.,* 1991).

When some markets are imperfect or missing for particular crops and /or some factors of production, goals other than profit maximization also affect crop choices and land use decisions and a pure profit maximization framework often fails to reflect real patterns of cropping and resource use and allocation for households producing primarily to meet their subsistence needs (Mendola, 2007). Alternatively, the random utility models have therefore been used to predict farm household choice behavior[7].

The random utility theory is adapted in this study following McFadden's (1974) random utility model. The random utility model is a sub-category of probabilistic choice models that are used to econometrically represent individuals' maximizing behavior (Manski, 1977). Utilities are regarded as random variables to reflect lack of full information about the characteristics of alternative choices and/or decision makers on the part of the researcher. Assuming that the expected utility is a random function, I specify the random utility function of each possible crop alternative as follows:

[7] The utility maximization framework accounts for both production and consumption side of the farm household decision making and therefore it considers farm households as both families and enterprises (Mendola, 2007).

$$U_{ijt} = EU_{ijt}(V_{ijt}, e_{ijt}) \qquad (1)$$

Simplifying equation (1) into an additive linear expression yields equation (2)

$$U_{ijt} = V_{ijt} + e_{ijt} \qquad (2)$$

I decompose the utility function into two components: 1) the deterministic part, V_{ijt}, which is the observed component of the latent utility of crop j of farm household i in crop growing season t; and 2) the stochastic (random) or the unexplained component, e_{ijt}. I do this to reflect farm households' demonstrated inability to perfectly discriminate the alternatives, given binding constraints and uncertainties on their choices. In addition, my analysis cannot fully account for and measure exactly the farm households' decision making environment.

In a typical revealed preference situation, in order to explain the observed choices, the interest is in defining the suitable form for V_{jht}. In economic theory, it is commonly understood that the kind of utility we deal with in the choice probability models is the indirect utility. It therefore requires converting the households' cropping pattern preference into choices by considering tangible factors (McFadden, 1980). In this case, we can take farm households' utility (V_{jht}) to be a function of production or yield per hectare, income, consumption smoothing and risk reduction obtained from a given crop choice alternative conditional to participation in the fertilizer subsidy program. Thus a real valued function can be defined as equation (3)

$$U = \mathrm{E}U(production / yield, income, consumptionsmooting, riskreduction) \qquad (3)$$

Let J be a unique finite set of crop alternatives comprising maize, tobacco, roots-tubers, ground nuts, tobacco and pulses which exhibits different distributions of production/yield, income, consumption smoothing, risk reduction that can be compared. The fundamental axiom of utility theory indicates that only the choice alternative that gives the greatest utility is preferred. Thus a farm household i in crop growing season t will assign a utility level U_{ijt} to each crop alternative $j = 1,2,..., J$ .and compares the maximum expected utility derived from each possible crop choice and land allocation. The crop alternative that the household presumes will yield maximum expected utility is chosen.

Because of the stochastic component in the utility function, researchers can predict farm household's decisions only up to a probability of alternatives of crop choice/cropland allocation decisions. The probability that farm household i will choose crop alternative j from a set of available J alternatives in crop growing season t can be expressed as follows:

$$P_{it}(j : J_{it}) = \Pr(U_{ijt} > U_{ikt}) \text{ for all } k \in J,\ k \neq j \tag{4}$$

Assuming the stochastic terms are independently and identically distributed, the probability that farm household i chooses a crop alternative j is equal to the probability that the utility from crop j is the highest of all of all crop utilities within the farmers' crop choice set J .

Given the nature of the utility function (the deterministic and stochastic components), the choice preference probability can be re-written as:

$$P_{it}(j : J_{it}) = \Pr(V_{ijt} + e_{ijt}) > \Pr(V_{ikt} + e_{ikt}) \text{ for all } k \in J,\ k \neq j \tag{5}$$

Or

$$P_{it}(j : J_{it}) = \Pr(V_{ijt} - V_{ikt}) > \Pr(e_{ijt} - e_{ikt}) \text{ for all } k \in J,\ k \neq j \tag{6}$$

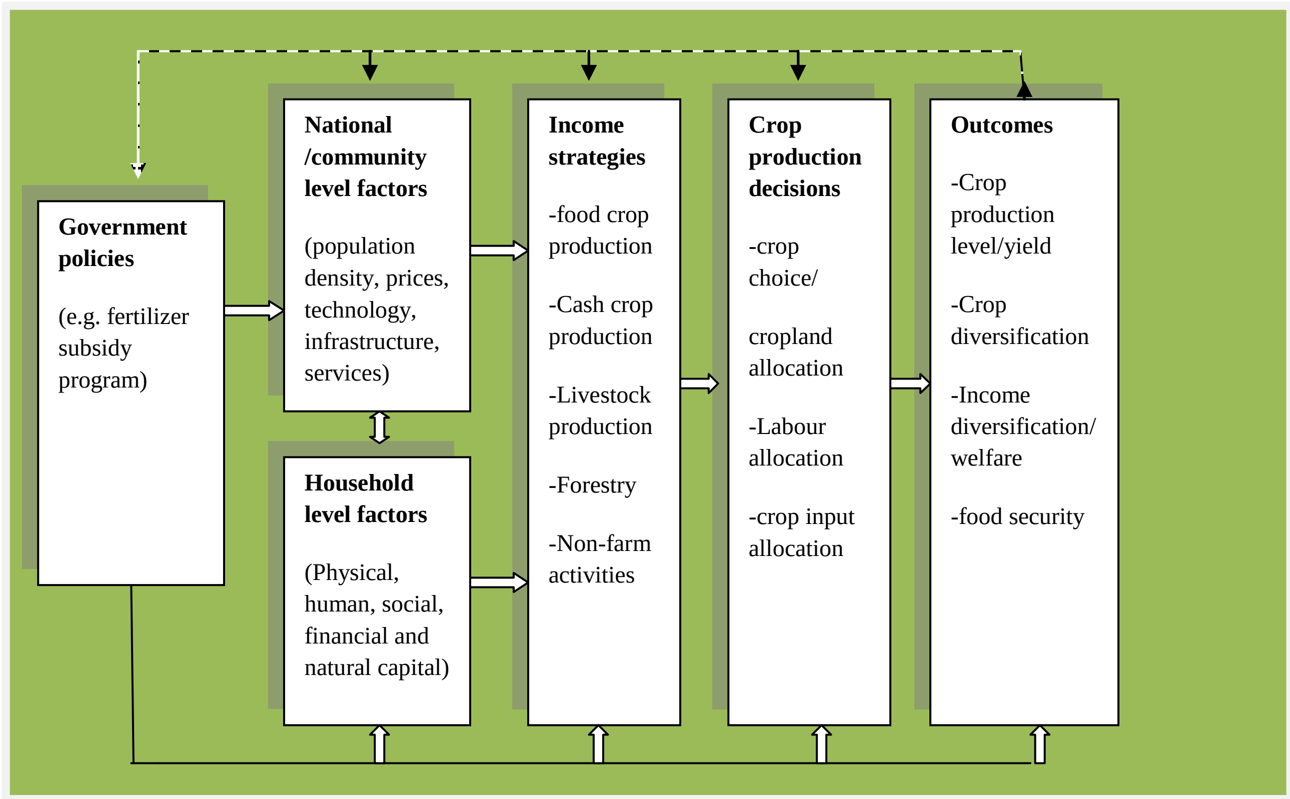
Equation (7) shows that the farm households' choice decisions are not only influenced by comparative returns or utilities from the alternatives denoted by Π_{ijt}, but also household level characteristics, Z_{ijt}, plot level characteristics, X_{ijt} and policy level factors (access/participation in the input subsidy program), P_{ijt}.

$$U_{ijt} = U_{ijt}(\Pi_{ijt} Z_{ijt}, \mathrm{X}_{ijt}, \mathrm{P}_{ijt}) \tag{7}$$

The above framework provides the basis upon which farm household's crop choice and cropland allocation behavior can be modeled. This however heavily depends on sensible assumptions on the variables influencing the expected utility of choice alternatives and the probabilistic structure of the utility function (McFadden, 1980). Section 4.3 provides details for the statistical procedures involved in the estimation of farm household's crop choice and cropland allocation decisions.

3.3 Linkages between farm households' crop choice, cropland allocation decisions, crop diversification and participation in the fertilizer subsidy program and implications

Figure 2 illustrate conceptually the linkages and the implications in the relationships between farm households' crop choice, cropland allocation decisions, crop diversification and participation in the fertilizer subsidy program. In figure 2, I illustrate that crop production decisions including crop choice/cropland allocation are determined by the choice of income strategies. Income strategies are in turn affected by national, community, household levels factors and government policy strategies including the fertilizer subsidy program. Outcomes from the crop production decisions in turn influence decisions by policy makers, farm household income strategies and cropping decisions.



Source: Adapted from Nkonya *et. al.* (2004)

Figure 2: Linkages between crop choices, cropland allocation, crop diversification & fertilizer subsidy

A rich body of literature and theoretical work investigates the role of agricultural input subsidies in influencing farm households' crop production decisions (Doroodian and Boyd, 1999; Guyomard *et al.*, 1996; Holden *et al.*, 2004; Lee and Helmberger, 1985; McDonald and Sumner, 2003). In addition, the role of input subsidies have been analyzed in the context of decoupled payments effecting farmers' acreage decisions for the United States Farm Bill Policy (Westcott & Young 2004) and European Union's Common Agricultural Policy (CAP) (Guyomard *et. al.*, 1996). Crawford *et al.* (2006) provide an outline of empirical findings on the role of agricultural input subsidies in this regard.

Arguments in favor of subsidies indicate that agricultural input subsidies can have green revolution outcomes because they play a primary role in promoting the adoption of new technologies and increasing agricultural productivity. This is achieved by improvement in farmers' liquidity[8] and reducing their risk aversion from investing in fertilizer inputs (Dorward *et. al.*, 2008). In this way, fertilizer subsidies can be seen as important for correcting missing or imperfect markets. Fertilizer subsidies also offset high fertilizer prices caused by high transport costs and limited market development. Therefore fertilizer subsidies encourage farmers to use fertilizer thereby influencing crop production decisions. Finally, fertilizer subsidies can reduce credit needs (Rao, 1989).

Based on the CGE model simulation for Mexico, (Doroodian and Boyd, 1999) found that a subsidy reduction for corn had a direct negative effect on corn production level. A subsidy reduction by 100 percent resulted into corn production decline of 20 percent through cropland reduction. On the other hand, production of other crops increased by 8 percent owing to shifting of input resources (land, labor and other key inputs) from corn to competing crops. Similar results were found in Ethiopia where a reduction in fertilizer subsidy caused a reduction in cereal production. Increases in the price of fertilizer caused shifts to crops that are less fertilizer intensive or pulses that grow without fertilizer (Holden *et al.*, 2004).

Other roles have been perceived to be paradoxically negative. Ellis (1992) argues that fertilizer subsidies distort the allocation of farm resources such that they encourage inefficient substitution of a scarce resource for an abundant resource (e.g. chemical fertilizer for labor); inefficient substitution of crops towards those that use the subsidized fertilizer despite market demand patterns favoring the substituted crops[9]. This may in a way also discourage crop diversification in the sense that farmers are guaranteed for the availability of inputs for the supported crops especially if the weather conditions are favorable. Less diversification implies

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[8] Decision to grow tobacco depends on farmers' ability to purchase inputs especially fertilizer as it is a fertilizer intensive crop.

[9] However, subsidized inputs may be diverted to farmer own favored but unsubsidized crops.

less crop rotation due to monocropping and crop intensification which leads to soil degradation and it discourages farmers from applying more sustainable land use practices such as the use of organic manure and agro-forestry technologies (Vavra and Colman, 2003).

From these empirical findings, it can be generalized that fertilizer subsidies through farm households crop choice and cropland allocation decisions can influence the level of crop productivity and crop diversification, the natural resource conditions and household welfare. This study will only analyze the relationships between crop choice, cropland allocation, and input subsidy program and the implications on crop diversification.

3.4 Determinants of farm households' crop choice and cropland allocation decisions

Farm households' annual crop choice and cropland allocation decisions are an outcome of several factors that act either individually or in interaction within the farm production environment. Literature in applied economics provides analysis on the determinants of crop choice and cropland allocation decisions both as separate and simultaneous decisions. These studies indicate that the major driving forces behind such farmers decisions include farm household and land characteristics (Bergeron and Pender, 1999), crop varietal characteristics (Smale *et al.*, 1998), production (Kurukulasuriya and Mendelson, 2008) and price risks (Collender and Zilberman, 1985), government policies, presence of technical programmes and financial incentives (Chembezi and Womack, 1992; Duffy *et al.*, 1994; Westcott and Young, 2004).

Based on the approach of Bergeron and Pender (1999) and Nkonya *et al.* (2004), I categorize these factors into three: plot level, farm household level and institutional (policy) level factors. The diversity of these factors arguably explains the stochastic nature of the farm production function.

Plot level factors: These are characteristics of the farm plot which vary in space and this variation among farm plots influence farm households' crop choice and cropland allocation patterns. Plot level factors broadly fall in the category of natural capital and they include soil type, soil fertility level, slope of the plot, plot distance from home, tenure (how it was acquired and ownership status) and other agro-ecological conditions (ibid). Empirical literature views these factors as the primary driving forces of changes in farm households crop choice and cropland allocation patterns.

Plot characteristics exert a large influence on cropping patterns such that they account for more than twice as much cropland allocation variation as the economic and policy variables (Bergeron and Pender, 1999; Vavra and Colman, 2003; Wu and Brorsen, 1995). Therefore, analyzing the determinants of crop choice and land allocation without controlling for land characteristics can yield seriously misleading results (Rashid *et al.*, 2004).

However, studies on the agricultural support programs such as input subsidies that control for plot level characteristics are limited. Other studies have considered plot level factors such as biophysical factors including additional variables such as extent of fragmentation of plots and land management practices (use of organic or inorganic fertilizers, crop rotation, type of cropping system). Variability in farming practices reflects the differences in the agro-ecological conditions. NEC, NSO and IFPRI (2001) identified 8 agro-ecological zones in Malawi. These are the Lower Shire Valley, the Shire Highlands and Lake Chilwa Plains, the Central Highlands, the Middle, Upper Shire and Southern Lake Shore, the Central mid-altitude plateaus, the Central Lake Shore and Bwanje Valley, the Northern mid-altitude plateau and the Northern Lake Shore. The sampled districts fall in three of these zones.

The theoretical impact of most of these factors on cropping patterns is ambiguous. Kan and Kimhi (2005) found that an increase in land fragmentation was not significant in one year but in the other year and for some crops but not for other crops. In addition the effect of an increase in plot size had both significant positive and negative outcomes for the different crops and their corresponding yields. An increase in farm size increases the proportion of cropland allocation to a particular crop alternative. However, the increase in farm size may lead to yield decrease due to the inverse relationship between farm size and productivity (Heltberg, 1998).

Farm household level factors: These constitute demographic and socioeconomic characteristics of the farm household and they include sex, age and education of the head of household, household labour endowment, household's endowments of physical assets such as farm size, livestock, household access to credit and attitude towards risk (Collender and Zilberman, 1985; Feder, 1980; Pender *et al.*, 2004). These factors explain farm households' management ability and access to factors of production and their motives and preferences including attitude towards risk. Therefore they influence farm households' decisions about crop choice and cropland allocation (Bergeron and Pender, 1999).

Following Nkonya *et al*. (2004), I broadly categorized these factors into i) physical capital (farm size, livestock and other household's assets); ii) human capital comprises sex, age and education of the head of household and household labour; iii) financial capital includes farm household's liquid financial asset and access to credit. Depending on the extent to which markets are imperfect or missing, household level factors affect the household's ability to finance crop production decisions such as purchasing of inputs and hiring of additional labor. However, financial constraints may also induce labor constraints, especially when the family labor is not sufficient. During the peak season, there is often need for hired labor but the household lacks liquidity to finance it (Zeller *et al.*, 1998). This may in turn affect crop choice and cropland allocation decisions.

According to Pender *et al.* (2004) and Zeller *et al*. (1998), agro-ecological conditions, human capital and social capital may also influence cropping pattern through crop yields. Farmers' crop yield expectations play an important role in farm households' crop choice and land allocation decisions (Arslan, 2008; Smale *et al.*, 1994). Well educated and experienced (old age) farmers will make better informed choices. This is because they have the ability to collect and interpret extension messages and they possess more knowledge of their socioeconomic environment (Pender *et al.*, 2004). Vavra and Colman (2003) argue that the influence of these factors can be so strong that they effectively mask effect of prices and profitability.

Policy and institutional level factors: These relate to farm household's access to or participation in agricultural support programs (e.g. fertilizer subsidy program) and farmer organizations, access to produce, input and credit markets and public infrastructure such as all weather roads. Vavra and Colman (2003) also urge that although plot and household characteristics account for a great part for the explanation for heterogeneity in farm households' behavior in terms of cropping pattern, it is essential to recognize such heterogeneity given market conditions and the agricultural policy support in place.

Farm households' participation and access to these programs and services significantly influence their crop choice and cropland allocation decisions. Fertilizer subsidy offers the farm households opportunities for reducing the high transaction costs, production risks and constraints (Feder, 1980; Nkonya *et al.*, 2004).

On the other hand, this creates a conflict in the allocation of the cropland to alternative crops given that land availability is limited (De, 2005). Subsidy will influence the re-allocation of farm inputs such as labor towards crops that are expected to yield high returns either in terms of crop yields and/or revenue. Crop specific financial support in terms of fertilizer subsidies tends to create an incentive to grow the most supported crop leading to a reduction in crop diversification. Farm households will tend to allocate most of their land to the single most supported crop instead of diversifying in order to manage risk (Chembezi and Womack, 1992; Di Falco and Perrings, 2005; McDonald and Sumner, 2003).

In Malawi, technical change that enhances productivity in maize production has the potential to influence farm households' crop choice and land allocation decisions. Such a change encourages crop intensification which makes it possible for the farmers to obtain high enough crop yields for the households food needs, but from a smaller crop area. Consequently, farm households can then reallocate land from maize to other important food staples as well as high value crops (Smale, 1995). If the current input subsidies contribute to this kind of outcome, then crop intensification and crop diversification may be viewed to be complementing each other.

Based on the evidence gathered from literature, I model crop choice and cropland allocation by depicting a Malawian smallholder farmer who decides to allocate their land among different crops taking into consideration their socioeconomic circumstances, plot level factors, crop type characteristics, input availability and the financial incentive derived from their participation into the fertilizer subsidy program through access to the subsidy coupon.

3.5 Determinants of farm households' access to and participation in the fertilizer subsidy program

I capture farm households' participation into fertilizer subsidy program in this study by considering whether they accessed subsidy coupons either through direct targeting using the official targeting criteria or by buying from private traders or fellow villagers. According to Ricker -Gilbert and Jayne (2009), the beneficiary targeting process for the subsidy coupons is long and complex as the allocation of subsidy coupons starts at regional level, then district and extension planning area (EPA) level, and finally at village level. Allocation of coupons at regional level is based on the total number of hectares under cultivation.

At village level, participation into the fertilizer subsidy program depends on a combination of a number of subjective factors which comprise both official and informal targeting criteria. Village development committees and village chiefs are supposed to identify beneficiaries of the subsidized inputs based on the following official criteria: the poorest and most vulnerable households (measured by levels of food stocks or social categories such as widows, elderly, orphans, disabled); those with access to land (including those who mange to rent in); those with access to cash for the redeeming of the coupon; those with the capacity to adopt/utilize the technology. Other farm household characteristics that determine access and participation into the subsidy program include the proximity of households to tarred roads, towns and ADMARC[10] depots. Households close to the ADMARC depots are said to be more likely to receive subsidy coupons than those very far away (Doward *et al.*, 2008).

The outlined targeting criteria are discriminatory against poor female headed households even though they are the principal targets on the social vulnerability basis. Female headed households are resource poor in terms of access to both land and cash resources. The informal targeting criteria is mainly employed by village leaders to include households' relation to village leaders, number of years that the household has lived in the village and if the household had a civil servant and other various non-economic factors (Ricker-Gilbert and Jayne, 2009). The combination of formal and informal criteria reflects the differences in access to the fertilizer subsidy among the regions. However, some criteria such as farm size were most commonly used in most districts. Households with bigger land size were more likely to receive subsidized coupons than those with small land size.

3.6 Hypotheses

The general theoretical framework and literature evidence outlined above are helpful in generating the following testable hypotheses:

H1: Crop specific input subsidy to maize will reduce the diversity of crops grown in favor of maize.

H2: Crop specific input subsidies positively affect cropland allocation of the supported crop (maize) but will reduce cropland allocated to other major crops such as tobacco, cassava, ground nuts, sweet potatoes and ground nuts.

H3: There are systematic differences in the farm households' crop diversification levels between the regions and between male headed and female headed farm households.

[10] ADMARC is a statutory corporation responsible for purchasing and selling farmers' crop produce.

CHAPTER FOUR

4.0 Methodology

4.1 Survey methodology

Malawi is administratively divided into three regions with a total of 28 districts. The data used in this study are from a sample of smallholder farm households from Kasungu and Lilongwe districts in the central region and Zomba, Chiradzulu, Machinga and Thyolo districts in the southern region of Malawi (See annex 5 for map of the sample districts and study sites). The data set is part of the larger three-year (2006, 2007 and 2009) panel survey under the NOMA program[11]. The choice of these districts is purposive, typically to account for the differences in the farm households cropping pattern decisions between regions and agro-economic zones[12]. Kasungu and Lilongwe districts are in the mid altitude plateau agro-ecological zone in the central region while Zomba and Chiradzulu districts lie in the Shire Highlands and southern lake shore zone and Machinga district is in the middle and upper Shire River valley and southern lakeshore (NEC, NSO and IFPRI, 2001).

Sampling of the study sites was based on the primary sampling units (PSU) obtained for the national integrated household survey (IHS) of 2004 by the National Statistical Office of Malawi. In each of these districts: Thyolo, Chiradzulu and Machinga, at least two PSUs were randomly selected but for Zomba, Kasungu and Lilongwe districts, three PSUs were selected. At least 30 households were randomly selected from each PSU. A detailed questionnaire was administered for household and all plots information (refer to annex 6 for the questionnaire used in 2009 survey). The questionnaires were administered to the same households for the three rounds (2006, 2007 and 2009) with some addition of new households in 2007 and 2009

[11] NOMA program is a collaborative masters program between universities from the South (Malawi, Uganda and Ethiopia) and the Norwegian University of Life Sciences.

[12] Malawi is divided into eight agro-ecological zones and the sites in this paper fall into three of these zones.

to make up for attrition. There were also some additions and revisions to the questionnaire in 2007 and 2009 surveys. Geographical Positioning System (GPS) equipment was used to physically measure household land sizes. After cleaning the data and selection of relevant variables, a total sample size of 458 households was obtained for analysis in this study.

The farm households are multi-crop growers who choose among a wide set of crops commonly grown either in a mono-cropping or mixed cropping system. However, in order to have sufficient observations to model each crop choice-cropland allocations decision, the crop choices were put into the following five categories: maize, tobacco, ground nuts, root-tubers and pulses. These categories are analyzed as major crops assuming each of these choices is independent of the minor crops. Thus, for computational simplicity, no crop combinations are considered in this study; also because of incomplete availability of data on crop combinations.

4.2 Data problems

This study is based on household level analysis. However, most of the data were collected at plot level. It was computationally difficult to convert plot level variables into household level. In some study sites, respondent households seemed to be tired of being interviewed and they refused to be interviewed. This brings about attrition problems. To overcome such problems, new households were added for replacement. It was difficult to collect price data at household level for the various crops. It depends on whether the household participated in a given crop sales in order to be able obtain precise data.

4.3 Specification of the econometric models

Empirical analysis in this study investigates two key relationships in line with the research objectives and hypotheses (H1-H2). The first model examines the relationship between farm household's access to input subsidy and crop diversification. This model explores whether or not crop-specific subsidy to maize encourages the diversification in terms of number of crops grown. The second model explores how crop-specific input subsidy for maize affect farm household's crop choices and cropland allocation to other major crops such as tobacco, ground nuts and roots and tubers (sweet potatoes and cassava). In addition, study also assesses gender and regional variations in crop diversification levels.

Model I: Crop Diversification

Following Joshi *et al.* (2004), I use the Simpson Index of Diversification to assess the relationship between farm household's access to the input subsidy for maize and the level of crop diversification. The index is computed and interpreted as follows:

$$SID_{ht} = 1 - \sum_{j=1}^{S} \left(\frac{n_j}{N} \right)^2 \tag{8}$$

Where SID_{ht} refers to the Simpson Index of crop diversification for household h in crop growing season t

n_j denotes the proportionate share of cropland allocated to crop j in the farm households' total cropland area

N denotes the total land endowment for household h for allocating the different s number of crop activities.

The index values range between 0 and 1. The value of zero indicates complete crop specialization while the value of 1 indicates maximum diversification. A farm household with no diversity, having only one crop type on its plot (s), such that $s = 1$ and $n_j = N$, then its crop diversification index will be zero. When the farm household increases crop diversity, its crop diversification index (SID) will approach unity.

I then use the calculated index in a linear regression model as a dependent variable to examine how farm households' access to input subsidy and other key factors influence crop diversification. This model is used to test hypothesis (H1) by assessing the significance of access to input subsidy dummy variable in the diversification index equation, while controlling for household and plot characteristics and also district and regional heterogeneity. A positive (negative) significant coefficient for access to input subsidy indicates that access to input subsidy for maize encourages (discourages) crop diversification. This outcome is also checked with the crop choice and cropland allocation equation. The regression model is specified as follows:

$$SID_{ht} = X'_{ht}\beta + S_{ht}\alpha + e_{ht} \tag{9}$$

In equation (9), SID_{ht} denotes the level of crop diversification in crop growing season t for household h and it depends on household and plot characteristics, district and regional factors (dummies) denoted by a vector X_{ht} and farm households' access to input subsidy (S_{ht}). β is a vector of the corresponding coefficients for the explanatory variables (X_{ht}) and it is assumed to have no correlation with the disturbance term (e_{ht}). The disturbance term, e_{ht}, is assumed to have a normal distribution with zero mean and variance, σ_{ε}^{2}. The coefficient α measures the effect of farm households' access to input subsidy (S_{ht}) on the level of crop diversification.

Empirical estimation of equation (9) is based on pooled panel data using instrumentation techniques to control for the endogeneity of the access to input subsidy. With crop diversification as a continuous dependent variable and access to fertilizer subsidy as an endogenous binary variable, the treatment effects model is chosen as a suitable estimator in order to obtain unbiased and consistent estimates of effect of access to fertilizer subsidy. The treatment effects model uses the predicted probability of access to fertilizer subsidy obtained in the first stage and using it to estimate the crop diversification equation in the second stage. Thus, I use equation (9) in the second stage and the equation (10) is used as first stage.

However, the treatment effects model used in this estimation applies the maximum likelihood procedure while correcting for clustering at household level to ensure robustness of the results. The probability of farm household's access to fertilizer subsidy is modeled as a linear function of factors determining farm household's access to subsidy (W'_{it}) and the disturbance term (v_{jt}).

Factors determining access to fertilizer subsidy are derived from the government administrative targeting criteria which include female headed households, elderly headed households, land-poor households, asset- poor households. The probability of access to fertilizer subsidy is specified as unobserved latent variable (S_{it}^{*}) as follows:

$$S_{it}^{*} = W_{it}^{'}\delta + v_{jt} \tag{10}$$

Where the observed variable (S_{it}) is defined as

$$S_{it} = \begin{cases} 1 & if \quad S_{it}^{*} > 0 \quad participation \\ 0 & if \quad S_{it}^{*} \leq 0 \quad otherwise \end{cases} \tag{11}$$

The disturbance terms e_{ht} and v_{jt} are assumed to have a bivariate normal distribution structure with mean zero and the following covariance matrix:

$$\begin{bmatrix} \sigma & \rho \\ \rho & \sigma \end{bmatrix}$$

For the further details on the specific explanatory variables, their measurement and hypothesized effect refer to tables 3 and 4 and annex 1.

Model II: Crop Choice and Cropland Allocation Decisions

In keeping with the theoretical framework outlined in chapter three, I consider that the farm household faces a joint decision problem of choosing which crops to grow and how much land to allocate to each of the selected crops. In this modeling framework, this joint decision is made conditional on households' participation in the fertilizer subsidy program. Further, the farm household makes this decision based on the maximum expected utility (returns) from each crop choice/land allocation possibility.

Assuming that the total cropland available to the household for allocating to the different crop activities is fixed and considering that the probability of crop choice is implicit within the cropland allocation decision, I specify an econometric model for annual farm household's crop choice and cropland allocation decisions with equation (12) in order to test hypothesis (H2):

$$A_{ijt} = X_{ijt}^{'}\beta + S_{it}\alpha + e_{ijt}\,; \quad \text{for i=1, 2,.., N; j=1, 2,..., 5; t=1, 2,3} \tag{12}$$

Equation (12) represents the farm household's cropland allocation decision and it forms the basis for assessing factors determining crop choice and cropland allocation decisions. It states that the cropland share of the total cropland (A_{ijt}) that farm household i allocates to crop type j in crop growing season t, is a function of a vector of explanatory variables (household and plot characteristics, other crop type dummies, district and regional dummies), $X_{ijt}^{'}$ and farm households' access to fertilizer subsidy dummy (S_{it}). β is a vector of the corresponding coefficients for the explanatory variables, $X_{ijt}^{'}$ and it is assumed to have no correlation with the disturbance term (e_{ijt}). The disturbance term, e_{ijt}, is assumed to have a normal distribution with zero mean and variance (σ_{ε}^{2}). The coefficient α measures the effect of farm households' access to input subsidy coupon (S_{it}).

However, estimating equation (12) by ordinary least squares (OLS) method, yields inconsistent and inefficient estimates due to the problems of selectivity biases. Selectivity bias arises because some unobservable factors in the error term e_{ijt} are likely to induce a non-zero correlation with the access to fertilizer subsidy. The potential sources of selection biases are as follows: first, as discussed in section 3.2, farm households' access to input subsidy coupons is typically non-random and partially observable. Thus we observe program access for only the participant households, a non-random sub-sample. However, there are systematic differences in the observable and unobservable characteristics of both participants and nonparticipants of the program. Second, an endogenous dummy variable, access to fertilizer subsidy is included as a regressor in the different cropland allocation equations. Third, all crop choice/cropland allocation decisions are not observed for all households. Finally, fertilizer subsidy program participation and cropland allocation equations are estimated based on data collected only for the years 2006, 2007 and 2009, while the subsidy program run continuously from 2005/2006 through 2008/2009. Obviously, this presents a missing data problem.

I therefore develop an empirical estimation framework to correct for the possible selection biases. Literature provides several estimation approaches to handle this problem. However, drawing from Gebel and Pfeiffer (2007), I use the control function approach which I apply within the random effects generalized least squares (GLS) model to estimate the effect of fertilizer subsidy on cropland allocation patterns. The GLS estimation technique provides more efficient estimates in the presence of heteroskedasticity and autocorrelation arising from the cross-section and time series effects respectively (Woodridge, 2009).

In order to control for endogeneity, the control function approach is implemented as a two-stage estimation procedure as follows, the access to fertilizer subsidy equation (10) is estimated as a selection equation in the first stage in order to construct the control function that is included as one of the explanatory variables, together with the access to fertilizer dummy, in the estimation of the five cropland allocation GLS models (12) in the second stage. The control function is derived as a reduced form residual from equation (10), which is the difference between the predicted access to fertilizer subsidy and actual access to fertilizer subsidy. A panel probit estimator is used to estimate the access to fertilizer subsidy as selection equation

$$S_{it}^{*} = W_{it}^{'}\delta + v_{it}; \tag{10}$$

Where: $$S_{it} = \begin{cases} 1 \quad if \quad S_{it}^{*} > 0 \quad participation \\ 0 \quad if \quad S_{it}^{*} \leq 0 \quad otherwise \end{cases} \tag{11}$$

Again, in equation (10), farm household's access to fertilizer subsidy program (S_{it}^{*}), in a given crop growing season, *t*, depends on a set of explanatory variables denoted by vector W_{it} whose effect is measured by a vector of coefficients, δ. Like in equation (12), the disturbance term (v_{it}) is also assumed to be normally distributed with zero mean, variance, σ_{ε}^{2} and uncorrelated with W_{it}.

For the identification of the above specified model framework assuming that the joint distribution assumption of the disturbance terms hold, the "exclusion restriction" requirement is applied such that at least one variable that influences access to fertilizer subsidy in equation (10) is not included in the outcome equation (12) (Heckman *et al.* 1999).

On one hand, the estimated coefficients of the reduced form residual provide information on the selection unobserved factors influencing cropland allocation to the different five groups of crops. On the other hand, the coefficient of access to fertilizer subsidy explains the effect of farm household's access to fertilizer subsidy to cropland allocation. For the reduced form residual, the positive (negative) coefficient implies that the unobserved factors positively (negatively) influence cropland allocation towards (away) from a given crop, respectively. In other words, the positive coefficient indicates crop intensification while the negative coefficient indicates cropland expansion. The same interpretation applies for estimated parameters for the access to subsidy.

4.4 Definition of variables used in the analysis and the descriptive statistics

Table 3 presents the definitions and measurements of the variables used in the study analysis. I use the explanatory variables largely as control variables, in as much as these could also be the determining factors in cropland allocation and crop diversification decisions. The explanatory variables can be grouped into four categories.

The first category comprises the socio-economic and demographic factors which include age, sex and education of the head of household. These variables capture farm households' variations in experience in growing the different crops and their management capabilities and skills in crop production. Tropical livestock units and land size capture wealth endowment levels. Household labour captures the level of labour endowment while the consumer-worker ratio captures the ability of the household to bear different risks and shocks in crop production. Distance from home to the nearest market captures the extent of transaction costs in factor and commodity markets.

The second category comprises plot level factors such as the degree of land fragmentation and I use the number of plots as a proxy to this variable, average fertility level of the plot, slope of the plot and soil type. Third, I include the year dummies to capture variations in weather, factor and commodity prices and other economic factors across the study period. In addition, I also include the district dummies to capture the differences in access to infrastructural facilities, technology and services and the agro-ecological differences across the six districts.

Finally, the policy factor is represented by farm households' access to fertilizer subsidy. Table 3 provides a list of variables used in the analysis, their definitions and measurement. Table 4 presents the hypothesized effect of some of the key variables. The descriptive statistics of the variables used in the analysis are provided in annex 1.

Table 3: Variables used in the analysis, their definitions and measurement

Variable Name	Variable definition/measurement
Dependent variables	
Crop diversification index	Derived from the Simpson's index of diversity
Cropland allocation to maize	A fraction of the total land size allocated to maize
Cropland allocation to ground nuts	A fraction of the total land size allocated to ground nut
Cropland allocation to tobacco	A fraction of the total land size allocated to tobacco
Cropland allocation to root-tubers	A fraction of the total land size allocated to root-tubers
Cropland allocation pulses	A fraction of the total land size allocated to pulses
Explanatory variables	
Access to fertilizer subsidy	(1= Access, 0= No access)
Age of the head of household	Age of the head of household in units of years
Ederly headed household	1=age of headed of household >65 years, 0=age<65 years
Sex of the head of household	1=female, 0 =male
School years of the household head	Years of education of the head of household
Average plot fertility level	1= very fertile, 2=moderate fertile, 3=not fertile
Average slope	1=flat, 2=Slight, 3=steep
Home to plot distance	Average home to plot distance in kilometers
Average soil type	1=sand, 2=loam soil, 3= clay
Number of children	Number of children in the household

male labour	Size of household male labour force
female labour	Size of household female labour force
Household labour	Total size of household labour force
Consumer-worker ratio	Proportion of consumer units to household labour
Quality of house	Index for the aggregate quality of walls, roof type, and windows
Real asset value	Average household real asset value in Malawi Kwacha
Tropical livestock units	Index for household's total livestock units
Number of plots	Index for the degree of land fragmentation
Home to market distance	Distance from home to the nearest market point in kilometers
Land size	Total household land size in hectares
Region	1=southern region, 0=central region
District	Dummies: 1=Thyolo, 2=Zomba, 3= Chiradzulu, 4=Machinga, 5= Kasungu, 6= Lilongwe

Table 4: Hypothesized effect of some explanatory variables on crop diversification and cropland allocation

	Hypothesized effect of some variables					
Variable Name	Crop diversifi-cation.	Maize share	gnut share	tobacco share	roottubers shares	pulses share
Access to fertilizer subsidy	-	+	-	-	-	-
Age of the head of household	+/-					
Elderly headed household	+/-					
Sex of the head of household (1=female)		+	+	-	+	+
School years of the household head	+			+		
Average plot fertility level						
Average slope						
Home to plot distance	-			-		
Average soil type						
Number of children						
male labour						
female labour						
household labour	+	+	+	+	+	+
Consumer-worker ratio	+/-					
Quality of house	+					
Real asset value	+					
Tropical livestock units	+					
Number of plots	+					
Home to market distance in km	-					
Land size	+					
Land-labour ratio	-	-	-	-	-	-
Region (1=south)	+					
District						

Figures 3 and 4 present cropland allocation patterns in 2005/2006 and for the whole period of study (2006-2009). The figures show that there have been a reduction in the cropland allocated to maize and this reduction has been associated with an increase in the allocation of cropland to other crops except for legumes possibly because legume crops are usually mixed cropped with maize. Vegetable crops however have also registered a decrease in cropland shares.

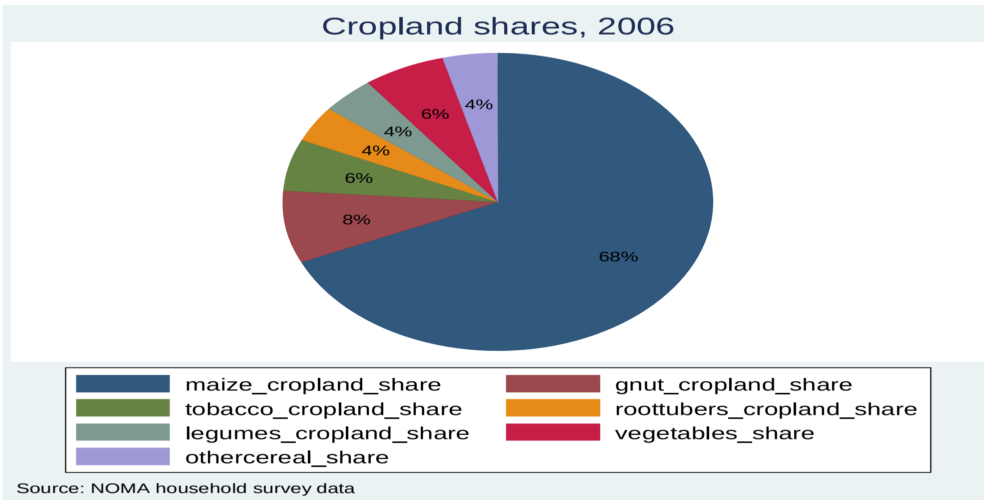

Figure 3: Percentage cropland shares across the six sample districts in 2006

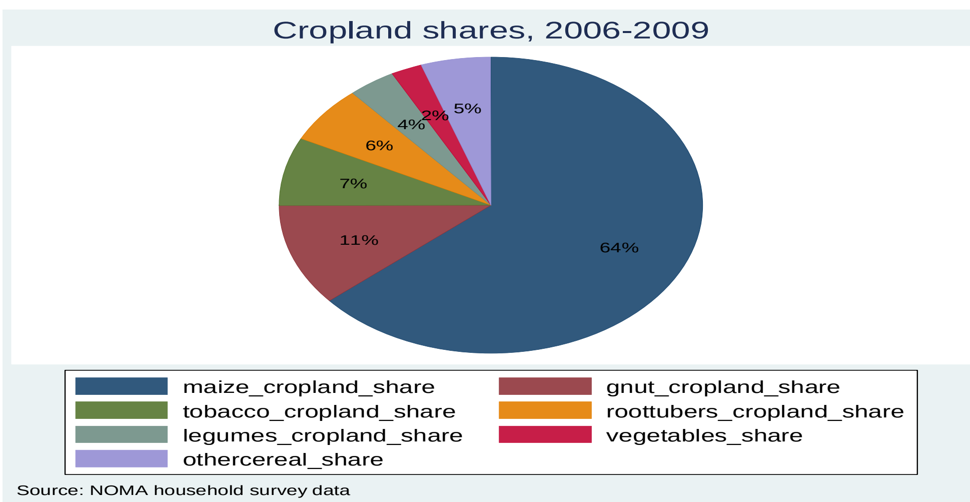

Figure 4: Percentage cropland shares across the six sample districts for the whole study period (2006-2009)

CHAPTER FIVE

5.0 Results and Discussion

5.1 Analysis of the key variable relationships

While the main focus of this chapter is on the econometric analysis[13] of the effect of fertilizer subsidy on farm households' crop diversification levels and cropland allocation patterns, it is useful to present also some additional descriptive analyses. These analyses provide a general picture of the relationships between farm households' access to fertilizer subsidy and their crop diversification levels, crop choices and cropland allocation patterns. The descriptive information also shows how farm households in the study sample differ by gender and region in terms of crop diversification and cropland allocation patterns.

Table 5 provides two-sample *t*-test results of some selected key variables. The results indicate that there are no statistically significant differences in the mean crop diversification levels between the farm households that accessed the fertilizer subsidy and those that did not. The results also show that farm households that accessed the fertilizer subsidy have a mean crop diversification level of 0.329 while those that did not access the fertilizer subsidy have a mean crop diversification level of 0.306, but this difference is not statistically significant. At regional level, the results show that southern region has a statistically significant lower mean crop diversification level (0.272) than the central region (0.385). In terms of gender, I find that there is a statistically significant difference between female headed households and male headed households. Female headed households have significantly lower mean crop diversification level (0.247) than their male counterparts (0.346). Figure 5 illustrates these gender and regional differentials crop diversification levels in a graph.

[13] All the regression analyses were done in STATA

Table 5: Two-Sample T-test of equal variance for key selected variables

Variable	No of observation	Mean	Standard error	t-statistic	p-value
Crop diversification index					
Access to fertilizer subsidy	683	0.329	0.009	-1.4805	0.1390
No access to fertilizer subsidy	424	0.306	0.012		
Maize area share of the total cropland					
Access to fertilizer subsidy	683	0.584	0.013	0.8923	0.3724
No access to fertilizer subsidy	424	0.606	0.017		
Ground nut area share of the total cropland					
Access to fertilizer subsidy	683	0.099	0.007	0.8923	0.3724
No access to fertilizer subsidy	424	0.110	0.010		
tobacco area share of the total cropland					
Access to fertilizer subsidy	683	0.075	0.008	-1.22377	0.2213
No access to fertilizer subsidy	424	0.061	0.007		
Root and tubers area share					
Access to fertilizer subsidy	683	0.060	0.006	-0.5877	0.5568
No access to fertilizer subsidy	424	0.055	0.007		
Crop diversification index					
Female headed households	285	0.247	0.015	5.7745	0.0000
Male headed households	822	0.346	0.009		
Crop diversification index					
Southern region	475	0.035	0.011	7.6214	0.0000
Central region	632	0.272	0.010		

Source: NOMA household survey sample data

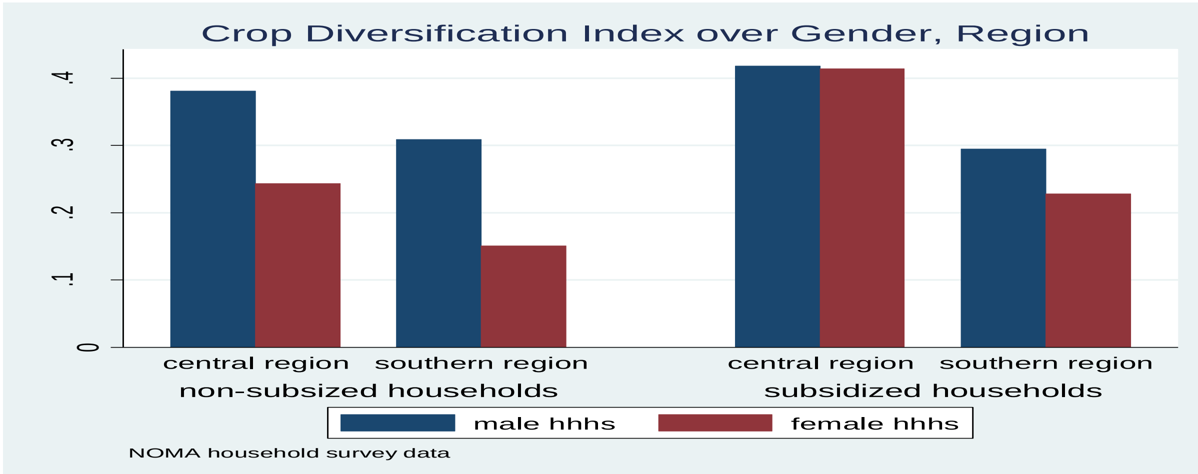

Figure 5: Mean farm household crop diversification over gender of head of household and region

In terms of cropland allocation to maize, ground nut, tobacco and roots and tubers, the *t*-test results in table 5 show that there are no statistically significant differences in all these cases between the households that accessed fertilizer subsidy and those that did not. However, figure 6 shows that there are some variations in the cropland allocation patterns across years.

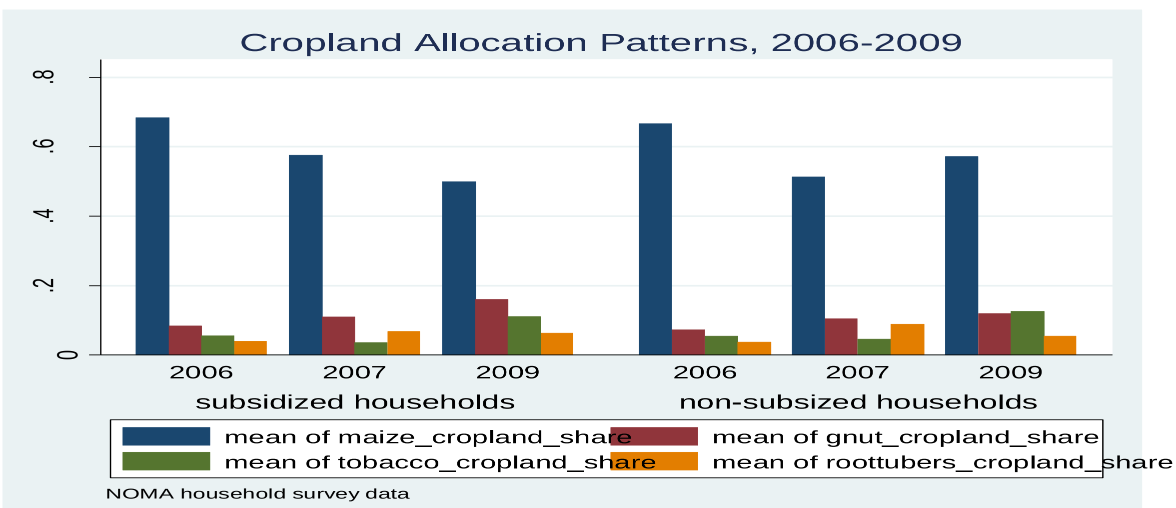

Figure 6: Cropland allocation pattern between fertilizer subsidized households and non-subsidized households

Based on these *t*-test results and the graphical analyses, it may therefore not be appropriate to make firm claims and conclusions regarding the relationships between farm household's crop diversification levels, cropland allocation patterns and their access to input subsidy at this point. This is because we do not control for many other factors both at farm household and district levels that may also explain changes in farm cropland allocation patterns and crop diversification. We would therefore rely on the econometric estimation results for any inferences and implications.

5.2 Effect of fertilizer subsidy on farm households' crop diversification level

The crop diversification equation (9) was estimated using the treatment effects model based on pooled panel data. The treatment effects model simultaneously estimates crop diversification (outcome) equation and the access to fertilizer subsidy (treatment) equation by assuming that the error terms of these two equations have a particular joint normal distribution (Greene, 2003). This helps to control for endogeneity bias arising from the use of access to subsidy dummy variable in the estimation of crop diversification equation.

The likelihood ratio test of independence of equations gives a p-value of 0.0022 indicating that *rho* is significantly different from zero and therefore the endogeneity bias has been controlled for. Quality of the house and number of children were used as relevant instrumental variables for the participation equation. Validity of these instruments was tested with instrumental variable regression (ivreg), as this was not possible with the treatment effects model. These two variables were both found to be statistically significant and positive at 5 percent level of significance. A positive sign for the estimated coefficient for quality of house suggests that the targeting process is biased towards the better off households. These findings are in accord with other earlier study findings on the impacts of fertilizer subsidy program in Malawi (Ricker-Gilbert and Jayne, 2009; Doward *et al.*, 2008).

Table 6 presents the estimation results of the treatment effects model. Estimation was done with robust standard errors to ensure robustness of results. Estimation results for the selection equations (access to fertilizer subsidy) are presented separately in annex 2.

Table 6: Treatment effects model for the effect of access to fertilizer subsidy on crop diversification level

Independent Variable	Parameter Estimates (Outcome Equation)	Robust Standard error
Log of square of age of head of household	-0.033	0.070
age of head of household in years	0.001	0.003
sex of head of household	-0.035	0.023
land-labor ratio	0.009	0.034
land size	-0.011	0.013
Education level of head of household	-0.0002	0.002
Average plot fertility level 2 (average fertile)	-0.001	0.018
Average plot fertility level 3 (not fertile)	-0.005	0.021
Average slope 2 (slight)	-0.008	0.017
Average slope 3 (steep)	0.011	0.041
Average soil type 2 (loam soil)	0.009	0.017
Average soil type 3 (clay soil)	0.024	0.021
Average home to plot distance in km	-0.008*	0.005
Consumer-worker ratio	0.090**	0.039
male labour	-0.009	0.009
female labour	0.022*	0.012
Total household livestock units	-0.011**	0.006
Log of household total real asset value (MK)	0.011**	0.005
Degree of land fragmentation	0.086***	0.006
Log of home to nearest market distance in km	0.002	0.006
year_2007 (dummy)	-0.003	0.032
year_2009 (dummy)	-0.010	0.036
Region (1=south, 0= central)	-0.203***	0.037
Zomba District (dummy)	0.068**	0.032
Chiradzulu District (dummy)	0.012	0.046
Machinga District (dummy)	0.190***	0.045
Kasungu District (dummy)	-0.034	0.026
Access to fertilize subsidy (dummy)	0.287***	0.081
Constant	-0.046	0.393
athrho constant	-0.921***	0.301
lnsigma constant	-1.484***	0.090
prob>chi2	0.0000	
Wald Chi2 (26)	470.29	
Log peudolikelihood ratio	-257.795	
Number of observations of equations	710	

Estimates are presented as marginal effects at the mean values of the explanatory variables. Significant levels (* 10 percent, **5 percent, ***1 percent). Log likelihood test of independence of equations (rho=0): chi2(1)= 9.35 Prob>chi2=0.0022.Lilongwe District and age of household in the 2nd stage estimation were dropped because of multicollinearity. For the categorical dummy variables, the base categories were automatically dropped. These are: year=2006, district=Thyolo, Soil type= soil type 1(sandy soil), slope= slope1 (flat), plot fertility= plot fertility level 1(very fertile)

These results reveal that several factors, both at farm and policy level influence the level of crop diversification at farm household level. First, contrary to the hypothesis, the findings provide strong evidence that there is a statistically significant positive relationship between the crop-specific fertilizer subsidy to maize and the level of farm household crop diversification. While controlling for farm household socio-economic and plot characteristics, the results indicate that farm households' participation in the fertilizer subsidy is associated with an increase in the crop diversification level of about 29 percent at 1 percent level of significance, *ceteris paribus*.

These findings support the theoretical argument that crop specific subsidies encourage crop diversification, possibly through land intensification in favor of the subsidized crop. According to Smale (1995), technology-induced land intensification, which in the case of Malawi is supported by fertilizer subsidies, can help farmers to release the unused land for the cultivation of other crops, subject to availability of other input resources needed to support the growing of these other crops. Thus the outcome rejects the null hypothesis that crop-specific subsidies will discourage crop diversification in favor of the subsidized crop(s).

This outcome has implications for the overall household income diversification and therefore welfare in general. The reason is that in Malawi, a great part of the rural household income is derived from crop sales[14] (Malawi Government and World Bank, 2006). Therefore more crop diversification may also imply an improvement in income diversification as crop income will now be derived from more crops, assuming that there is an available functioning commodity market within the district and /or at village community level. Income diversification in turn

[14] Non-farm income sources for rural Malawian households are limited to *ganyu* (casual labour). Three quarter of farm household income is derived from agriculture (Malawi Government and World Bank, 2006)

implies improved household welfare and lessened vulnerability to risks and shocks such as price fluctuation, crop failure due to drought or pest attacks. As the same, improved income diversification can enhance household's resilience to these risks and shocks.

On the other hand, it is also important to recognize the effect of control variables in the model. In line with findings in Wu and Brorsen (1994), my results show that farm household and plot level factors are also statistically significant in influencing farm household crop diversification level. In terms of farm household socio-economic variables, the regression results indicate that the gender of the head of household, total household land size, consumer-worker ratio and the number of livestock units are statistically significant in influencing the level of crop diversification at household level, *ceteris paribus*.

I also find that the number of plots, a proxy for the degree of land fragmentation and the distance from home to the plot are similarly significant influencing factors of crop diversification level. However, the study findings show that age of the head of household, education level of the household head, land quality variables (soil types, slope of the plot and the general plot fertility level), distance from home to the nearest market and the year dummies did not have statistically significant effect on the level of farm household's crop diversification.

The consumer-worker ratio, a proxy for the ability of the household to bear risk and shocks[15], was found to be positively correlated with the level of farm households' crop diversification; implying that less able farm households will diversify their crop portfolios to hedge against risks and shocks. As expected, total household land size and the degree of land fragmentation were found to have a statistically positive significant influence on the farm household's crop diversification level. The effect of land fragmentation may imply that crop diversification could be one of the adaptation measures that households employ in response to the problem of land pressure due to the rising population density in the country.

[15] The higher the consumer-worker ratio, the less capable the household is in managing the various risks and shocks.

The results show that there are no systematic differences in crop diversification between male and female headed households. Female headed households are less likely to diversify their crop portfolios than male headed households, but such differences are not statistically significant. However, significant differences in crop diversification exit at regional level. Southern region is associated with less crop diversification than the central region. The lower level of crop diversification in the southern region could indicate that fewer households grow cash crops such as tobacco and ground nuts than it is the case in the central region.

One limitation in the use of the Simpson's index for measuring the level of crop diversification is that as an overall indicator, it fails to account for the balance in cropland cultivated among the crops (Duc and Waibel, 2009). It is also difficult to infer from the index to which crop (s) most of the household's resources are flowing. The next section therefore provides an analysis of the relationship between farm household's access to fertilizer and crop choice and cropland allocation patterns.

5.3 Effect of fertilizer subsidy on farm households' crop choice and cropland allocation patterns

Under the assumption of fixed total land input and multi-crop setting, farm households' cropland allocation decisions involve a zero-sum game such that an increase in the land allocated to one crop results in a reduction in the amount of land allocated to the other crops (Perz, 2002). To investigate this phenomenon, the control function approach was applied within the random effects generalized least squares (GLS) model to estimate the effect of fertilizer subsidy on cropland allocation patterns using equation (12), and the analysis was based on pooled panel data. In order to control for the endogeneity of the access to fertilizer subsidy variable, the reduced form residual and the access to fertilizer subsidy dummy itself were included in the GLS model as regressors.

A panel probit estimator was used to estimate the access to fertilizer subsidy as selection equation (10) in the first stage, after which the reduced from residual was obtained and a GLS estimator was used to estimate the five cropland share equations in the second stage. The regression results of panel probit model are provided in table 8 in the annex section. Table 7 presents the GLS-control function model results for the effect of access to fertilizer subsidy on cropland allocation for maize, ground nuts, tobacco, root-tubers and legumes. Regression results for cropland shares for other cereals (millet, sorghum and rice) and vegetable crops have not been included because the models were statistically insignificant. Full details for the explanatory variables used in the GLS model regression results are provided in the annex 4.

Table 7: GLS-Control function model results for the effect of access to fertilizer subsidy on cropland allocation

Dependent Variable	**Parameter Estimates (Access to fertilizer subsidy)**	**Standard error**
Maize cropland share	-0.104**	0.051
Ground nut cropland share	0.010	0.008
Tobacco cropland share	0.036***	0.012
Root-tubers cropland share	0. 046***	0.012
Pulses cropland share	-0.025***	0.006
prob>chi2	0.0000	
Number of observations of equations	702[16]	

Significant levels (* 10 percent, **5 percent, ***1 percent).

The results in Table 7 show that for the estimated cropland shares equations of ground nut, tobacco and tubers, access to fertilizer subsidy variable has a positive effect while the coefficient for fertilizer subsidy in the maize and pulses cropland share estimated equations are negative. The negative coefficient for fertilizer subsidy in the estimated maize and pulses cropland share equations suggests that there is cropland intensification in favour of maize and legumes. On the other hand, the positive coefficient for subsidy in the ground nut, tobacco and roots/tubers models indicate that cropland allocation these crops are expanding. Pulses (legumes) are mostly inter-planted with maize; it is therefore not surprising to obtain a negative coefficient for pulses. Hence this confirms that farm households' access to fertilizer subsidy is positively associated with intensification for maize. The regression results therefore

[16] Equation for pluses was estimates with 399 observations

provide evidence against the null hypothesis that maize-specific subsidies will increase cropland allocation for maize and reduce the allocation to other major crops.

In the maize cropland share estimated equation, farm households' participation in the fertilizer subsidy program is associated with a decrease in cropland allocated to maize of 10 percent at 5 percent significance level, *ceteris paribus*. The cropland share estimated equation for tobacco and root-tubers indicate that access to fertilizer subsidy is associated with 4 and 5 percent increase in cropland allocated to tobacco and root-tubers respectively, at 1 percent level of significance, *ceteris paribus*. However, the positive effect of access to fertilizer subsidy in the cropland allocation to ground nut cropland share equation is not statistically significant. Intuitively, it is expected that the decrease in the cropland share to maize should come with a corresponding increment in the cropland land shares to other crops. This is not reflected in this analysis as not all crops were estimated. Small other crops including vegetables were left out in the analysis due to insufficient number of observations and seasonal differences[17].

In accounting for the effect of control variables on farm households' cropland allocation pattern; the positive (negative) coefficient for the reduced form residuals implies that unobserved factors lead to increased cropland allocation to maize and pulses but a reduction in the cropland allocation to ground nuts, tobacco and root-tubers respectively. The findings further show that the household and plot level factors statistically and significantly contribute to explaining farm households' crop choice and cropland allocation behavior. At household level, the findings show that the size of total household land holdings encourages cropland allocation away from maize in favour of other crops including ground nuts, tobacco and root-tubers at 1 percent level of significance, holding all other factors constant. For maize, the coefficient for land size is positive but not statistically significant.

Other household and plot level factors including distance from home to plot, soil quality, education, age of head of household, distance from home to market, sex of headed of

[17] Mostly vegetables are grown in winter, while all other crops are grown in summer.

household, district and year dummies, etc have either statistically significant or insignificant but with mixed results in terms of their influence on cropland allocation to the different crops (see annex 4 for details).

In reconciling the crop diversification and cropland allocation regression results, the findings suggest that there is generally a positive correlation between cropland intensification in favour of maize and the farm household crop diversification levels. The study findings revealed that more cropland intensification in favour of maize is associated with increased crop diversification levels. These results are in line with the findings in (Holden *et al*., 2004) in Ethiopia and in Mexico where an increase in the subsidy was found to have a corresponding increase in cereal/corn production and vice versa (Doroodian and Boyd, 1999).

Crop prices constitute one of the major determinants of cropland allocation to various crops at household level. However, this study captured more than twenty crops and price data for all of the crops could not be collected at household level, resulting in missing observations for crop prices. In the context of imperfect factor and commodity markets, the study therefore assumes the use of district and household level factors determining commodity prices considering that crop prices during the study period were relatively stable.

The district and household level factors influence not only the magnitude of transaction costs but also farm household's marketing capacities and therefore have been used to reflect the role of crop prices in determining household cropland allocation decisions in the analysis. The statistical significance of the district dummies verifies the importance of accounting for such factors in the analysis.

CHAPTER SIX

6.0 Conclusions and recommendations for future research

This study has investigated three main issues related to how crop-specific subsidies affect farm households cropping pattern decisions. First, I have analyzed how fertilizer subsidies affect farm households' crop diversification levels. Then, I explored how this crop-specific subsidy to maize affects farm households' cropland allocation to maize, ground nuts, tobacco and root-tuber crops (cassava and sweet potato). Finally, I assessed gender and regional differences in the farm households' crop diversification between the two regions and between male and female headed households.

Treatment effects model and the GLS estimation techniques have been used to analyze the effect of fertilizer subsidies on farm households' crop choice/cropland allocation patterns and crop diversification. I find that farm households' cropland allocation patterns and the subsequent crop diversification levels are generally sensitive to fertilizer subsidy programs. The econometric results strongly reject the first two null hypotheses while being in line with the third null hypothesis. These empirical findings suggest that crop-specific fertilizer subsidies to maize are associated with 1) an increase the diversity of crops grown; and 2) a decrease in the cropland allocated to maize while increasing the cropland allocation for the other crops especially ground nuts, tobacco and tubers. These study findings are in line with the Malawi Government's expected outcomes for the implementation of such a policy program (Malawi Government, 2006b).

Learning from the context of Malawi's program of fertilizer subsidy, the study results illustrate that fertilizer subsidy can positively contribute to promoting farm households' crop diversification level through crop intensification in favour of the supported crop, maize. The extent to which farm households' cropping patterns change in response to economic incentives such as fertilizer subsidy, should therefore form part of the analysis of the impact of fertilizer subsidies on crop yields. Other factors were also statistically significant in influencing cropland allocation to the different crops. This suggests that should also be considered when analyzing the effect of a policy on farm household crop diversification and cropping patterns.

On gender differences, the empirical findings indicate that there are no significant differences in crop diversification between male and female headed households. However, in terms of cropland allocation, the results show that female headed households are associated with allocating more cropland to maize and pulses than to tobacco and roots-tubers crops. These results are not surprising considering that women are said to prefer more food crop cultivation than cash crops. On the other hand, the results could suggest that the root-tuber crops could also considered new cash crops as women are allocating less cropland to these crops.

There are significant regional differences in crop diversification. Southern region is associated with less crop diversification than the central region. The lower level of crop diversification in the southern region could be explained by the fact that there are fewer households that grow more of other cash crops such as tobacco and ground nuts than it is the case in the central region.

On a cautionary note, the interpretation of the results in this study should bear in mind that the econometric estimation of the models does not control for crop prices which are also an important determinant of cropland allocation decisions and crop diversification. It is expected that big changes in prices may significantly affect the study outcomes. Analysis of cropland allocation in this study did not extend to crop combinations such as mixed and inter-cropping systems due to partial availability of data on crop areas. In practice, many farmers may actually combine two or more crops on the same plot. Therefore analysis based on crop mixtures and intercropping systems would be much more informative and as such, the quantitative results in this study should only be regarded as suggestive and not conclusive.

As an extension to this empirical analysis, it would therefore be interesting to investigate the effect of fertilizer subsidy on maize in a mixed crop setting. Furthermore, changes in cropland allocation patterns to various crops will have implications for input resource allocation decisions for labour and other crop inputs. It would therefore be interesting to extend this study to the analysis of farm households input resource re-allocation behavior as a response to their access to fertilizer subsidy. Simulations can also be done to analyze the extent to which one crop displaces the other. Subsequent similar analyses are also encouraged to include crop prices. Finally, it would also be worth exploring the relationship between crop intensification and productivity, especially of the crops other than maize; and relate the outcomes with the farm size-productivity relationship.

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Annexes

Annex 1: Descriptive statistics of the variables used in the analysis

Variable Name	Mean	Min.	Max.
Dependent Variables			
Crop diversification index	0.320	0	0.774
Maize cropland share	0.592	0	1
gnut_cropland share	0.103	0	1
tobacco cropland share	0.069	0	1
Pulses cropland share	0.055	0	1.875
Roottuber cropland share	0.058	0	0.968
Explanatory Variables			
Access to fertilizer subsidy	0.617	0	1
Year	2007.2	2006	2009
Region	0.573	0	1
Thyolo District	0.135	0	1
Zomba District	0.211	0	1
Chiradzulu District	0.104	0	1
Machinga District	0.123	0	1
Kasungu District	0.230	0	1
Lilongwe District	0.198	0	1
Average plot fertility level 1	0.201	0	1
Average plot fertility level 2	0.520	0	1
Average plot fertility level 3	0.279	0	1
Average slope 1	0.689	0	1
Average slope 2	0.271	0	1
Average slope 3	0.040	0	1
Average soil type 1	0.311	0	1
Average soil type 2	0.497	0	1
Average soil type 3	0.191	0	1
Average home to plot distance in km	0.445	0	22.505
Sex of the head of household	0.257	0	1
Age of household head	44.511	16	85
School years of the household head	4.712	0	17
Male labour	1.612	0	8

Female labour	1.380	0	7.7
Household labour	3.011	0.5	12.1
Number of children	2.655	0	10
Consumer –worker ratio	1.290	0.483	3
Quality of house	8.790	4	16
Real asset value	8536.647	1.591	311712.4
Tropical livestock units	1.267	0	23.6
Number of plots	3.268	0	12
Home to market distance	17.995	0	400
Elderly headed household	0.113	0	1
land -labor ratio	0.441	0.006	4.519
Land size	1.184	0.015	10

Note: All variables have 1102 observations, except for pulses cropland share with 789 observations and home to plot distance with 1035 observations.

Annex 2: Selection Equation Estimates for the Treatment Effect Model

Independent variable	Parameter estimates (Selection Equation)	Standard Error
Elderly headed household	-0.020	0.154
sex of head of household	-0.031	0.119
Household total land size in hectares	0.016	(0.051)
Number of children	0.063*	0.038
Quality of house	0.044**	0.017
Total household livestock units	0.034	0.032
Consumer-worker ratio	-0.419*	0.241
year_2007 (dummy)	0.162	0.160
year_2009 (dummy)	0.470***	0.163
Zomba District (dummy)	-0.148	(0.186)
Chiradzulu District (dummy)	-0.490**	0.238
Machinga District (dummy)	-0.791***	0.237
Kasungu District (dummy)	-0.720***	0.185
Lilongwe District (dummy)	-0.758***	0.188
Constant	0.528	0.402
prob>chi2	0.000	
Wald Chi2 (26)	58.31	
Log peudolikelihood ratio	-434.5365	
Number of observations of equations	710	

Estimates are presented as marginal effects at the mean values of the explanatory variables.

Significant levels (* 10 percent, **5 percent, ***1 percent). Standard errors are provided in parenthesis

For the categorical dummy variables, the base categories were automatically dropped. These are: year=2006, district=Thyolo,

Annex 3: Panel Probit Model Results for the Access to Fertilizer Subsidy

Independent Variable	Parameter estimate
	b/se
Quality of house	0.049***
	(0.018)
Number of children	0.066**
	(0.034)
Sex of head of household (1=female)	-0.038
	(0.107)
Land size in ha	0.013
	(0.044)
Consumer worker ratio	-0.343
	(0.233)
Zomba District	-0.185
	(0.166)
Chiradzulu District	-0.728***
	(0.189)
Machinga District	-0.680***
	(0.179)
Kasungu District	-0.757***
	(0.165)
Lilongwe District	-0.840***
	(0.164)
Year 2007	0.143
	(0.096)
Year 2009	0.389***
	(0.105)
Tropical livestock units	0.022
	(0.021)
Log of age of household head	0.046
	(0.165)
Log age squared	0.014
	(0.108)
Constant	0.249
	(0.668)
lnsig2u constant	-2.205***
	(0.678)
prob>chi2	0.000
Number of observations	1085

Significant levels (* 10 percent, **5 percent, ***1 percent), Standard errors are provided in parenthesis

For the categorical dummy variables, the base categories were automatically dropped. These are: year=2006, district=Thyolo, Soil type= soil type 1(sandy soil), slope= slope1 (flat), plot fertility= plot fertility level 1(very fertile)

Annex 4: GLS model regression results of cropland shares equations for maize, gnut, tobacco, root-tubers and pulses

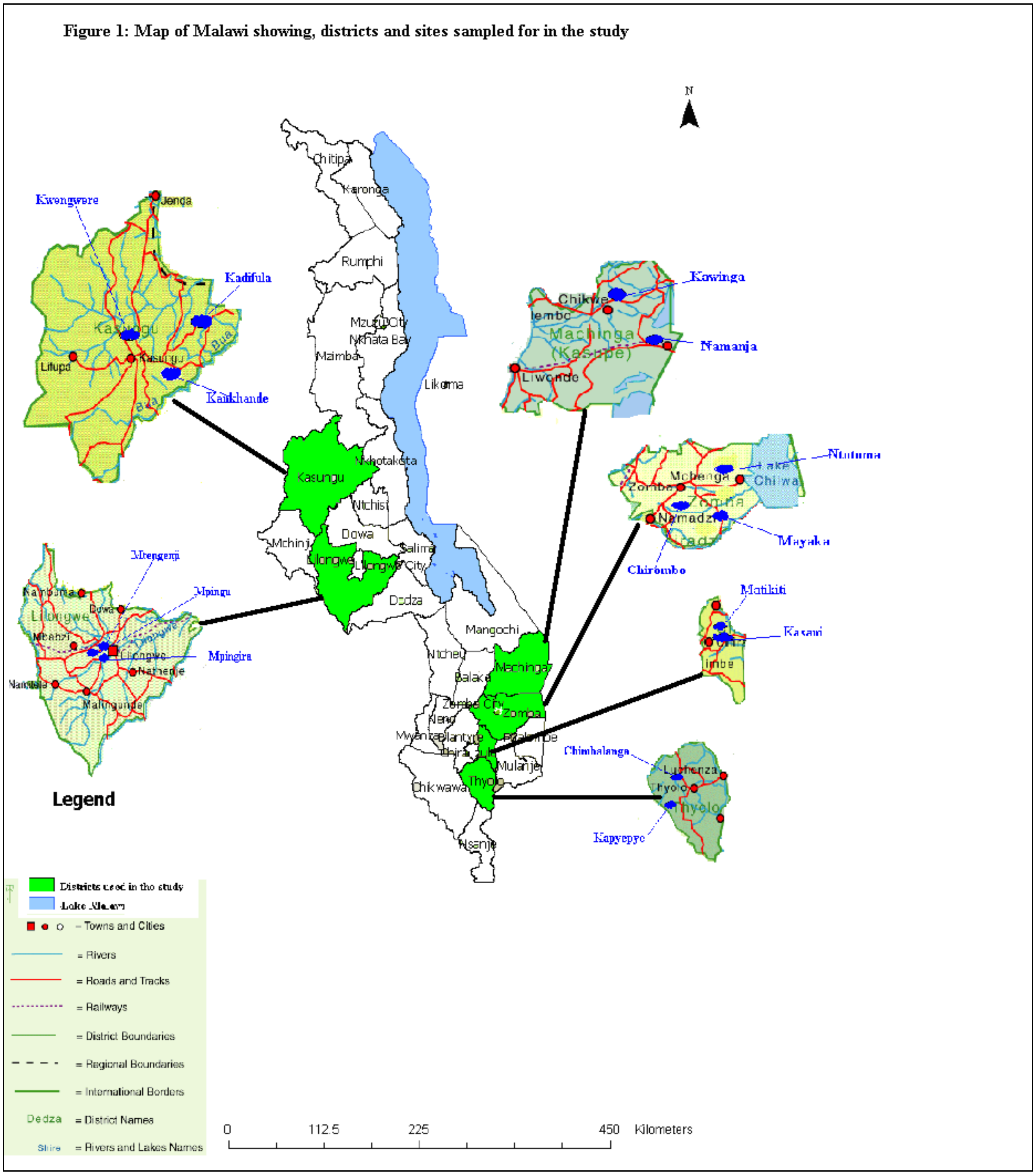
Independent Variable	Maize	Gnut	tobacco	root-tubers	pulses
	b/se	b/se	b/se	b/se	b/se
Access to fertilizer subsidy (1=access)	-0.104**	0.010	0.036***	0.046***	-0.025***
	(0.051)	(0.008)	(0.012)	(0.012)	(0.010)
Reduced form error	0.081	-0.009	-0.021*	-0.050***	0.034***
	(0.049)	(0.008)	(0.011)	(0.012)	(0.011)
Landsize in ha	0.004	-0.001	0.012***	-0.004**	0.004**
	(0.008)	(0.002)	(0.002)	(0.002)	(0.002)
Tropical livestock units	0.015***	0.000	0.003***	-0.004***	-0.002**
	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Number of plots	-0.084***	0.002*	0.001	0.020***	0.013***
	(0.005)	(0.001)	(0.001)	(0.001)	(0.002)
log_market distance	0.019***	-0.002	0.010***	-0.004***	-0.002
	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)
School years of head of household	0.005**	0.000	0.000	-0.002***	-0.000
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Year 2007	-0.052**	0.003	-0.022***	0.036***	0.007
	(0.026)	(0.004)	(0.005)	(0.004)	(0.005)
Year 2009	-0.050	0.006	0.014**	0.021***	0.000
	(0.037)	(0.007)	(0.007)	(0.007)	(0.000)
Average plot fertility level 2	0.013	0.003	-0.016***	0.001	-0.008**
	(0.018)	(0.003)	(0.003)	(0.003)	(0.003)
Average plot fertility level 3	0.016	0.006*	-0.024***	-0.001	-0.016***
	(0.023)	(0.003)	(0.004)	(0.004)	(0.004)
Average slope 2	0.019	0.001	0.004	0.001	0.006***
	(0.016)	(0.003)	(0.003)	(0.003)	(0.002)
Average slope 3	-0.068	0.000	0.007	0.038***	-0.032
	(0.046)	(0.004)	(0.006)	(0.010)	(0.034)
Average soil type 2	-0.046***	-0.002	0.029***	-0.004	0.005*
	(0.016)	(0.002)	(0.003)	(0.003)	(0.003)
Average soil type 3	-0.070***	0.002	0.034***	-0.034***	-0.002

	(0.021)	(0.003)	(0.004)	(0.004)	(0.004)
Zomba District	-0.019	0.006	0.066***	0.005	-0.080***
	(0.033)	(0.004)	(0.010)	(0.008)	(0.026)
Chiradzulu District	0.028	0.010	0.086***	0.030***	-0.102***
	(0.042)	(0.006)	(0.009)	(0.011)	(0.027)
Machinga District	-0.117**	0.014	0.032***	0.029**	-0.104***
	(0.046)	(0.009)	(0.009)	(0.013)	(0.027)
Kasungu District	-0.184***	0.183***	0.095***	0.054***	-0.082***
	(0.044)	(0.014)	(0.010)	(0.013)	(0.027)
Lilongwe District	-0.181***	0.261***	0.069***	0.035***	-0.109***
	(0.051)	(0.013)	(0.012)	(0.013)	(0.028)
Plot distance	0.002	0.000	-0.004***	-0.000	0.001***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.000)
Log of age of household head	-0.050***	0.000	0.011***	0.003	0.005**
	(0.008)	(0.002)	(0.004)	(0.002)	(0.002)
Log of age squared	0.014	0.001	-0.004	0.012***	-0.012***
	(0.014)	(0.002)	(0.003)	(0.003)	(0.002)
Sex of head of household (1= female)	0.085***	0.002	-0.026***	-0.009**	0.033***
	(0.019)	(0.003)	(0.003)	(0.004)	(0.005)
Consumer worker ratio	-0.059*	0.005	0.026***	0.012**	-0.006
	(0.034)	(0.004)	(0.007)	(0.006)	(0.007)
Household labour	0.012*	0.000	0.002*	-0.010***	0.002
	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	1.062***	-0.034	-0.143***	-0.149***	0.146***
	(0.138)	(0.022)	(0.027)	(0.021)	(0.031)
prob>chi2	0.000	0.000	0.000	0.000	0.000
Number of observations	699.000	699.000	699.000	699.000	399.000

Significant levels (* 10 percent, **5 percent, ***1 percent), Standard errors are provided in parenthesis

For the categorical dummy variables, the base categories were automatically dropped. These are: year=2006, district=Thyolo, Soil type= soil type 1(sandy soil), slope= slope1 (flat), plot fertility= plot fertility level 1(very fertile)

Annex 5: Map of Malawi showing districts and sites sampled in the study



Source: Lunduka (2010)

Annex 6: 2009 Questionnaire for NOMA Household survey