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The impact of farm input subsidies on household welfare in Malawi

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Abstract

This paper analyzes the impact of a fertilizer subsidy program in Malawi on household food security and the total annual per capita consumption expenditure. The study uses the nationally representative two-wave Integrated Household Panel Survey (IHPS) data of 2010 and 2013. Fixed effect and correlated random effect quantile regression models are employed to estimate the conditional mean and heterogeneous effects of subsidized fertilizer. The study finds a positive effect of subsidized fertilizer on the availability of kilocalories per capita per day, the number of months of household food security, and the probability of a household being food secure over the whole year. The study also finds heterogeneous effects of the program with relatively higher impact on food secure households. However, the study finds no evidence of effects on annual per capita consumption expenditure. These results suggests that farm input subsidy programs could be beneficial for the improvement of food security, particularly of larger food crop producers, but such programs are less useful when the main policy objective is to decrease poverty.

Key words: Farm Input Subsidies; Food Security; Quantile Regression; Malawi.

JEL Classification: Q1, Q18

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1. Introduction

Most smallholder farmers in developing countries are subsistence oriented, cultivating food crops mainly for household consumption and growing a small proportion of cash crops to meet non-food household needs. Furthermore, 75 per cent of rural people in developing countries are poor and food insecure, and therefore, improvement of agricultural production is the main strategy to reduce rural poverty and food insecurity (World Bank, 2007). Among several factors that impede such a livelihood strategy is the low use of improved farm inputs in crop production, especially fertilizer and hybrid seeds (Morris *et al.,* 2007). Druilhe and Barreiro-Hurle (2012) argue that with low household incomes and limited income sources most smallholder farmers, especially in Africa, are unable to self-finance the purchase of adequate improved farm inputs to produce enough food and cash crops to meet household food and income security requirements. In order to promote the use of fertilizer and hybrid seeds, subsidies are one of the most pervasive policy instruments used by most governments in developing countries (World Bank, 2007).

Prior to the implementation of structural adjustment and stabilization programs in the 1980s and early1990s, which were promoted by the World Bank and the International Monetary Fund (IMF), most governments in sub-Saharan Africa (SSA) implemented farm input subsidies, which were phased out to conform to the agreements with the World Bank and IMF (Morris *et al.*, 2007; Druilhe and Barreiro-Hurle, 2012). However, in recent years, many countries in SSA have reintroduced these subsidies, including Malawi (DANIDA, 2011; Druilhe and Barreiro-Hurle, 2012; Ricker- Gilbert *et al.*, 2013).

Recent studies on the reintroduced farm input subsidies in SSA have focused on their direct and general equilibrium impact. Direct impact studies include effects on: (i) maize output (Chibwana, *et al.,* 2010; Holden and Lunduka, 2010; Ricker-Gilbert and Jayne, 2011); (ii) input markets (Xu, *et al.,* 2009; Chibwana *et al.*, 2010; Ricker-Gilbert, *et al.*, 2011); (iii) land allocation (Holden and Lunduka, 2010; Chibwana, *et al.,* 2012) and (iv) household welfare, including food security (Dorward and Chirwa, 2011); income from crops production, livestock and asset worth (Ricker-Gilbert and Jayne, 2011; 2012); school attendance, health, household shocks and stress (Chirwa, *et al.,* 2013). Studies investigating general equilibrium effects have focused on maize prices, GDP and agricultural sector growth (Chirwa *et al.*, 2013, Ricker-Gilbert *et al.*, 2013).

The Malawi Government has reintroduced a large scale farm input subsidy program since the 2005/06 agricultural season and use it as a policy tool to improve maize production, productivity, food security and household income from crop sales. However, despite the implementation of the program, food insecurity and poverty are still wide-spread among smallholder farmers. This raises doubts about the effectiveness and sustainability of the program. Recent studies show that poverty rate has only decreased by two percent from 52.4 percent in 2004/05 to 50.7 percent in 2010/2011 (GOM, 2012b). A comparison of household food security during the same period shows slight improvement. According to the GOM (2005; 2012b), 57 percent of households subjectively assessed themselves to be food insecure in 2004/2005, while in 2010/2011, 42 percent felt food insecure.

As mentioned previously, a number of studies have been carried out on the impact of farm input subsidies, however, there are still gaps in the literature on their effects on household welfare. Since farm input subsidies increase the purchasing power of beneficiaries, they may have direct household welfare effects, which may affect households' annual consumption expenditure and food security. These effects have not been fully analyzed in the previous studies. Chirwa *et al.,* (2013); Doward and Chirwa (2011); Ricker-Gilbert and Jayne (2011, 2012) are four recent studies which analyze the effects of fertilizer subsidizes on household welfare. However, the current study estimates the effect of input subsidies on a different set of household welfare indicators.

The main objective of this study is to estimate the effects of fertilizer subsidy on household food security and consumption expenditure in Malawi, based on the nationally representative two-wave Integrated Household Panel Survey (IHPS) data of 2010 and 2013. Specifically, the study aims to assess the impact of subsidized fertilizer on: (i) kilocalories available per capita per day; (ii) number of household food secure months; (iii) household food security status; (iv) total annual per capita consumption expenditure; and (v) heterogeneous effects on kilocalories available per capita per day; number of household food secure months; and total annual per capita consumption expenditure.

Differently from previous studies, which use subjective self-assessment food security indicators (Dorward and Chirwa, 2011; Chirwa *et al.,* 2013; and Dorward *et al.,* 2013), this study empirically quantifies the effects of subsidized fertilizer on household food security by calculating household calorific requirements and the kilocalories available from own cereals and legumes production. This helps to more accurately determine annual household food security status and the number of household food secure months for smallholder farmers who are mainly subsistence farmers. Furthermore, this study uses total annual per capita consumption expenditure as a proxy for household income, which is the indicator that is used in calculating poverty in the World Bank Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) Project. Consequently, examining the effects of farm input subsidies using this indicator provides direct estimates on poverty alleviation implications, which is important for developing countries since one of the objectives of implementing farm input subsidies is to reduce poverty.

The next section of the study presents an overview of agricultural policy reform in Malawi. A review of empirical studies on the impact of farm input subsidies in the post-structural adjustment period is discussed in section three. The conceptual and empirical strategy is included in section four. Section five presents the empirical model. Data source, descriptive statistics and endogeneity tests are discussed in section six. The discussion of empirical results is incorporated in section seven and section eight concludes.

2. An overview of agricultural reforms in Malawi

Malawi's population is predominantly rural, with 85 per cent living in rural areas. Agricultural activities are the main livelihood strategy. The reliance on agriculture by 80 per cent of the labor force makes it a strategic sector in addressing food insecurity and poverty at household and national levels. The agricultural sector is also considered as the main engine of economic growth through its contribution to about 30 per cent of gross domestic product (GDP) and 75 per cent of foreign exchange income (GOM, 2012).

Farm structure in Malawi is divided into two sub-sectors - the estate and the smallholder. The estate sub-sector is mainly involved in the production of high value crops for the market, while the smallholder sub-sector is mainly involved in subsistence farming (Chirwa *et al.,* 2008; GOM, 2011). Due to the economic importance of agriculture, the government uses agricultural policies as the main tool to achieve economic growth and alleviate poverty (GOM, 2011).

Several policy reforms have taken place in the agricultural sector since independence. Chirwa *et al*., (2008) categorize agricultural policies into three periods: pre-reform, reform and post-reform. During the pre-reform period (between 1964 and 1979), the focus on the smallholder sector was to increase agricultural production and productivity, mainly for maize, in order to meet food security requirements at household and national levels, and generate cash income. The government used a range of policy instruments including input subsidies, and assessment of the performance of agriculture during this period provides evidence of improved crop production and productivity, mainly for maize, and better food security (Chirwa *et al*., 2008).

The reform period, between 1980s and early 1990s, followed the implementation of structural adjustment and stabilization programs, promoted by the World Bank and IMF. Agricultural policy reforms during this period involved liberalization of prices and marketing of agricultural commodities; and phasing out fertilizer subsidies. Agricultural performance assessment during this period suggests poor crop yields and severe food shortages among smallholder farmers (Chirwa *et al*., 2008). These negative developments have been mainly attributed to the low use of fertilizer due to the higher prices after the removal of fertilizer subsidies and the low access to agricultural credit by smallholder farmers (World Bank, 2003).

The post-reform period, which is the period from 1995 to to-date, has also experienced several agricultural policy reforms. They include the introduction of an input subsidy program from 1998/99-1999/2000 agricultural seasons called Starter Pack Scheme (SPS), which was later scaled-down and changed into Targeted Input Program (TIP) (2000/01-2004/05 agricultural seasons) (Harrigan, 2003; Levy, 2005). Beneficiaries to these programs were smallholders and each received 15 kg of fertilizer and 2 kg of maize seed to cultivate a 0.1 hectare (ha) of crop area (Levy, 2005).

The impact evaluations (Levy and Barahona, 2002; Levy, 2005) suggest that these programs contributed to increased production of maize and promoted food security. However, implementation shortfalls and the perceived fiscal burden had led to criticism by donors (Levy, 2005; Harrigan, 2008). This was followed by the scaling down of the TIP in 2004/2005 agricultural season. This season was characterized by poor rainfall and resulted into low agricultural yields and severe food shortage (Levy, 2005). In order to address these challenges, in 2005/06 agricultural season the government reintroduced a large scale Malawi Farm Input Subsidy Program (MFISP), which was later renamed Farm Input Subsidy Program (FISP), with the aim of improving smallholder farmers' production, food security and income from crop sales (Dorward and Chirwa, 2011).

The FISP beneficiaries are selected based on the following indicators: farm households which are classified as poor and cannot manage to self-finance purchases of improved farm inputs such as fertilizer and hybrid seeds at commercial prices; households headed by the elderly or females; households with agricultural land and are permanently resident in the village (Lunduka *et al.*, 2013). For the 2012/2013 agricultural season FISP, the selected household was expected to receive a standard package of four coupons to be used to redeem two 50 kg bags of fertilizer (for NPK and Urea); one pack of improved maize seed (5 kg if hybrid or 8 kg if open pollinated variety); and one legume pack (Dorward, *et al.*, 2013).

3. The impact of farm input subsidies in the post-structural adjustment period: a review of previous studies

As mentioned previously, there are several studies investigation the impact of the reintroduced farm input subsidies in sub-Saharan Africa (SSA). Concerning crop output effects, Ricker-Gilbert and Jayne (2011) and Mason *et al.* (2013) who analyze the effects of subsidized fertilizer on maize production in Malawi and Zambia find that an additional kg of subsidized fertilizer increases maize production by1.82 kg and 1.88 kg, respectively. Analyzing maize output response, Chibwana *et al.* (2010) and Dorward *et al.* (2013) also find positive effects of farm input subsidies in Malawi. Clearly, all these studies suggests improved food availability due to the use of farm input subsidies and this is supported by studies on the household welfare effects of farm input subsidies in Malawi, which using subjective self-assessment indicators find improvement in adequacy of food availability at household level (e.g. Dorward and Chirwa, 2011; Chirwa *et al.,* 2013 and Dorward *et al.,* 2013).

Concerning income and poverty, a study by Ricker-Gilbert and Jayne (2011) find positive effects on farm net crop income, but no effects on asset worth. However, Ricker-Gilbert and Jayne (2012) find positive effects on crop income only among richer households. Chirwa *et al.* (2013) finds no evidence of effects on the subjective self-assessed poverty at household level. Similarly, Dorward *et al.* (2013) find no effects in school attendance, sickness of a household member or of and under-five year old child.

The effects of farm input subsidies on input market has also been analyzed by several researchers. Ricker-Gilbert *et al.* (2011), Chirwa *et al.* (2013), and Mason and Ricker-Gilbert (2013) all find crowding-out effects on commercial purchases fertilizer and hybrid maize seed in Malawi. However, Xu *et al*, (2009) find both crowding-out and crowing-in effects on commercial fertilizer purchases in Zambia. Equilibrium effects studies include Ricker-Gilbert *et al.* (2013), and Takeshima and Liverpool-Tasie (2015) who find marginal effects on maize prices in Malawi and Zambia and on grain prices in Nigeria, respectively.

This short literature review indicates relatively consistent positive direct effects on beneficiaries although their implications for commercial transactions are questionable. Farm input subsidies help improve the purchasing power of beneficiaries. However, the level of incremental benefit may differ among beneficiaries depending on their economic characteristics. The poor who could not afford to purchase improved inputs at all without subsidies is expected to benefit more from the program than a non-poor beneficiary.

For the poor, the direct benefit arises from either selling the received coupons for subsidized purchases or buying the inputs and using them in production (SOAS, 2008). The use of improved farm inputs is expected to lead to three positive effects: increased yields that could result in improved food security; increased market participation of poor farmers as sellers and, therefore, increased farm income from crop sales; and reduced market participation as buyers of food crops resulting in savings of household cash income. The cash income from sales and the income savings from purchased food could be invested in farming or in non-agricultural enterprises, and or used to increase the consumption of non-food commodities. If the savings are invested in farming, this could lead to a further increase in purchases of farm inputs in subsequent agricultural seasons and boost of future agricultural production. Purchase of durable assets and consumption of food and non-food commodities could lead to reduced poverty levels and possibly to increased investment in human, social and physical capital - essential for future sustainable production and smooth exit from subsidy programs.

Similarly, the direct impact of farm input subsidies on non-poor beneficiaries could be through direct savings on purchases of farm inputs and or through the purchase of additional farm inputs due to the increased purchasing power. However, FISP can also lead to a displacement of commercial fertilizer purchases by non-poor beneficiaries which may undermine the development of the private input traders.

Based on the above review, three hypotheses are formulated and will be tasted in this paper:

Hypothesis 1: There is a positive relationship between FISP and household food security.

Hypothesis 2: There is a positive relationship between FISP and household consumption expenditure.

Hypothesis 3: The poorer and less food secure a household is, the higher the incremental effect of FISP is.

4. Households food security and consumption expenditure indicators

In order to test these hypotheses, the study focuses on two household welfare indicators: food security and consumption expenditure.

For food security, the main indicator used are the kilocalories available per capita per day. We have constructed it by adding up the kilocalories available from cereals and legumes grown by the household and dividing them by the household adult equivalent. The food security proxies of household food security status (secure or insecure) and the number of household food secure months are determined by comparing the household calorific requirements and the kilocalories available from own crop production (cereals and legumes). For this comparison, the recommended daily requirements per adult equivalent of 2,100 kilocalories per day and the Tanzanian Food Composition Tables of calorific content of food commodities are used (Lukmanji *et al.*, 2008).

The focus is on household produced cereals and legumes because most farmers in developing countries produce food crops for subsistence. Furthermore, cereals contribute to about 54 percent of kilocalories in developing countries, while in Asia and Africa the account for about 70 percent of energy intake (Kearney, 2010). The inclusion of legumes makes the combined kilocalories contribution from own production much larger. The use of produced cereals and legumes in calculating proxies of household food security indicators for small farmers chosen in this study provides more realistic measures of available food, covering the whole year, compared to the use of subjective and self-assessment indicators such as in Chirwa *et al.* (2013) and Doward and Chirwa (2011), in which food consumed may actually be below the recommended daily intake during lean food supply periods of the year. The lack of information on quantities of food accessed through purchases and other sources that supplements households' own production means that we underestimate the household annual food supply. The only available information in the data used in this study is on the food quantities consumed at household level from all sources, but the information covers a recall period of only seven days. It is inadequate to estimate household annual food security.

Concerning consumption expenditure, the total annual household consumption expenditure is determined by summing up household expenditure on food and non-food covering a period of one calendar year (GOM, 2012b, NSO, 2014).

5 Empirical models

The effect of farm input subsidies on household food security and consumption expenditure is estimated using the quantity of subsidized fertilizer a farmer redeemed. This is done in order to capture only the subsidized fertilizer used and, thus, the direct impact of the program. Fertilizer subsidies are chosen since they form the largest share of the total FISP (Lunduka *et al.*, 2013) and 99 per cent of FISP beneficiaries received and redeemed a fertilizer coupon in the 2009/2010 and 2012/2013 agricultural seasons. Furthermore, we do not use a binary variable indicating whether a household is a subsidy recipient or not because beneficiaries received heterogeneous subsidy coupon packages and, therefore, have different degree of benefit from the program.

5.1 Model for estimating the continuous outcome variables

The continuous household food security and consumption expenditure outcome variables are modelled in relation to food security as: (i) kilocalories available per capita per day and (ii) the number of household food secure months; and (iii) total annual per capita consumption expenditure. In this study we estimate the conditional mean effects of subsidized fertilizer on the continuous food security and consumption expenditure indicators by employing fixed effect (FE) models, and the heterogeneous effects by employing CRE quantile regression models. The estimation is of the following form:

$$\log_{welfare_{it1}} = hhc_{it1}\beta_1 + rain_{i1}\beta_2 + \beta_3 dist_{it1} + \beta_4 subfert_1 + \varphi_i + \mu_{it} \qquad (1)$$

where $\log_{welfare}$ denotes household food security indicators (kilocalories available per capita per day, and number of household food secure months) and consumption expenditure indicator (total annual per capita consumption expenditure) for farmer *i* in natural logarithm. The model's control variables are as follows: hhc_{it1} is a vector of household and farm characteristics and include sex, age and education of household head, total land owned, location in rural areas; crop diversification; $rain_{i1}$ is a vector of annual average district rainfall; $dist_{it1}$ is a vector representing distance to daily market in natural logarithm; *subfert* is vector of quantity of subsidized fertilizer redeemed; φ_i is the time-invariant unobserved heterogeneity of the household; μ_{it} is an idiosyncratic error term; and β are the parameters to be estimated.

5.2 Model for estimating the binary household food security indicator

The binary outcome of household food security in relation to annual food security status is modelled by applying the pooled correlated random effect (CRE) Probit model, following Papke and Wooldridge, (2008); Wooldridge (2010). Therefore, the estimation equation is as follows:

$$y_{it1} = hhc_{it1}\beta_1 + rain_{i1}\beta_2 + dist_{it1}\beta_3 + \beta_4 subfert_1 + \varphi_i + \overline{w}_i\beta_5 + \mu_{it} \qquad (2)$$

where y_{it1} is the binary dependent variable and equal to one if the household has adequate kilocalories from cereals and legumes from one harvest season to the next (i.e. 12 months or more) or zero otherwise. The model's control variables are the same as described in Eq. (1); φ_i is the time-invariant unobserved heterogeneity of the household; $\overline{w}$ is a vector of the time averages of the time-variant explanatory variables; μ_{it} is an idiosyncratic error term; and β are the parameters to be estimated.

5.3 Model for estimating heterogeneous effects of subsidized fertilizer on continuous household food security and consumption expenditure indicators

Hypothesis 3 implies heterogeneous welfare effects of FISP on different segments of the farm households' distribution. In order to test it, this study employs a correlated random effects (CRE) quantile regression approach. The heterogeneous effects of subsidized fertilizer on continuous household food security and consumption expenditure outcomes are modelled in relation to (i) kilocalories available per capita per day; (ii) the number of household food secure months; and (iii) the total annual per capita consumption expenditure. CRE quantile regression approach is employed in a number of studies, e.g. Ricker-Gilbert and Jayne (2012)

The estimation is of the following form:

$$\log H_{welfare_{it1}} = Z^{'}\lambda_{1(\tau)} + \xi_1 Fert_{1sub(\tau)} + \varphi_i + \overline{w_i}\psi_1 + \mu_{it} \qquad (3)$$

where $H_{welfare}$ denotes household welfare indicator; $Fert_{sub}$ represents quantity of subsidized fertilizer in kilograms; $Z^{'}$ is a vector of exogenous variables which are the same as described in Eq. (1); φ_i is the time-invariant unobserved heterogeneity of the household; $\overline{w_i}$ is a vector of the time averages of the time-variant explanatory variables; λ_1, ξ_1 and ψ_1 are vectors of parameters of interest to be estimated in the structural Eq. (3) and $0 < \tau < 1$. The estimations are carried out at 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles.

5.4 Empirical estimation strategy

The use of panel data in this study enables to control for the unobserved time-constant household heterogeneity. For the continuous food security and consumption expenditure indicators, estimations use the fixed effects (FE) estimator to examine the conditional mean effects (Eq. 1) and CRE quantile regression to analyze the heterogeneous effects of subsidized fertilizer (Eq. 3). Since the study includes a binary dependent food security indicator, (the annual food security status in Eq. (2), and a quantile regression in (Eq. 3), the use of FE estimators and standard quantile regression, respectively, are inconsistent (Wooldridge, 2010). For the estimators of Eq. (2) and the quantile regression in Eq. (3) to be consistent and the APEs to be identified, we use the correlated random effects (CRE) approach (Wooldridge, 2010) following Mundlak (1978) and Chamberlain

(1984). This approach allows to control for the correlation between the time-invariant unobserved household heterogeneity φ_i and the explanatory variables in Eq. (2) and Eq. (3), here we represented by W_{it}. Wooldridge, (2010) provides more details on the application of CRE estimators.

6. Data sources and descriptive statistics

Data used is the nationally representative two-wave Integrated Household Panel Survey (IHPS) data for Malawi from the World Bank Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) Project. The data was collected by the National Statistics Office of Malawi between March and November 2010 for the first wave and between April and December 2013 for the second wave, which included the farm input subsidy data for the 2009/2010 and 2012/2013 agricultural seasons, respectively. The IHPS data is a balanced panel sample of 4,000 households. However, for the current analyzes, households who do not have agriculture as a livelihood strategy and did not grow cereals or legumes, and households with missing key information are excluded. As a result, for food security estimations this article uses a balanced panel sample of 2,474 households.

Table 1 present averages of available kilocalories per capita per day of and the number of months of food security from own production of cereals and legumes. These averages are based on quantiles of per capita annual consumption expenditure. The results show a positive correlation between the number of kilocalories per capita per day and months of food security, on the one hand, and the quantile of per capita annual consumption expenditure. Households with higher per capita annual consumption expenditure in the 4^{th} and 5^{th} quantiles meet both the standard requirement of kilocalories per capita per day and annual food security of at least 12 months of adequate available kilocalories. This suggests that the top richest 40 percent of the households are food secure, while the bottom 60 per cent are food insecure. Furthermore, the results show that households belonging to the 1^{st} quantile have available kilocalories per capita per day which only meet about half of the standard requirement and are food secure only a half of the year.

Table 1. Average available kilocalories and number of months of food security by quantiles of per capita annual consumption expenditure (the mean represents the two-survey waves)

Food security Indicator	**Quantiles of per capita annual consumption expenditure**				
	1st Quantile	**2nd Quantile**	**3rd Quantile**	**4th Quantile**	**5th Quantile**
Kilocalories per capita per day	1116	1602	1946	2424	3183
Months of food secure	6.46	9.36	10.99	14.06	17.72

Source: Calculated by authors based on IHPS (2010 and 2013) data

A similar situation is observed in Table 2 where data are presented by poverty status of the household as non-poor, poor and extremely poor. A household whose individuals have a total annual per capita consumption expenditure below the total poverty line (MK85,852 in 2013) is defined as poor, while those with total annual per capita consumption expenditure of below the food poverty line (MK53,262 in 2013) are defined as extremely poor (NSO, 2014). The results show that poor and extremely poor households are food insecure. While poor households are food secure for about eight months, the extremely poor meet calorific requirements form own production of cereals and legumes for only six months. These results suggests a positive association between poverty status and food security of the household.

Table 2. Average available kilocalories and number of months of food security by poverty status of the household (the mean represents the two-survey waves)

Food security Indicator	**Poverty status of the household**		
	Non-poor	**Poor**	**Extremely Poor**
Kilocalories per capita per day	2455	1318	1013
Months of food secure	13.92	7.67	5.84

Source: Calculated by authors based on IHPS (2010 and 2013) data

Descriptive statistics of the variables used in this study are presented in Table 3. Concerning the input subsidies, the data show that overall, 54 per cent of the farmers received a coupon for fertilizer subsidy during the two agricultural seasons under the study. Since the government target in FISP is to reach at least 50 per cent of smallholders, these results suggest that this target was met. However, the beneficiaries received heterogeneous coupon packages instead of the full standard package of four coupons to redeem two 50 kg bags of subsidized fertilizer (NPK and Urea); one pack of maize seed (5 kg if the farmer chose hybrid or 8 kg for open pollinated variety); and one legume pack (Dorward, *et al.*, 2013). Only 24 per cent of the beneficiaries received the full standard package. Some of the remaining beneficiaries received coupons for different quantities of fertilizer and maize seeds, and some received either fertilizer or maize coupons only. In terms of quantities of redeemed fertilizer, the sample average is 43 kg, while considering beneficiaries only the average is 80 kg per beneficiary

Food security indicators show that most of the households run out of adequate food supply from own production before the next harvesting season. The results indicate that only 32 per cent are food secure throughout the year. Fertilizer subsidy beneficiaries have 302 kilocalories more per capita kilocalories per day; two months more of food security and higher probability of being food secure with a mean difference of five percentage points compared to non-beneficiaries. However, the average of 2,053 kilocalories per capita per day suggests that many households in Malawi do not meet the standard of 2,100 kilocalories from own production of cereals and legumes. This highlights the importance of alternative sources of food for household consumption, i.e. through market purchases. The result of household consumption expenditure shows that fertilizer subsidy beneficiaries have lower total annual per capita consumption expenditure compared to non-beneficiaries, which indicates that FISP is really targeting relatively poor farm households.

6.1 Endogeneity Tests of subsidized fertilizer

Since fertilizer coupons are distributed to households non-randomly (i.e. to only targeted households), the unobserved time-invariant household heterogeneity which influences receipt of subsidy coupons may also influence household income potentials and production levels of cereals and legumes for household food consumption. This will make subsidized fertilizer endogenous in the estimations. We use the control function approach of the instrumental variables method to test for the endogeneity of subsidized fertilizer. We employ the residence of the Member of Parliament (MP) in the community as an instrument following Ricker-Gilbert and Jayne (2011). The politicization of the farm input subsidy program makes coupons distributions to be prone to the influence of politicians and, therefore, households in communities with resident MP may receive more coupons than in communities with only occasional MP visits.

Due to the discreteness of the quantity of subsidized fertilizer and because non-beneficiaries have a zero quantity, a Tobit model of corner solution is estimated and the generalized residuals are obtained and used as additional explanatory variable in estimating the household food security indicators. The results suggest that the quantity of subsidized fertilizer is endogenous in all our estimations, with the exception of the 75th and 90th percentiles of the total annual per capita consumption expenditure.

The estimation of the heterogeneous effects of subsidized fertilizer on continuous food security and consumption expenditure indicators is carried out semi-parametrically by employing the control function approach to the structural quantile regression model Eq.(3) following Lee (2004).

7. Results and discussion

This section discusses the empirical results and the focus is on the effects of the subsidized fertilizer on household food security and consumption expenditure. The results of the random effect (RE) model (I) and fixed effect (FE) model (II) in Tables 4 and 5 are presented to check the robustness of the results of the IV-FE model, since the robust Hausman model selection test, based on the Sargan-Hansen statistic, rejects the RE model and the statistically significant generalized residuals indicates that subsidized fertilizer is endogenous. Regression results concerning factors determining the available kilocalories per capita per day are presented in Table 4 and the determinants of the number of months of household food security in Table 5. The discussion is based on the results of the instrumental variable fixed effect (IV-FE) model (III).

The results show that subsidized fertilizer has positive effects on the kilocalories available per capita per day with an increase by 0.18 per cent for an additional kilogram, which means by 18 per cent for the standard package, and translate into 372 kcal per capita per day. This positive effect is consistent with a previous study by Holden and Lunduka (2012) who find that farm input subsidy program beneficiaries were less likely to be net buyers of maize and more likely to be net sellers and that the beneficiary households had 43 per cent higher maize production.

As expected, age, secondary and tertiary education of the household head, the total landholding size, crop diversification and the presence of a resident agricultural extension officer have statistically significant effects of on kilocalories available per capita per day. However, the study finds no evidence of effects on the kilocalories available per capita per day of gender and primary education level of the household head; rural location; distance to daily market; availability of an irrigation scheme, micro-credit institution, number of households in the community and the rainfall in the district.

Table 5 presents the regression results of the factors influencing the number of household food secure months. Subsidized fertilizer has the expected positive effect. An additional kilogram of subsidized fertilizer increases the number of household food secure months by 0.2 per cent, thus, representing a 20 per cent increase for the FISP standard package. Estimation in levels indicates that, on average, the FISP standard package increases the number of months of food security by 2.5. This positive effect is consistent with the study by Dorward and Chirwa (2011) who report that the subsidy program has significantly contributed to improved national food self-sufficiency.

The results concerning factors determining household annual food security status are presented in Table 6. The discussion is based on the average partial effects (APEs) of the pooled CRE probit (model III), which controls for the household time-invariant unobserved heterogeneity and endogeneity of subsidized fertilizer. This model is chosen because the joint statistical significance of the added time averages of the time-variant explanatory variables cannot be rejected, indicating the need of controlling for the household time-invariant unobserved heterogeneity in the estimation, and the generalized residuals are statistically significant indicating that subsidized fertilizer is endogenous in the estimations and hence requires controlling the effects of endogeneity. The results show that subsidized fertilizer has statistically significant and positive effects on household annual food security status. An additional kilogram of subsidized fertilizer increases the probability of a household being annually food secure by 0.07 percentage point. This represents seven percentage points increase for the 100 Kg fertilizer of the standard fertilizer program package. Contextualizing this result vis-à-vis previous studies, Chirwa *et al.,* (2013) find that the receipt of subsidized fertilizer coupons continuously for six times has increased the probability of household reporting adequate food consumption by 22 percentage points compared with non-beneficiaries and that an additional 100 kg of subsidized fertilizer increases the probability of household food consumption adequacy by seven percentage points.

Overall, the results in Tables 4, 5 and 6 indicate that the input subsidies could be useful in contributing to improved food security among farming households in Malawi. However, the magnitude of the effects suggests that they alone are not a magic bullet solution to food insecurity, but only one tool that has to be built-in in a more comprehensive agricultural policy package facilitating agricultural and rural development.

In relation to the total annual per capita consumption expenditure, the results are presented in Table 7. All three models run do not show a statistically significant effect of subsidized fertilizer. One possible explanation is that since the FISP main target crop is maize, which most farm households grow for subsistence, has little contribution to sales and consequently to household's income and to the overall total household consumption expenditure. The policy implication is that when the main subsistence crop is targeted the subsidized fertilizer will hardly has significant effects on poverty alleviation. To a certain extent, these results explain the persistence of high poverty levels of above 40 per cent of the population in Malawi despite the implementation of the FISP.

As previously mentioned, the analysis of the heterogeneous effects of subsidized fertilizer employs CRE quantile regression models and estimations are carried out at 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles of the continuous dependent variables (i.e. kilocalories available per capita per day, number of months of food secure and total annual per capita consumption expenditure). Table 8 presents the CRE quantile regression model results on factors affecting the kilocalories available per capita per day; Table 9 the determinants of the number of food secure months and Table 10 – the effect on consumption expenditure. The results in Table 8 show that an additional standard package of subsidized fertilizer increases the kilocalories available per capita per day by 25 per cent at the 10^{th} and 50^{th} percentiles, compared to 22 per cent at the 90^{th} percentile. Therefore, the percentage incremental effect is slightly larger at the lower percentiles. However, in terms of the impact in levels, the results indicate that an additional 100 kg of subsidized fertilizer increases the per capita kilocalories by 113 kilocalories at the 10th percentile, 378 kilocalories at the median (50th percentile) and 977 kilocalories at the 90th percentile.

The results concerning the factors affecting the number of months of household food security, presented in Table 9, indicate that subsidized fertilizer has a clearly higher percentage incremental effect at lower percentiles, increasing the months of household food security by 31 per cent at the 10th percentile, 27 per cent at the 50th percentile, and 23 per cent at the 90th percentile. In levels, the results indicate that an additional 100 kg of subsidized fertilizer increases the months of household food security by 0.76 month at the 10th percentile, 2.2 months at the 50th percentile and 6.3 months at the 90th percentile.

These results give support to Hypothesis 3 and suggests heterogeneous effects of subsidized fertilizer across the farm households' distribution. Although the results are consistent with the theory of higher percentage of incremental effects within the percentiles of the poor and food insecure households, compared to percentiles of the rich and food secure, in levels the effects are significantly higher at higher percentiles. Since the calories and the number of months of food security are calculated based on farm households' own production, this suggests that households with higher production levels of cereals and legumes produce more additional outputs by using subsidized fertilizer compared with households with lower levels of production. This could be due to scale of economies in use of subsidized fertilizer. However, this raises the question of extent to which targeting farm households at the lower percentiles of food crops production with subsidized fertilizer offers value for money in achieving food security. The small magnitude of effects of subsidized fertilizer among households at the lower percentiles provides an explanation of the persistence of food insecurity among farming households in Malawi despite the implementation of the FISP.

Concerning consumption expenditure, similar to results in Table 7, the CRE quantile regression model in Table 10 shows no evidence of statistically significant effects across the farm households' distribution.

8. Conclusion

Agriculture is the main livelihood strategy for most rural households in Malawi, and in sub-Saharan Africa in general, and consequently, agricultural policies are vital for achieving economic growth, food security and poverty alleviation. Farm input subsidy programs are one of the pervasive policy tools used to address the problems of food insecurity and poverty through improvement of agricultural production and productivity. This study estimates the effects of a fertilizer subsidy program on kilocalories available per capita per day, household annual food security status, the number of household food secure months and the total annual per capita consumption expenditure in Malawi.

The study finds that fertilizer subsidy has a positive impact on food security and its effect is heterogeneous across the population distribution. Even though the percentage incremental effect is the highest for poorest and most food insecure household, measured in levels the effect is higher among the most food secure households. Furthermore, the magnitude of the effects of subsidized fertilizer on food security are not large enough to eradicate food insecurity among poor households in isolation, and this underscores the importance of integrated livelihood approach in development interventions. However, the study finds no evidence of effects on annual per capita consumption expenditure.

From the policy point of view, these results provide several important insights. First, farm input subsidy programs could be beneficial for some improvement of food security, based predominantly on subsistence agriculture where food security is achieved through consumption of own production. Such programs are less useful when the main policy objective is to decrease consumption expenditure poverty due to the marginal contribution of fertilizer subsidies to income from crop sales and the lack of contribution to development of non-farm income sources.

Second, a fertilizer subsidy program has a higher positive impact on the most food secure, raising the question of whether targeting households in the lowest food crops production percentiles offers value for money in order to achieve the objective to improve food security. However, since households in lower food crops production percentiles are the most food insecure, provision of subsidized fertilizer to these groups of farmers can be justified on the basis to achieve social protection objectives.

Third, the results highlight the need for promoting complementary policy interventions in addition to fertilizer subsidies in order to achieve sustainable household food and income security. Implementing policies which promote family planning to slow down population growth and farm household sizes would be important in order to improve available kilocalories and total consumption expenditure per capita, consequently, reducing poverty and food insecurity. An increase in land holdings can substantially improve household food security and reduce poverty.

Fourth, policies which support crop diversification and access to agricultural extension services would also significantly contribute to improved household food security.

Overall, the input subsidies could be useful for food insecure and poor households in some locations in Malawi, but they alone are not a solution to food insecurity and poverty. They are only one tool that has to be built-in in a more comprehensive agricultural policy package facilitating agricultural and rural development.

9. References

Chamberlain, G., (1984). Panel data. In:Griliches, Z., Intriligator, M.D., (Eds.). *Handbook of econometrics*, 2, 1247-1318. Amsterdam: North-Holland.

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

Chibwana, C., Fisher, M., Jumbe, C., Masters, W. and Shively, G. (2010). *Measuring the impacts of Malawi's farm Input Subsidy Programme*. Paper presented at the 2010 meeting of the African Agricultural Economics Association, September 20-23, 2010. Available at: http://ssrn.com/abstract=1860867 (accessed on 25th January, 2014)

Chirwa, E.W., Kumwenda, I., Jumbe, C., Chilonda, P. and Minde, I. (2008). *Agricultural growth and poverty reduction in Malawi: Past performance and recent trends*. ReSAKSS Working Paper No.8. International Crops Research Institute for Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI) and International Water Management Institute (IWMI).

Chirwa, E.W., Matita, M.M., Mvula, P.M., and Dorward, A. (2013). Repeated Access and Impacts of the Farm Input Subsidy programme in Malawi. Any Prospects of Graduation? *Future Agricultures*, Working Paper 065.

Danish International Development Agency. (2011). *Agricultural input subsidies in sub-Saharan Africa.* International Development Cooperation, Ministry of Foreign Affairs of Denmark. Evaluation Study 2011/2.

Dorward, A., and Chirwa, E. (2011). The Malawi Agricultural Input Subsidy Programme: 2005-6 to 2008-9, *International Journal of Agricultural Sustainability*, 9(1), 232-247.

Dorward, A., Chirwa, E., Matita, M., Mhango, W., Mvula, P., Taylor, E., and Thorne, K., (2013). *Evaluation of the 2012/2013 Farm Input Subsidy Programme, Malawi*, *Final Report*, Ministry of Agriculture and Food Security, Malawi.

Druilhe, Z. and Barreiro-Hurle, J. (2012). *Fertilizer subsidies in sub-Saharan Africa.* ESA Working paper No. 12-04, Rome, *FAO.*

Government of Malawi, (2005). *Integrated Household Survey 2004-2005: Household Socio-Economic Characteristics*, Volume 1, National Statistics Office, Zomba.

Government of Malawi, (2011). Malawi Agricultural Sector Wide Approach. A prioritised and harmonised Agricultural Development Agenda: 2011-2015. *Ministry of Agriculture and Food Security.*

Government of Malawi, (2012). *Malawi Growth and Development Strategy II: 2011-2016.* International Monetary Fund, Washington, DC. IMF Country Report No.12/222.

Government of Malawi, (2012b). Integrated Household Survey 2010-2011: Household Socio-Economic Characteristics Report. National Statistics Office, Zomba.

Greene, W.H. (2003). *Econometric Analysis*, Fifth Edition, New York University, Pearson Education International, USA.

Harrigan, J. (2003). U-Turns and Full Circles. Two Decades of Agricultural Reform in Malawi 1981-200, *World Development*, 31(5), pp. 847-863.

Harrigan, J. (2008). Food insecurity, poverty and the Malawian Starter Pack: Fresh start or false start? *Food Policy*, 33(3), pp. 237-249.

Holden, S. and Lunduka, R. (2010). *Too poor to be efficient? Impacts of targeted fertilizer subsidy program in Malawi on farm plot level input use, crop choice and land productivity*, Department of Economics and Resource Management, Norwegian University of Life Sciences. May 2010.

Holden, S. T. and Lunduka, R.W. (2012). Who Benefits from Malawi's Targeted Farm Input Subsidy Program? *Forum for Development Studies*.

Kearney, J., (2010). Review: Food consumption trends and drivers, *Phil. Trans. R. Soc. B*, 365, 2793-2807. Available on: http://rstb.royalsocietypublishing.org/. Accessed on March17, 2015.

Lee, S. (2004). *Endogeneity in Quantile Regression Models: A Control Function Approach*. The Institute for Fiscal Studies and Department of Economics, University College of London, Centre for Micro data Methods and Practice, Working Paper CWP08/04.

Levy, S. and Barahona, C. (2002). *2001-02 TIP, Main Report of the Evaluation Programme.* Calibre Consultants, Reading (UK) and Statistical Services Centre, University of Reading (UK).

Levy, S., ed. (2005). *Starter Packs: A strategy to Fight Hunger in Developing Countries? Lessons from Malawi Experiences, 1998-2003,* Wallingford*:* CABI Publishing.

Lukmanji, Z., Hertzmark, E., Mlingi, N., Assey, V., Ndossi, G., Fawzi, W., (2008). Tanzania food composition Tables. MUHAS- TFNC, HSPH, Dar es Salaam Tanzania.

Lunduka, R., Ricker-Gilbert, J. and Fisher, M. (2013). What are the farm level impact of Malawi's farm input subsidy program? A critical Review. *Agricultural Economics*. (Accepted for Publication), August 1, 2013.

Mason, N.M., and Richer-Gilbert, J., (2013). Disrupting Demand for Commercial Seed: Input subsidies in Malawi and Zambia. *World Development*, 45, pp.75-91.

Mason, N.M., Jayne, T.S., and Mofya-Mukuba, R., (2013). Zambia's input subsidy programs. *Agricultural Economics*, 44, pp.613-628.

Morris, M., Kelly, V.A., Kopicki, R., and Byerlee, D. (2007). *Fertilizer use in African Agriculture: Lessons Learned and Good Practice Guidelines*, Washington, DC: World Bank.

Mundlak, Y., (1978). On the pooling of time series and cross section data, *Econometrica*, 46, 69-85.

Papke, L.E., Wooldridge, J.M., (2008). Panel data methods for fractional response variables with an application to test pass rates, *Journal of Econometrics*, 145, 121-133.

Ricker- Gilbert, J., Mason, N., Jayne, T., Darko, F., and Tembo, S. (2013). *What are the effects of input subsidy programs on equilibrium maize prices? Evidence from Malawi and Zambia*. Selected Paper prepared for presentation at the Agriculture and Applied Economics Association 2013 AAEC and CAE's Joint Annual Meeting, Washington DC.

Ricker-Gilbert, J. and Jayne, T.S. (2012). *Do fertilizer subsidies boosts staple crop production and reduce poverty across the distribution of smallholders in Africa? Quintile Regression Results from Malawi*. Accessed on 25th January 2014 and available at: http://iaae.confex.com/iaae/iaae28/webprogram/Paper16263.html.

Ricker-Gilbert, J., Jayne, T.S., and Chirwa, E. (2011). Subsidies and Crowding out: A double hurdle Model of fertilizer demand in Malawi, *American Journal of Agricultural Economics*, 93(1), pp. 26-42.

Ricker-Gilbert. J. and Jayne, T.S. (2011). *What are the enduring effects of fertilizer subsidies on recipient households*? Staff Paper 2011-09. Department of Agricultural Food and Resource Economics, Michigan State University. East Lousing, MI. USA.

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

Takeshima, H., and Liverpool-Tasie, L.S.O., (2015) Fertilizer subsidies, political influence and local food prices in sub-Saharan Africa: Evidence from Nigeria, *Food Policy*, 54, pp.11-24.

Wooldridge, J.M. (2010). *Econometric Analysis of Cross Section and Panel Data*, MIT Press Books, The MIT Press, 2nd Edition, Vol.1.

World Bank, (2003). *Malawi Country Economic Memorandum: Policies for Accelerating Growth*. World Bank, Washington.

World Bank, (2007). Agriculture *for Development, World Development Report 2008*, The International Bank for Reconstruction and Development, Washington, DC: World Bank.

Xu, Z., Burke, W.F., Jayne, T.S. and Govereh, J. (2009). Do input subsidy programs 'crowd in' or 'crowd out' commercial market development? Modeling fertilizer demand in a two-channel marketing system. *Agricultural Economics*, 40(1), pp.79-94.

Table 3: Descriptive statistics (the mean represents the two-survey waves' average)

Variable	All (Full Sample) (I)		Subsidy Beneficiaries Only (II)		Subsidy Non-Beneficiaries Only (III)		Difference (II)-(III)
	Obs	**Mean**	**Obs**	**Mean**	**Obs**	**Mean**	**Mean /SE**
Head (female)	4948	0.23	2693	0.24	2255	0.22	0.02* (0.01)
Head age (years)	4948	44.27	2693	46.28	2255	41.86	4.43*** (0.46)
Head no education	4948	0.2	2693	0.21	2255	0.2	0.013 (0.01)
Head primary educ	4948	0.59	2693	0.61	2255	0.56	0.06*** (0.01)
Head secondary edu	4948	0.1	2693	0.17	2255	0.20	-0.04*** (0.01)
Head tertiary educ	4948	0.03	2693	0.01	2255	0.05	-0.04*** (0.01)
Land total (hectares)	4948	0.79	2693	0.85	2255	0.71	0.14*** (0.02)
Rural location	4948	0.9	2693	0.94	2255	0.85	0.1*** (0.01)
Crop diversification	4948	2.13	2693	2.26	2255	1.98	0.28*** (0.03)
Distance daily mkt	4948	9.05	2693	10.74	2255	7.03	3.71*** (0.54)
Irrigation scheme	4948	0.16	2693	0.18	2255	0.13	0.05*** (0.01)
No. of households	4948	984	2693	967	2255	1005	-38.03 (44.44)
Agricultural Officer	4948	0.37	2693	0.37	2255	0.37	-0.001 (0.01)
Microfinance institu	4948	0.11	2693	0.1	2255	0.13	-0.03*** (0.01)
Rainfall amount	4948	967.96	2693	988.01	2255	944.01	44.01*** (8.01)
Percapita annual exp	4948	142213	2,693	130262	2255	156486	-26223*** (3840)
Percapita/day calorie	4948	2053.9	2693	2191.6	2255	1889.4	302.24*** (49.36)
Months food secure	4948	11.72	2693	12.6	2255	10.66	1.94*** (0.37)
Annual food secure	4948	0.32	2693	0.34	2255	0.29	0.05*** (0.01)
Subsidized fertilizer	4948	43.43	2693	79.8			

Note: *, **, *** represents statistically significance at 10 %, 5 % and 1 % levels; SE represents standard errors.

Source: Authors based on IHPS 2010 and 2013 data

Table 4: Regression results on factors influencing available per capita calories. Dependent variable: Log per capita kilocalories.

Explanatory Variables	RE (I)	FE(II)	IV-FE
	Coef./SE	Coef./SE	Coef./SE
Generalized residuals			-0.24***
			(0.04)
Subsidized fertilizer quantity in Kg	0.0014***	0.0012***	0.0018***
	(0.0003)	(0.0004)	(0.0004)
Household head (female)	0.03	-0.05	-0.08
	(0.04)	(0.06)	(0.06)
Household head age (years)	0.004***	0.01***	0.01***
	(0.001)	(0.002)	(0.002)
Household head primary education	0.09**	0.05	0.02
	(0.04)	(0.05)	(0.05)
Household head secondary education	0.28***	0.2***	0.17**
	(0.05)	(0.08)	(0.08)
Household head tertiary education	0.48***	0.43***	0.41***
	(0.1)	(0.17)	(0.17)
Total landholding size (hectares)	0.35***	0.29***	0.31***
	(0.03)	(0.04)	(0.04)
Rural location of the household	0.01	-0.07	-0.003
	(0.06)	(0.13)	(0.13)
Crop diversification	0.22***	0.22***	0.21***
	(0.01)	(0.02)	(0.02)
Log distance to daily market (Km)	-0.02	-0.004	0.004
	(0.01)	(0.02)	(0.01)
Irrigation scheme in the community	0.07**	0.06	0.06
	(0.03)	(0.05)	(0.05)
Log number of households in the community	0.01	0.02	0.02
	(0.01)	(0.01)	(0.01)
Agricultural Extension Officer in the commu	0.14***	0.16***	0.15***
	(0.03)	(0.04)	(0.03)
Micro-finance institution in the community	0.01	0.03	0.03
	(0.04)	(0.05)	(0.05)
Log annual average district rainfall	-0.19***	-0.18*	-.12
	(0.06)	(0.10)	(0.10)
Constant	13.09***	13.02***	6.53***
	(0.4)	(0.75)	(0.74)
Number of observations	4948	4948	4948
Wald chi2(15)/ F-Statistic	688.59	20.42	22.65
Prob > chi2/ F	0.0000	0.0000	0.0000
R-squared	0.1687	0.1572	0.1812
Rho	0.4081	0.5485	0.5472
Robust Hausman test: Sargan-Hansen statistic	25.743**		

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; robust cluster standard errors (SE) are in parentheses.

Table 5: Regression results on determinants of months of household food secure.

Dependent variable: Log months of household food secure.

Explanatory Variables	**RE**	**FE**	**IV-FE**
	Coef./SE	**Coef./SE**	**Coef./SE**
Generalized residuals			-0.26***
			(0.04)
Subsidized fertilizer quantity in Kg	0.0015***	0.0013***	0.0020***
	(0.0003)	(0.0004)	(0.0004)
Household head (female)	0.01	-0.05	-0.09
	(0.04)	(0.06)	(0.06)
Household head age (years)	0.003***	0.01***	0.01***
	(0.001)	(0.002)	(0.002)
Household head primary education	0.09**	0.04	0.01
	(0.04)	(0.05)	(0.05)
Household head secondary education	0.27***	0.19**	0.15
	(0.05)	(0.08)	(0.08)
Household head tertiary education	0.51***	0.56***	0.53***
	(0.11)	(0.18)	(0.17)
Total landholding size (hectares)	0.37***	0.31***	0.33***
	(0.03)	(0.04)	(0.04)
Rural location of the household	0.03	-0.07	0.01
	(0.05)	(0.13)	(0.13)
Crop diversification	0.21***	0.21***	0.20***
	(0.01)	(0.02)	(0.02)
Log distance to daily market (Km)	-0.02	-0.01	0.002
	(0.01)	(0.02)	(0.01)
Irrigation scheme in the community	0.08**	0.06	0.06
	(0.03)	(0.05)	(0.05)
Log number of households in the community	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)
Agricultural Extension Officer in the community	0.14***	0.15***	0.14***
	(0.03)	(0.04)	(0.03)
Micro-finance institution in the community	0.01	0.01	0.01
	(0.04)	(0.05)	(0.05)
Log annual average district rainfall	-0.17***	-0.15	-.09
	(0.05)	(0.10)	(0.10)
Constant	1.97***	1.86**	1.24*
	(0.39)	(0.75)	(0.74)
Number of observations	4948	4948	4948
Wald chi2(15)/ F-Statistic	776.75	19.99	22.52
Prob > chi2/ F	0.0000	0.0000	0.0000
R-squared	0.1790	0.1667	0.1913
Rho	0.3849	0.5355	0.5348
Robust Hausman test: Sargan-Hansen statistic	25.242**		

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; robust cluster standard errors (SE) are in parentheses.

Table 6: Regression results on factors influencing the probability of household annual adequate calories availability. Dependent variable: Annual food secure=1

Explanatory Variables	Pooled Probit (I)	Pooled CRE Probit (II)	Pooled CRE & CF Residuals Probit (III)
	ME/SE†	APE./SE††	APE./SE††
Generalized residuals			-0.12***
			(0.02)
Subsidized fertilizer quantity in Kg	0.0003*	0.0004**	0.0007***
	(0.0002)	(0.0002)	(0.0002)
Household head (female)	0.04**	-0.01	-0.02
	(0.02)	(0.03)	(0.03)
Household head age (years)	0.001	0.002***	0.004***
	(0.001)	(0.001)	(0.001)
Household head primary education	0.03	-0.01	-0.02
	(0.02)	(0.03)	(0.03)
Household head secondary education	0.12***	0.04	0.02
	(0.03)	(0.04)	(0.04)
Household head tertiary education	0.18***	0.12	0.12
	(0.05)	(0.08)	(0.07)
Total landholding size (hectares)	0.19***	0.14***	0.15***
	(0.01)	(0.02)	(0.02)
Rural location of the household	0.01	-0.08	-0.04
	(0.02)	(0.06)	(0.05)
Crop diversification	0.06***	0.06***	0.06***
	(0.01)	(0.01)	(0.01)
Log distance to daily market (Km)	-0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)
Irrigation scheme in the community	0.03	0.01	0.002
	(0.02)	(0.02)	(0.02)
Log number of households in com.	0.0002	0.003	0.004
	(0.01)	(0.01)	(0.01)
Agricultural Extension Officer in co.	0.04***	0.06***	0.06***
	(0.01)	(0.02)	(0.02)
Micro-finance institution in the com.	0.04**	0.02	0.02
	(0.02)	(0.02)	(0.03)
Log annual average district rainfall	-0.03	0.02	0.04
	(0.03)	(0.05)	(0.05)
Number of observations	4948	4948	4948
Wald chi2(15)	514.48	542.15	593.17
Prob > chi2	0.0000	0.0000	0.0000
Pseudo R-squared	0.1225	0.1288	0.1457
Log-pseudolikelihood	-2714.925	-2695.376	-2643.265
Chi2: Joint stat sig of time averages		42.49***	45.21***
Correctly classified	72.15 %	72.64 %	73.73 %

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; SE† = cluster standard errors; SE††= bootstrap standard errors (1000 reps); estimation of model (II) include time averages of time-variant regressors and year dummy.

Table 7: Regression results on determinants of total annual per capita consumption expenditure. Dependent variable: Log total annual per capita consumption expenditure.

Explanatory Variables	RE	FE	IV-FE
	Coef./SE	Coef./SE	Coef./SE
Generalized residuals			-0.04*
			(0.02)
Subsidized fertilizer quantity in Kg	-0.0003	-0.0003	-0.0002
	(0.0002)	(0.0002)	(0.0002)
Household head (female)	0.06***	-0.04	-0.05
	(0.02)	(0.04)	(0.04)
Household head age (years)	0.001	-0.01***	0-.01***
	(0.001)	(0.001)	(0.001)
Household head primary education	0.17***	0.04	0.03
	(0.02)	(0.03)	(0.03)
Household head secondary education	0.48***	0.26***	0.26***
	(0.03)	(0.05)	(0.05)
Household head tertiary education	0.99***	0.54***	0.53***
	(0.07)	(0.11)	(0.11)
Total landholding size (hectares)	0.12***	0.07***	0.07***
	(0.02)	(0.02)	(0.02)
Rural location of the household	-0.29***	-0.19**	-0.18*
	(0.04)	(0.09)	(0.09)
Crop diversification	0.03***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)
Log distance to daily market (Km)	-0.05***	-0.02**	-0.02**
	(0.01)	(0.01)	(0.01)
Irrigation scheme in the community	0.01	0.01	0.01
	(0.02)	(0.03)	(0.03)
Log number of households in the community	0.02***	0.03***	0.03***
	(0.01)	(0.01)	(0.01)
Agricultural Extension Officer in the community	0.02	0.01	0.01
	(0.02)	(0.02)	(0.02)
Micro-finance institution in the community	0.07**	0.002	0.001
	(0.03)	(0.03)	(0.03)
Log annual average district rainfall	0.002	-0.01	0.001
	(0.03)	(0.07)	(0.07)
Constant	11.37***	11.84**	11.75***
	(0.24)	(0.47)	(0.48)
Number of observations	4948	4948	4948
Wald chi2(15)/ F-Statistic	683.29	8.26	8.03
Prob > chi2/ F	0.0000	0.0000	0.0000
R-squared	0.1973	0.1135	0.1163
Rho	0.3528	0.5542	0.5535
Robust Hausman test: Sargan-Hansen statistic	25.242**		

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; robust cluster standard errors (SE) are in parentheses.

Table 8: CRE Quantile Regression Model results on factors influencing available per capita calories. Dependent variable: Log per capita kilocalories.

Explanatory Variables	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
	Coef./SE	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Generalized residuals	-0.43***	-0.46***	-0.39***	-0.33***	-0.24***
	(0.06)	(0.05)	(0.04)	(0.04)	(0.07)
Subsidized fertilizer in Kg	0.0025**	0.0032***	0.0025***	0.0028***	0.0022***
	(0.0011)	(0.0007)	(0.0007)	(0.0005)	(0.0008)
Household head (female)	-0.15	-0.01	-0.12**	-0.14	-0.04
	(0.16)	(0.12)	(0.06)	(0.09)	(0.13)
Household head age (years)	0.010***	0.013***	0.014***	0.011***	0.010**
	(0.004)	(0.003)	(0.003)	(0.003)	(0.005)
Household head primary educ	0.04	0.08	0.02	-0.04	-0.03
	(0.15)	(0.08)	(0.07)	(0.09)	(0.11)
Household head secondary ed	0.24	0.24*	0.15	0.05	0.12
	(0.18)	(0.14)	(0.11)	(0.15)	(0.20)
Household head tertiary educ	0.26	0.69**	0.38	0.22	0.51*
	(0.29)	(0.32)	(0.26)	(0.30)	(0.30)
Total landholding size (hec)	0.28***	0.31***	0.39***	0.45***	0.44***
	(0.08)	(0.08)	(0.06)	(0.07)	(0.08)
Rural location of the house	0.40	0.18	0.06	-0.15	-0.25
	(0.26)	(0.23)	(0.21)	(0.20)	(0.22)
Crop diversification	0.24***	0.27***	0.17***	0.13***	0.12***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)
Log distance daily market	0.01	0.06**	0.03	0.03	0.04
	(0.04)	(0.03)	(0.02)	(0.02)	(0.04)
Irrigation scheme in the com	0.27**	0.13**	0.03	0.002	-0.05
	(0.13)	(0.07)	(0.06)	(0.07)	(0.10)
Log number of households	0.03	0.05*	0.01	0.03	0.02
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Agricultural Extension Office	0.05	0.13*	0.15**	0.06	0.19**
	(0.09)	(0.07)	(0.06)	(0.06)	(0.08)
Micro-finance institution	0.08	-0.08	0.07	0.13**	0.05
	(0.11)	(0.10)	(0.09)	(0.06)	(0.10)
Log average district rainfall	-0.24	0.07	0.01	0.18	-0.14
	(0.30)	(0.24)	(0.14)	(0.18)	(0.30)
Year dummy 2013=1	0.13***	0.13***	0.13***	0.15***	0.16***
	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)
Constant	5.86***	6.56***	7.01***	7.06***	7.69***
	(0.65)	(0.63)	(0.46)	(0.53)	(0.70)
Number of observations	4,948	4,948	4,948	4,948	4,948
Pseudo R-squared	0.1158	0.1155	0.1235	0.1336	0.1257

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; bootstrap standard errors (SE) are in parentheses (1000 reps); estimation includes time averages of time-variant regressors.

Table 9: CRE Quantile Regression Model results on determinants of months of household food secure. Dependent variable: Log months of household food secure.

Explanatory Variables	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
	Coef./SE	Coef./SE	Coef./SE	Coef./SE	Coef./SE
Generalized residuals	-0.45***	-0.47***	-0.40***	-0.32***	-0.23***
	(0.05)	(0.05)	(0.03)	(0.03)	(0.07)
Subsidized fertilizer in Kg	0.0031***	0.0031***	0.0027***	0.0028***	0.0023***
	(0.0011)	(0.0007)	(0.0006)	(0.0006)	(0.0009)
Household head (female)	-0.18	-0.04	-0.12*	-0.14	-0.04
	(0.12)	(0.12)	(0.07)	(0.11)	(0.13)
Household head age (years)	0.01***	0.01***	0.01***	0.01***	0.01*
	(0.004)	(0.003)	(0.002)	(0.003)	(0.005)
Household head primary educ	0.06	0.08	-0.01	-0.06	-0.06
	(0.13)	(0.08)	(0.08)	(0.09)	(0.11)
Household head secondary ed	0.27	0.25**	0.13	0.04	-0.04
	(0.18)	(0.12)	(0.11)	(0.13)	(0.19)
Household head tertiary educ	0.39	0.78***	0.55**	0.27	0.52**
	(0.30)	(0.28)	(0.24)	(0.26)	(0.25)
Total landholding size (hec)	0.31***	0.34***	0.40***	0.45***	0.41***
	(0.07)	(0.07)	(0.05)	(0.05)	(0.07)
Rural location of the house	0.38	0.21	0.03	-0.14	-0.36*
	(0.33)	(0.28)	(.24)	(0.20)	(0.20)
Crop diversification	0.24***	0.24***	0.16***	0.13***	0.11***
	(0.04)	(0.04)	(0.02)	(0.03)	(0.04)
Log distance to daily market	0.02	0.07**	0.03	0.02	0.04
	(0.04)	(0.03)	(0.02)	(0.02)	(0.03)
Irrigation scheme in the com	0.21	0.13	0.03	0.003	-0.08
	(0.13)	(0.08)	(0.07)	(0.08)	(0.10)
Log number of households	0.04	0.05	0.003	0.02	0.02
	(0.04)	(0.04)	(0.02)	(0.02)	(0.03)
Agricultural Extension Office	0.02	0.12*	0.15***	0.06	0.17**
	(0.08)	(0.07)	(0.05)	(0.05)	(0.07)
Micro-finance institution	0.05	-0.06	0.05	0.14*	-0.003
	(0.13)	(0.12)	(0.08)	(0.08)	(0.08)
Log average district rainfall	-0.32	0.08	0.05	0.20	-0.19
	(0.32)	(0.26)	(0.18)	(0.24)	(0.29)
Year Dummy 2013=1	0.11**	0.13***	0.14***	0.15***	0.17***
	0.05	(0.04)	(0.03)	(0.03)	(0.05)
Constant	0.62	1.21**	1.88***	1.81***	2.46***
	(0.72)	(0.56)	(0.47)	(0.53)	(0.81)
Number of observations	4948	4948	4948	4948	4948
Pseudo R-squared	0.1227	0.1217	0.1250	0.1411	0.1342

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; bootstrap standard errors (SE) are in parentheses (1000 reps); estimation includes time averages of time-variant regressors.

Table 10: CRE Quantile Regression Model results on determinants of total annual per capita consumption expenditure. Dependent variable: Log total annual per capita consumption expenditure

Explanatory Variables	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
	Coef./SE	**Coef./SE**	**Coef./SE**	**Coef./SE**	**Coef./SE**
Generalized residuals	-0.09***	-0.05*	-0.05**		
	(0.03)	(0.03)	(0.03)		
Subsidized fertilizer in Kg	0.0003	0.0003	0.0002	0.0001	0.0005
	(0.0004)	(0.0003)	(0.0004)	(0.0004)	(0.0005)
Household head (female)	0.04	-0.11*	-0.03	-0.06	-0.06
	(0.09)	(0.06)	(0.05)	(0.07)	(0.10)
Household head age (years)	-0.01**	-0.01**	-0.01**	-0.01***	-0.01**
	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)
Household head primary educ	0.10*	0.07	0.02	0.07	-0.08
	(0.06)	(0.05)	(0.05)	(0.06)	(0.08)
Household head secondary ed	0.08	0.23***	0.24***	0.28***	0.26**
	(0.09)	(0.09)	(0.07)	(0.10)	(0.11)
Household head tertiary educ	0.54***	0.63***	0.52***	0.52**	0.52**
	(0.15)	(0.17)	(0.15)	(0.26)	(0.24)
Total landholding size (hec)	0.11***	0.08*	0.07*	0.06*	0.03
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Rural location of the house	-0.21	-0.12	-0.10	-0.24	-0.39
	(0.13)	(0.15)	(0.14)	(0.16)	(0.24)
Crop diversification	0.03	0.02	0.02	0.01	0.06**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Log distance to daily market	0.01	0.01	0.01	-0.02	-0.04*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Irrigation scheme in the com	-0.01	0.04	-0.002	-0.06	-0.06
	(0.06)	(0.04)	(0.04)	(0.06)	(0.07)
Log number of households	0.05***	0.02	0.02	0.01	0.04*
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
Agricultural Extension Office	-0.07*	0.01	0.01	0.02	-0.04
	(0.04)	(0.05)	(0.03)	(0.05)	(0.07)
Micro-finance institution	-0.05	-0.004	-0.03	0.06	-0.03
	(0.06)	(0.05)	(0.04)	(0.07)	(0.07)
Log average district rainfall	0.20	0.16	-0.04	-0.09	-0.003
	(0.13)	(0.12)	(0.10)	(0.14)	(0.18)
Year dummy 2013	0.09**	0.05**	0.07***	0.04	0.07**
	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Constant	10.35***	10.80***	10.80***	11.50***	11.45***
	(0.34)	(0.35)	(0.30)	(0.43)	(0.42)
Number of observations	4948	4948	4948	4948	4948
Pseudo R-squared	0.1006	0.1019	0.1150	0.1202	0.1512

Note: *, **, *** represents statistically significant level at 10%, 5% and 1%, respectively; bootstrap standard errors (SE) are in parentheses (1000 reps); estimation includes time averages of time-variant regressors.