Impact of Improved Maize Adoption on Welfare of Farm Households in Malawi: A Panel Data Analysis

Sosina Bezu and Girma Kassie and Bekele Shiferaw and Jacob Ricker-Gilbert

School of Economics and Business, Norwegian University of Life Sciences, International Maize and Wheat Improvement Center (CIMMYT), Department of Agricultural Economics, Purdue University

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Sosina Bezu

School of Economics and Business, Norwegian University of Life Sciences

E-mail: sosinac@yahoo.com

Girma Tesfahun

International Maize and Wheat Improvement Center (CIMMYT)

Bekele Shiferaw

International Maize and Wheat Improvement Center (CIMMYT)

Jacob Ricker-Gilbert

Department of Agricultural Economics, Purdue University

ABSTRACT

This paper assesses improved maize adoption in Malawi and examines the link between adoption and household welfare using a three-year household panel data. The distributional effect of maize technology adoption is also investigated by looking at impacts across wealth and gender groups. We applied control function approach and IV regression to control for endogeneity of input subsidy and improved maize adoption. We found that modern maize variety adoption is positively correlated with the household's own maize consumption, income and asset holdings. We found evidence that improved maize adoption has stronger impact on welfare of female-headed households and poorer households.

Key words: Improved maize, hybrid maize, technology adoption, subsidy, Malawi, Africa

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1 INTRODUCTION

Half the population in sub-Saharan-Africa (SSA) lives in poverty. This rate of poverty is twice that of the global average and the highest in the world (African Development Bank [AfDB], 2012). Three quarters of Africa's poor live in rural areas where the primary economic activity is agriculture (International Fund for Agricultural Development [IFAD], 2011]). Evidently, the agriculture sector has not been able to ensure food security in most of the SSA countries both at the national and the household level. Although production has increased over the years, productivity has not increased as much as the area cultivated. For example, in the 50 years between 1961 and 2010, the maize area in SSA tripled. However, excluding South Africa, maize yields in SSA increased only by about 40% over this period (Shiferaw, Prasanna, Hellin, & Banziger, 2011).

Malawi's economy reflects this general agricultural dependence in SSA. Agriculture accounts for 80% of employment and 41% of gross domestic product (AfDB, 2011). Most farming households depend on rain-fed production that is not sufficient to meet their consumption needs. In 2009, for example, 64% of the households ran out of staple food before the end of the year (National Statistical Office [NSO], 2011). The average months of food security for rural households from their own production in a normal year is between six and seven months [Ministry of Agriculture and Food Security [MoAFS], 2011). Poverty is prevalent in the country, particularly in rural areas where the poor account for 43% of the rural population (NSO, 2011).

Maize is the main staple food for Malawi. So much so that national food security is mainly defined in terms of access to maize (MoAFS, 2011). However, maize is produced mainly for subsistence consumption with only 15% of production going to the market (MoAFS, 2011). In fact, 60% of maize producers are net buyers of maize (SOAS, Wadona Consult, Overseas Development Institute, & University of Michigan, 2008). The poor performance of the agricultural sector in Malawi, including maize production, is partly because of low yields and stagnating productivity growth. In the 25 years between 1970 and 2005, there have been only marginal increases in maize and rice productivity (MoAFS, 2011). It has been argued that the use of improved agricultural technologies, such as high-yielding inputs, improves agricultural productivity and, thus, improves food security (Katengeza, et al., 2012; Smale, 1995). The Government of Malawi believes that the major contributing factor to low productivity in the smallholder sector is low input use (MoAFS, 2011). To ameliorate this, the government launched a Farm Input Subsidy Program (FISP) in 2005 explicitly targeting smallholder farmers who do not have the resources to purchase inputs. The official objectives of this large subsidy program (subsidized commodities were worth 210 Million USD in 2008/09 alone) were to increase food sufficiency and crop income (Dorward & Chirwa, 2011).

Minten and Barrett (2008) argue that agricultural technology adoption and productivity improvements have the potential to increase food security for all sections of the poor. Net food buyers benefit from the lower food prices while unskilled workers benefit from increased real wages. If output grows faster than the fall in grain price, net food sellers also benefit from farm profits. With 97% of farmers in Malawi planting maize, even smaller changes in maize productivity are likely to impact the life of many poor farm households in the country.

Using three rounds of household-level panel data (2004, 2007 and 2009), this study aims to assess the adoption of modern maize varieties in Malawi and its impacts on the welfare of rural households in the country. We investigate the distributional effects of maize technology adoption by looking at impacts across wealth and gender groups. The paper contributes to the growing body of knowledge on the subject through panel data analysis with due consideration for observed and unobserved heterogeneity within the sample. The study applies control function approach and IV regression to control for endogeneity of input subsidy and improved maize adoption. A disaggregated analysis of poor versus better-off households and male-headed versus female-headed households enables us to test whether or not improved maize seed adoption is pro-poor or neutral in its impact. We found that the likelihood of modern maize adoption increases with education, male labor, land holding, access to subsidized inputs and access to farm credit. We found that maize variety adoption is positively correlated with the household's own maize consumption, income and asset holdings. A 1% increase in the area planted to modern varieties is associated with a 0.36% increase in the maize available for consumption, a 0.26% increase in income and a 0.07% increase in asset wealth. Improved maize adoption has more impact on female-headed households and the poorest households.

The paper is organized as follows. Section 2 briefly describes maize technology development and diffusion in Malawi. It is followed by a description of data in Section 3 and the empirical approach in Section 4. In Section 5, we present the results and discussion, and finish with concluding remarks in Section 6.

2 BACKGROUND: MAIZE PRODUCTION AND PRODUCTIVITY IN MALAWI

The Malawian economy depends primarily on rain-fed agriculture, which is characterized by low productivity, low technology and high labor intensity. The low productivity has been attributed to the loss of soil fertility, low application of inorganic fertilizers and traditional, low technology, rain-fed farming systems (Chibwana, Fisher, & Shively, 2012). Malawian agriculture is also characterized by the dominance of maize-producing farmers who own small plots of land.

Maize is the staple food crop of Malawians and its production and productivity plays a crucial role in ascertaining both household and national level food security. Maize is grown by 97% of farming households and accounts for 60% of the total calorie consumption (Famine Early Warning Systems Network [FEWSN], 2007). Due to low productivity and small farm size, only 20% of maize farmers produce surplus and sell their product (Denning, et al., 1995). On-farm storage losses are also high. As a result, most households purchase maize at much higher prices when stocks are exhausted, typically during January to March (Republic of Malawi, 2006).

Smallholder farmers in Malawi find it difficult to diversify their crop production, due mainly to their limited farm land size. The mono-cropping that characterized Malawian crop production for decades has led to land degradation. It has long been argued that adoption of improved (high yielding) maize varieties and improved soil fertility management – for example through the application of inorganic fertilizer – helps productivity per unit area, thereby freeing land for diversification and concomitantly improving food security (Denning, et al., 1995; Smale, 1995). However, the adoption of improved maize varieties in Malawi has always been slow and low

(Smale, 1995; Katengeza *et al.*, 2012). Smallholder farmers continue to maintain preferences for local (as opposed to improved) maize, despite its lower yield potential (Denning *et al.*, 2009), due to the perceptions that local varieties produce better quality flour, require less external inputs, and exhibit better pest resistance in storage (Lunduka, Fisher, & Snapp, 2012; Smale, 1995; Smale & Rusike, 1998). Although improved maize varieties first became available in Malawi in the 1950s, these were mainly dent hybrids bred for high yield in foreign contexts where the commercial role of maize was far more important. In addition to good storage and processing, other qualities, such as yield stability and the capacity to either escape or withstand drought, are highly important for Malawian smallholders who operate in risky production conditions (Kassie, et al., 2011; Peters, 1995). In the early 1990s, the national breeding attempts led to the release of varieties with qualities better-suited to the needs of smallholders in Malawi. But most of the hybrids in Malawi now are dent varieties that don't store as well and are harder to pound than the local flint varieties.

The slow (and low) adoption of improved maize varieties and soil fertility management has persisted despite concerted efforts by Malawi's governments over the last five decades to stimulate uptake through the provision of subsidies and free agricultural extension services. Malawi, like some other SSA countries (e.g., Kenya, Tanzania, Zambia and Zimbabwe), implemented a universal subsidy program in the 1970s and early 1980s through several interventions, including direct subsidies that reduced fertilizer prices for farmers, government financed and managed input credit programs, centralized fertilizer procurement and distribution, and the control of output markets (Denning, et al., 1995; Druilhe & Barreiro-Hurlé, 2012).

Throughout the seventies and eighties the country was able to produce a maize surplus and agricultural productivity grew in general terms, under-girded by a pervasive reliance on input subsidies to support the adoption of hybrid maize and fertilizer (Katengeza, et al., 2012). But in the mid-nineties the credit and subsidy programs, upon which the country had been relying, were abandoned in response to conditions imposed by the structural adjustment programs (SAP) of the World Bank and IMF (Denning, et al., 1995; Harrigan, 2003). Liberalization had severe negative effects for smallholders in Malawi, as the purchase price of maize skyrocketed and key inputs like fertilizer became prohibitively expensive (Blackie & Mann, 2005). Severe productivity shortfalls were forecast and, despite donor reticence, government-led interventions were resumed, first, from 1998 to 2000 in the form of the Starter Pack Program, then up to 2005 as the Targeted Input Program, and finally, to date, as the Agricultural Input Subsidy Program (Chinsinga, 2011).

The large subsidy program that started in 2005 garnered some attention in the development literature. A series of studies have been done to document the impact of the subsidy programs on different output and outcome indicators. As summarized by Druilhe and Barreiro-Hurle (2012), available evidence suggests that subsidies have been effective in raising fertilizer use, average yields and agricultural production, but that they could be improved in design and implementation. Economic efficiency and equity considerations have been less studied and results are less conclusive. The few published economic impact assessment studies of improved maize adoption (Alene, et al., 2009) and subsidy programs (Chibwana, et al., 2012; Holden & Lunduka, 2010; Kremer, Duflo, & Robinson, 2011; J Ricker-Gilbert & Jayne, 2012) showed small but positive results.

3 DATA AND DESCRIPTIVE STATISTICS

(a) Data

The analysis is based on a panel data of 1,375 households in the period 2004-2009. The first wave of this panel, called Integrated Household Survey II (IHHS2), was conducted by Malawi's National Statistical Office in 2002/03 and 2003/04 and covered 11,280 households. However, only a small part of this sample was included in the subsequent Agricultural Inputs Support Surveys (AISS). The second wave (AISS I) was conducted after the 2006/07 growing season and covers 2,968 households. The third wave (AISS II) was conducted after the 2008/09 growing season and covers 1,375 households giving us a matched panel of 1,375 households in the three waves (2004, 2007, 2009).

(b) Descriptive

Maize is the main staple crop in Malawi. More than 90% of households in our sample have planted maize in each of the survey years in 2004-2009. Besides the local maize seeds, farmers plant hybrid maize seeds and open-pollinated varieties (OPVs). As farmers often do not clearly distinguish between the last two types of seeds, we jointly refer to both hybrid and OPV maize seeds as improved seed. More than half of the households in our sample planted improved maize seed in each of the survey years. In 2004 and 2007 about 55%-56% of households adopted improved maize. Significantly more households adopted improved maize (64%) in 2009.

Table 1 shows the proportion of households who benefited from FISP in 2007 and 2009. FISP started in 2005 and targets poor farmers through the distribution of coupons to eligible households who use the coupons to buy fertilizers and maize seed at a much reduced price. Although FISP only started in 2005, a limited amount of subsidized fertilizer was provided for selected households in the early 2000s (SOAS, et al., 2008). The figure for 2004 shows such subsidies. About one-third of our sample indicated that they acquired some subsidized fertilizer in 2003/2004. The proportion of households who received input subsidy from the new subsidy program significantly increased from 58% in 2007 to 70% in 2009[1].

(Table 1 here)

Householders' land holdings are typically small with the mean in our sample slightly more than one hectare (Table 2) and an even smaller median holding of 0.81 ha. Households devote the greater part of their land for maize cultivation. For improved maize seed adopters, the area under improved maize seed accounts for the majority of the total maize area under cultivation. Note, however, that some of the improved maize areas may contain other crops since the data does not specify what percentage of the crops are purely improved maize when there is intercropping.

(Table 2 here)

(i) Who are the adopters of improved maize in Malawi?

The socio-economic characteristics of improved maize seed adopters and non-adopters are reported in Table 3. Households adopting improved maize seed are headed by younger and more educated farmers, perhaps because these households are more receptive to new ideas. In addition, improved maize seed adopters own more assets and have more adult labour. This is in line with the higher financial and labor requirements of improved maize technologies. The prevalence of an imperfect factor market implies that own assets and family labor play an important role in technology adoption. On the other hand, we see higher household size for adopters, possibly indicating the subsistence pressure on the adoption decision. There are proportionately more female-headed households among non-adopters than there are in the adopter group. All the differences discussed are statistically significant at the 1% level.

(Table 3 here)

An evaluation of the change in a household's improved maize adoption in the years 2004-2009 shows that the probability of staying an adopter and/or moving towards adoption seems higher compared to the probability of dis-adoption and non-adoption. While 66% of households who ever adopted improved maize remain adopters during the period covered by the panel, only 48% of non-adopters remain so in the same period.

(ii) Improved maize seed adoption and welfare outcomes

Adopters of improved maize earn significantly more income from crop production than non-adopters (Table 4).They earn about 18% more in total family or household income. Table 4 shows that non-adopters are more likely to experience chronic illness in the family, perhaps an indicator of a generally poorer nutrition and wellbeing in such households. Alternatively, this may be an indication that illness hampers a farmer's ability to adopt improved technology. The majority of households in Malawi are unable to produce enough food to meet their subsistence needs. Staple crops from households' own production last only 7-8 months, but the production of adopters lasts longer than that of non-adopters. Households' own evaluations of their welfare suggest that improved maize seed adopters may be better off. Proportionately more adopters report that they are 'satisfied with their lives'. We should not, however, read too much into this as two-thirds of the total households admitted to being dissatisfied with their lives[2].

(Table 4 here)

One may argue that, wealthier households are more likely to adopt improved maize seed as they are less liquidity constrained to purchase improved seeds and perhaps less risk averse. The positive correlation we see between the adoption of improved maize and welfare outcomes may, thus, be attributable to the impact of wealth on both adoption and welfare, rather than the effect of adoption on welfare. If adopting improved maize seed indeed makes a difference for well-being, households with equal resources should experience different welfare outcomes depending on their adoption status. Therefore, we compared the poorest households to test if their welfare outcomes differ by their adoption status. As Table 5 shows, poor households who adopted improved maize varieties earn more crop and total income than equally poor households who did not adopt improved maize varieties. Moreover, poor adopter households' staple production lasts longer than the non-adopters. These differences are statistically significant.

(Table 5 here)

4 EMPIRICAL APPROACH

As stated in the introduction, this paper assesses: 1) improved maize seed adoption in Malawi; and 2) its impact on household welfare. We do this in two stages. First, we estimate the model for adoption of improved maize seed. We then use the predicted improved maize adoption values to estimate its impact on short-term and long-term welfare. There are some challenges in estimating such a model particularly regarding how the unobserved heterogeneity and potential endogeneity of some of the variables are addressed. Below we discuss the estimated models and how these issues are addressed in this paper.

(a) Estimated models

Given the market failures prevalent in rural areas of developing countries, input use decisions of farmers in Malawi cannot be reasonably assumed to depend only on market prices. Absence and imperfection of factor and product markets create non-separability between production and consumption decisions. For example, the lack of access to credit causes some inputs' prices to be marked upwards by the shadow price of credit(Sadoulet & De Janvry, 1995).

Accordingly, in addition to relevant prices, our model of improved maize adoption includes a vector of household, village and plot characteristics as determinants. Let ***M*** refer to improved maize planted:

$$M = f(P, L, D, S; A, V) \tag{1}$$

Where P refers to a vector of input and output prices, while vectors L and D refer to labor endowment and demographic characteristics of the household, respectively. S refers to selection to the farm input subsidy program. The vector A refers to agro ecological factors such as plot characteristics and rainfall conditions, while V controls for village level covariates.

The improved maize variable is given in terms of area under improved maize varieties. As we saw in Section 3, as high as 45% of the households did not adopt improved maize seed and as such the variable has several zero values. Therefore, the improved maize seed equation is best formulated in the framework of a corner solution model. Such models recognize that the optimal choice for some of the agents is at zero (Wooldridge, 2011). So M_{it} (area planted by improved maize variety) is given by:

$$M_{it} = \max(0, M_{it}^{*}) \qquad (2)$$

Where the latent variable M_{it}^{*} refer to a linear specification of the improved maize adoption equation:

$$M_{it}^{*} = \beta_0 + \boldsymbol{\beta}_1\mathbf{p}_{it} + \boldsymbol{\beta}_2 \boldsymbol{L}_{it} + \boldsymbol{\beta}_3\mathbf{D}_{it} + \boldsymbol{\beta}_4\mathbf{A}_{it} + \boldsymbol{\beta}_4\mathbf{V}_{it} + \boldsymbol{\gamma} S_{it} + c_i + \varepsilon_{it} \qquad (3)$$

Where $\boldsymbol{P_{it}}$ refers to a vector of input and output prices. We expect input prices to negatively influence improved maize adoption. The maize output prices are those observed before planting season. We expect that higher maize prices encourage farmers to produce more maize. For net sellers, higher maize prices increase profitability while for net buyers, higher maize prices still have a similar positive effect because farmers try to be self-sufficient as producers when facing higher food expenditure. $\boldsymbol{L_{it}}$ refers to the human and physical capital variables, such as family male and female members, the education of the household head and farm size. We expect all the labor variables to contribute positively to improved maize variety adoption. The implication of imperfect factor markets is that households who have more labor and more skills will face fewer constraints when adopting improved maize varieties. The vector $\boldsymbol{D_{it}}$ includes household demographic variables such as the age and gender of the household head and the household size. We expect that households with more educated household heads are more likely to adopt improved maize technologies, because these households may be more likely to be persuaded by the benefits of improved technology than households headed by less-educated heads. The vector $\boldsymbol{A_{it}}$ is included in the model to account for: (1) plot characteristics that determine the suitability of improved maize seed for the farm; and (2) weather conditions, particularly rainfall and rainfall variation. $\boldsymbol{V_{it}}$ refers to village level dummies and availability of farm credit institutions. The variable S_{it} refers to access to subsidized inputs. Not all households who were selected for subsidy program in 2007 and 2009 received a maize seed subsidy. Some received only a fertilizer subsidy. The limited subsidy available before the start of the 2005 FISP was primarily targeting fertilizer provision, not maize. But, because fertilizer is an important complementary input for improved maize, we expect input subsidy always to have a positive effect on improved maize seed adoption. The term c_i refers to the unobserved household effects. It is included to capture unobserved, time-constant factors such as household farming skills. The term ε_{it} is a mean zero, identically and independently distributed random error and is assumed to be uncorrelated to all the explanatory variables.

If we assume that $\varepsilon_{it} \mid \mathbf{x}_{it} \sim Normal(0, \sigma^2)$, this model is referred to as a standard censored tobit model (Tobin, 1958) which can be consistently estimated using maximum likelihood methods. We can separately estimate the probability of improved maize adoption only using the probit model on the binary adoption decision.

The indicators of household welfare outcome for the purpose of this analysis are the short-term welfare indicator ***own maize consumption*** (maize available for consumption from own production); the relatively more long-term welfare outcome measures ***income*** (household income) and ***asset holdings*** (value of household asset holdings), all measured per adult equivalent. The outcome equation is simple and relatively straight forward. We define own maize consumption (income or asset) as a function of improved maize planted ($\mathbf{M_{it}}$), human and physical capital variables ($\boldsymbol{L_{it}}$), household demographic characteristics ($\boldsymbol{D_{it}}$), rainfall conditions ($\boldsymbol{R_{it}}$), village level access to credit and village dummies ($\boldsymbol{V_{it}}$).

$$Y_{it} = \alpha_0 + \boldsymbol{\alpha}_1\mathbf{M_{it}} + \boldsymbol{\alpha}_2\mathbf{D_{it}} + \boldsymbol{\alpha}_3\mathbf{L_{it}} + \boldsymbol{\alpha}_4\mathbf{R_{it}} + \boldsymbol{\alpha}_5\mathbf{V_{it}} + c_i + \varepsilon_{it} \tag{4}$$

(b) Estimation issues

(i) Controlling for endogenous regressor

We have seen earlier that a significant number of households received subsidy in all of the survey years. The core objective of the input subsidy is to increase resource poor farmers' access to improved agricultural inputs (Dorward & Chirwa, 2011). The subsidies were, therefore, targeted to poor households and as such cannot be considered random. Thus, the subsidy variable S_{it} in the above equation is possibly correlated with the error term.

We will use the control function approach to control for endogeneity of selection for subsidy. Using more compact expression, we write the improved maize equation as follows:

$$M_{it} = \max(0, \beta X_{it} + \gamma S_{it} + \upsilon_{it}), \quad where\ \ \upsilon_{it} = c_i + \varepsilon_{it} \tag{5}$$

The Smith-Blundell (1986) approach for controlling endogeneity in a corner solution model involves using the residuals from the reduced form regression of the endogenous variable to control for and test endogeneity in the structural equation. Below, we write the reduced form of subsidy as a linear projection of the exogenous variables, including the instruments ($IV_{it)}$.

$$S_{it} = \beta X_{it} + \delta IV_{it} + \eta_{it} \ , where\ \ \eta_{it} \ = c_{i2} + \varepsilon_{it2} \tag{6}$$

Our estimation of improved maize adoption involves two steps: 1) estimate the reduced form model for subsidy using probit and obtain the generalized residual; 2) Include the generalized residual in the structural maize equation along with the observed selection variable S_{it}. A significance test on the coefficient of the residuals tests for endogeneity. We use bootstrapping in the second stage to adjust standard errors for the two-step procedure.

The main requirement for this procedure to work is, of course, having valid instruments. We expect subsidy to be endogenous mainly because administrators may use selection criterion that are unobservable to us in addition to the observable criteria set in the program, namely indicators of poverty and the ability to farm. The observable criteria are either outcome variables or are used as regressors in the structural equation and, hence, cannot be used as instruments. Instead we used '*the number of years the household lived in the village*' and '*a Member of Parliament resides in the village*' variables as instruments. These two variables capture the social capital at an individual and village level that may influence access to subsidy by farmers. An earlier study shows that these variables are viable instruments (Jacob Ricker-Gilbert, Jayne, & Chirwa, 2011).

The welfare outcome equation itself may suffer from endogeneity problems. The main variable of interest, i.e. improved maize adoption, is itself a decision variable and, hence, may be correlated with the error term in the welfare outcome equation. To control for the possible endogeneity problem, we used fixed effects instrumental variable estimation. Unlike the standard IV model, however, here we used the predicted values from the improved maize equation to instrument for observed values of area under improved maize. This procedure is more efficient than the standard 2SLS when the endogenous regressor is a corner response or censored variable. It is more robust than the control function approach which depends on the improved maize function correctly specified (Wooldridge, 2007). The exclusion restriction in this model is satisfied by the plot characteristics variables in the improved maize equation, which are not included in the welfare outcome equation. We do not expect these variables to affect the welfare outcome equations directly after controlling for improved maize planted.

(ii) Controlling for unobserved heterogeneity

In estimating nonlinear panel models another important problem is how to handle the unobserved effect $\boldsymbol{c_i}$. The fixed effects estimator, which is the workhorse for linear models, is not easy to apply for non-linear models because of the incidental parameters problem. If we are prepared to assume that the time invariant unobserved heterogeneity $\boldsymbol{c_i}$ is not correlated to any of the other covariates (strict exogeneity assumption), we can consider $\upsilon_{it} = c_i + \varepsilon_{it}$ as a composite error and estimate the model as a random effect model. However, this assumption is very strong.

The Correlated Random Effect (CRE) model of Mundlak (1978) and Chamberlain (1982), relaxes the strict exogeneity assumption by allowing dependence between $\boldsymbol{c_i}$ and $\boldsymbol{X_{it}}$, although this dependence is restricted. The estimation procedure in CRE involves adding the mean of time varying variables $\overline{X_i}$ as an extra set of explanatory variables. The inclusion of these mean variables controls for time-constant unobserved heterogeneity (Wooldridge, 2011). Both the reduced form subsidy equation and the structural improved maize equations are estimated using the CRE estimator. For the welfare outcome equations, the unobserved effect is easily controlled for by applying the Fixed Effects model. Unlike the Random Effects model that assumes strict exogeneity of covariates, the Fixed Effects model allows correlation between the individual effects and the explanatory variables.

5 RESULTS

(a) Improved maize seed adoption

The number of panels used in the estimation is 1,311 rather than 1,375 because of missing values for some of the regressors. The first two columns of Table 6 show the results from the probit model of improved maize seed adoption and the last two columns from the tobit model.

(Table 6 here)

One of the regressors in the improved maize adoption equation is access to input subsidy which, as we argued earlier, may be endogenous. Hence, the generalized residual from the first stage subsidy equation is included along with the observed subsidy indicator to test and control for the endogeneity of subsidy. Standard errors are estimated using the bootstrap method to account for the two stage estimation in this control function procedure. The coefficient for the generalized residual is significant indicating that subsidy is endogenous and, therefore, our procedure was necessary.[3]

Access to subsidy is positively and significantly correlated with the adoption and area of improved maize varieties planted. This indicates that the subsidy is addressing the main concerns of the Government of Malawi. The new subsidy program was initiated to drive adoption of modern technologies by the poor. Households who secured access to subsidized inputs are 44% more likely to adopt improved maize seed. Adopters are also more likely to put larger areas under improved varieties if they have access to the subsidy.

Households headed by older household heads are less likely to adopt improved maize seed, possibly indicating risk-aversion and a technology mistrust behavior. But, the economic and statistical significance are not strong. Education of the household head is positively correlated with both adoption decision and area planted with improved maize seed. This is in line with the expectation that educated farmers are more receptive to improved technologies and perhaps have a better capability to utilize and manage such technologies. The probability of improved maize adoption and the amount of improved maize planted increases with male labor and land holding. Male labor has a stronger impact on the adoption decision, while land holding has a stronger impact on the amount decision. These results are as expected. Other things held the same, households who have more land can set aside larger land areas for planting improved maize. The positive and significant coefficient for labor is explained by the imperfect factor market in Malawi and the importance of labor for improved maize cultivation. More adult labor at home relaxes the labor constraint. A parallel argument can be applied to explain the positive correlation between credit availability in the village and improved maize adoption. It indicates that the liquidity constraint is binding for input use in Malawi. As expected, a higher price for seed reduces the probability of improved maize adoption, but did not affect the amount decision. On the other hand, an increase in the price of the complementary input fertilizer does not affect improved maize variety adoption, but it reduces the amount planted.

Although we reported results from separate probit and tobit models to show adoption decision and the intensity of adoption, respectively, a tobit model, in fact, reflects both and assumes that the direction of the effect of any explanatory variable on adoption decision is identical to the intensity of adoption. This is a limitation of the tobit model. To check for robustness of results from the tobit model on the intensity of adoption, we ran the two-tier truncated normal hurdle model (Cragg, 1971) which extends the standard tobit model by assuming that the adoption decision follows a probit model, while the intensity decision has a truncated normal distribution. Adoption and intensity of adoption decisions are assumed to be independent in this model. The results from the two-tier Cragg model are similar to the results from the tobit model, except in cases where the adoption and amount decision move in opposite directions, such as for year dummy. Access to subsidy is still positively correlated with the adoption and amount decisions. We estimated the Fixed Effect IV model, ignoring the censoring in the dependent variable. However, most of the variables were not significant in this model, including the subsidy variable, probably because the instruments for the endogenous variable did not change over time. (See Appendix 2.)

(b) Improved maize adoption and household welfare

We ran a Fixed Effects model to estimate the relationship between improved maize adoption and welfare. The measures of welfare outcomes are household per capita maize available for consumption, household per capita income and household per capita asset holdings. A household's own maize consumption is computed by subtracting the amount of maize sold from the household's own production. Because of the lack of data, we do not deduct maize set aside for seed or given away to others. The household income includes crop income, livestock income, non-crop plant income, such as that from trees, and income from off-farm activities. Asset holdings include the value of household physical assets, including livestock. Because we are discussing household welfare, we use an adult equivalent rather than simple household size to compute the per capita values. To control for endogeneity of improved maize adoption, we use an IV regression where the predicted values from the tobit model are used as an instrument for observed values. Table 7 reports the results from the fixed effects models.

(Table 7 here)

We found that improved maize planted is positively and significantly correlated with per capita own maize consumption, per capita income and per capita asset holdings. The effect is both statistically and economically more significant for the own maize consumption and income equations. The FE estimates show that controlling for other factors, a 1% increase in improved maize area is associated with a 0.36% increase in own maize consumption, and 0.26% increase in income. This is an encouraging result given the fact that land holdings are small and sustainable intensification using modern inputs is the only option available to increase food production in Malawi. Other studies found a similar positive impact of agricultural technology adoption on household welfare. In Bangladesh, for example, the adoption of high yielding rice varieties was found to increase the income of adopters and reduce the probability of falling into poverty (Mendola, 2007). Similarly, improved maize adoption in Mexico and Nepal was associated with improvement in farmers' well being (La Rovere, et al., 2008). A 1% increase in improved maize area increases per capita asset holdings by 0.07%. Although small in relation to the values for income and maize consumption, the correlation between area under improved maize and asset holdings is not small in light of the general small asset holdings.

Other significant covariates are land holdings, household size, rainfall variables and year dummies. As would be expected, households who have a larger land holding have better 'own maize consumption', an indication that those who have larger land holdings will have generally more production capacity even controlling for area under improved maize. 'Land holdings' was positively correlated with asset holdings, perhaps an indicator of their potential to accumulate over time, as a result of their better production capacity. The land holdings variable was not significant in the income equation. Household size is negatively and significantly correlated with all the outcome variables. This indicates the negative impact of larger family size on welfare in rural areas, once the labor contributions of the household members are controlled for. Better rainfalls are associated with better maize consumption, while households who live in villages with higher rainfall variability have a significantly lower income, indicating the effect of risk on household welfare. Controlling for planting decisions, households earned lower income and registered smaller asset holdings in 2007 than 2004, perhaps a residual effect from the 2005 drought.

(c) Who benefits more from improved maize adoption

In this section, we present a disaggregated estimation of the income equation to compare male-headed households with female-headed households, and poor with better-off households.

Table 8 reports the results from separate Fixed Effects estimations of own maize consumption and income equations for male-headed and female-headed households. The figures show that improved maize variety adoption increases both own consumption and income for all households regardless of the gender of the household head. While improved maize adoption seems to be gender-neutral in its effect on the longer-term welfare-measure income, it has a stronger correlation for female-headed households in the own maize consumption equation. It seems that members in households headed by women benefit more from improved maize adoption by increasing their staple food consumption, compared to similar households headed by men. Given that we found no evidence of household-head gender difference in the improved maize adoption decision, it seems that those all households have a potential to enjoy the same benefits from adoption in the long run through higher income, although in the short run female-headed households may have better nutritional outcome. However, this analysis does not capture the intra-household gender inequalities due to data limitations. It is possible that women in male-headed households have less access to, and control of, the income.

(Table 8 here)

Results from estimation of income disaggregated by a households' wealth status are reported in Table 9. Wealth refers to the value of household durables and livestock owned by the household. The 'poorer households' group refers to the bottom tercile in the wealth distribution, while the 'better-off households' group refers to the top tercile. The results indicate that improved maize adoption is positively correlated with per capita income for the poorer households, but does not have any impact for households in the top of the wealth distribution. A percentage increase in the area under improved maize is associated with an income increase of 0.3% for households in the bottom asset tercile[4].

(Table 9 here)

The final set of regressions, reported in Table 10, shows the income function for each region. Improved maize adoption is positively correlated with per capita income in all regions. A first look suggests that it has the most impact in the Northern region, but further tests show that the ceofficients across the three regions are not statstically different.

(Table 10 here)

6 CONCLUSION

Malawi is one of the poorest countries in the world, with a rural poverty rate of 43%. Maize is the staple food crop in Malawi, grown by 97% of farming households. However, Malawi has struggled to improve agricultural productivity from its low levels to enhance food and nutritional security.

It has been argued that the adoption of agricultural technologies such as improved maize varieties increases food security, not only through higher productivity but also through the freeing up of land for agricultural diversification. Recent efforts by national breeders (both public and private) and international organizations, such as CIMMYT, have developed and supplied high-yielding varieties that are better-suited to the needs of smallholders in Malawi. Over 30 varieties of hybrid maize and five OPVs were developed and released in the last 20 years. On the demand side, the Government of Malawi tried to encourage uptake through the provision of subsidies, as well as extension services. Most recently, the large scale Farm Input Subsidy Program that started in 2005 tried to target millions of poor farmers to increase their access to these technologies.

This paper assesses improved maize variety adoption in Malawi and the link between adoption and household welfare. We used three years of panel data collected during the period 2004-2009. We estimated improved variety adoption using the Correlated Random Effects models where we applied the control function approach to account for endogenous access to input subsidies. We found that the likelihood of improved maize seed adoption increases with access to subsidized inputs, the education of the household head, land holdings, male labor, and access to farm credit. Households with older household heads are less likely to adopt improved maize. We found no evidence of difference between male-headed and female-headed households in terms of maize technology adoption. This indicates that female farmers are equally likely to use new technologies once access and asset related factors that often disadvantage women are fully accounted for.

The ex-post welfare impact of improved maize seed adoption is estimated using Fixed Effects models of household income and assets that control for endogeneity of the adoption decision. We found that a 1% increase in area under improved maize seed is associated with a 0.36% increase in own maize consumption, 0.26% increase in income and 0.07% increase in assets owned. The income of both male-headed and female-headed households increases with improved maize adoption. But female-headed households experience a higher increase in own maize consumption than male-headed households indicating that female-headed households may better utilize productivity changes in maize to improve nutritional consumption. Poorer households benefit more from improved maize adoption than households in the top of the wealth distribution in terms of income earned. A 1% increase in area under improved maize is associated with a 0.3% change in income for the poorest households, while for better-off households, it has no impact. This shows the importance of maize for poor farmers and how changes in maize productivity affect overall income.

The positive correlation between improved maize adoption and household welfare is an encouraging result, especially in view of the finding that male- and female-headed households are equally likely to adopt improved technology. The higher elasticity for women in the own maize consumption model suggests that to increase the nutritional benefits of technology adoption by farmers we may have to look beyond productivity into how the yields are managed within a household. The results in this study taken together lend evidence to the potential of agricultural technology-led poverty alleviation when smallholders have secured access to modern inputs and markets.

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Table 1. Improved maize adoption and input subsidy in the current sample

Variable	2004	2007	2009
Households who planted maize	92%	93%	96%
Households who adopted improved maize seed	56%	55%	64%
Households who received subsidized input	34%	58%	70%
Number of observation	1375	1375	1375

Source:Own computation from data

Table 2. Land holdings and maize planted (in hectares), 2004-2009

	2004		2007		2009	
Variable	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev
Total land holding	1.06	0.95	1.01	0.84	1.15	0.94
Cultivated area	0.97	0.88	1.01	0.91	0.97	0.73
Area under maize	0.72	0.85	0.83	0.74	0.73	0.54
Total area under improved maize	0.35	0.49	0.46	0.66	0.33	0.45
Intensity of adoption (for adopters)	0.86	0.28	0.9	0.23	0.71	0.33

Source: Own computation from data

Table 3. Socio-economic characteristics of improved maize adopters and non-adopters

Variable	Adopter	t-test	Non-Adopter
Value of per capita[a] asset owned (in'000 MK)[b]	14.20	***	9.45
Amount of adult labor in the household	2.82	***	2.41
Land holding per adult equivalent	0.31		0.30
Education of household head (# of years)	4.94	***	3.93
Household size	5.5	***	4.9
Age of household head	44.36	***	45.88
Female-headed household	0.23	***	0.33

a– Per capital values in this study are computed using adult equivalent units rather than nominal household size.

b- MK refers to the country's currency Malawi Kwacha. 1USD is equivalent to 140 MK. (SOAS *et al.*, 2008).

Source: Own computation from data

Table 4. Household well-being measures for adopters and non-adopters

Welfare indicators	Adopters	*t-test*	Non-Adopters
Total net income from crop production[a]	20791.93	***	15243.29
Per capita household income[a]	13494.24	**	11437.34
HH experienced chronic illness in the family the previous two years[*]	0.13	**	0.16
HH consumption past 12 months was adequate [a]	0.53	***	0.43
Maximum number of months staple crop lasted[a]	8.27	***	7.20

a- Average annual income in 2009 MK

b-These statistics are from 2007 and 2009 surveys only (as reported by respondent for direct question).

Source: Own computation from data

Table 5. Income and Well-being measures for the poorest [a] 25% of households, by adoption status

Welfare Outcome	Poor Adopters	*t-test*	Poor Non-Adopters
Net income from crop production	12778.07	**	8928.69
Per capita income	7130.93	**	5660.77
How long own production lasted	6.32	***	5.57

a-Households are grouped by their asset quartile

Source: Own computation from data

Table 6. Correlated Random Effect models results for the probability of improved maize adoption and the intensity of adoption [a]

	Improved maize adoption(Probit)				Area under improved maize (Tobit)			
	Coefficient		Bootstrap se	Average marginal effect	Coefficient		Bootstrap se	Average marginal effect
Access to subsidy(dummy=1 if HH received subsidy)	1.278	***	0.248	0.444	0.879	***	0.145	0.879
Generalized residual	-0.367	**	0.152	-0.127	-0.372	***	0.089	-0.372
Age of household head	-0.004	**	0.001	-0.001	-0.002	*	0.001	-0.002
Education of household head (# of years)	0.019	***	0.006	0.007	0.016	***	0.004	0.016
Female-headed household	-0.173		0.119	-0.060	-0.107		0.064	-0.107
Male adult labor	0.089	**	0.044	0.031	0.047	*	0.025	0.047
Female adult labor	-0.073		0.053	-0.025	-0.020		0.025	-0.020
Household size	0.031		0.024	0.011	0.017		0.012	0.017
Land holdings in hectare	0.064	*	0.032	0.022	0.271	***	0.033	0.271
Village has farm credit organization	0.171	***	0.054	0.059	0.091	***	0.029	0.091
Year 2007	-0.632	***	0.140	-0.219	-0.151	*	0.079	-0.151
Year 2009	-0.187		0.154	-0.065	-0.209	**	0.082	-0.209
North region	0.228	*	0.136	0.079	0.023		0.068	0.023
Central region	-0.012		0.075	-0.004	0.008		0.046	0.008
Rainfall over growing season	0.000		0.000	0.000	0.000	*	0.000	0.000
Coefficient of variation on rainfall	0.290		0.385	0.101	-0.279		0.243	-0.279
Price of commercial seed (real 2009, kwcha)	-0.011	**	0.004	-0.004	-0.002		0.002	-0.002
Price of commercial fertilizer (real 2009, kwcha)	-0.002		0.001	-0.001	-0.002	***	0.001	-0.002
Plot soil type:sandy	-0.179	***	0.065	-0.062	-0.134	***	0.034	-0.134
Plot soil type: Clay	-0.074		0.053	-0.026	-0.077	***	0.028	-0.077
Constant	-0.492		0.487		-0.901	***	0.276	

Chi2	606.128	687.806
		-
Log likelihood	-2396.4	3655.45
Number of observation	3933	3933

a-The mean of time varying variables are included as additional regressors in this correlated random effect model, but they are not reported here to save space;

Significance levels: *: 10%, **: 5%, ***: 1%

Table 7. Fixed Effects estimation of relationship between improved maize adoption and short-term and Long-term welfare

	Own Maize [a] consumption			Income[a]			Asset holdings[a]		
	Coeff.		Se	Coeff.		se	Coeff.		Se
Ln (Area under improved maize)[b]	0.355	***	0.041	0.261	***	0.054	0.073	**	0.032
Female-headed household	0.041		0.128	0.013		0.170	-0.421	***	0.101
Male adult labor	-0.070		0.047	0.001		0.063	0.037		0.038
Female adult labor	0.041		0.050	0.040		0.067	0.051		0.040
Land holdings in hectare	0.167	***	0.043	0.072		0.057	0.139	***	0.034
Household size	-0.133	***	0.025	-0.113	***	0.033	-0.139	***	0.020
Year 2007	-0.152		0.099	-0.750	***	0.131	-0.248	***	0.078
Year 2009	-0.324	***	0.121	0.169		0.160	0.057		0.096
Rainfall over growing season	0.000	**	0.000	0.000	*	0.000	0.000		0.000
Coefficient of variation on rainfall	-0.290		0.446	-1.646	***	0.591	-0.538		0.353
Maize price prior to planting season(real 2009, kwcha)	0.006		0.005	0.010		0.006	-0.006		0.004
Price of commercial fertilizer (real 2009, kwcha)	0.003	**	0.001	-0.001		0.001	0.001		0.001
Constant	5.525	***	0.310	9.875	***	0.410	9.244	***	0.245
R2 – Overall	0.087			0.053			0.079		
Chi2	37151			82944			208000		
Rho	0.393			0.295			0.546		
Number of sample	3933			3933			3933		
Number of groups	1311			1311			1311		

a- All outcome (dependent) variables are per adult equivalent and given in logarithmic terms; Significance levels: *: 10%, **: 5%, ***: 1%

b- We control for possible endogeneity of improved maize adoption through a Fixed Effect estimation where the predicted improved maize area from the tobit model is used as an instrument for observed values.

Table 8. Comparison of the Fixed Effects model estimations of income and own maize consumption for male-headed and female-headed households

	Income						Own maize consumption					
	Female-headed Household			Male-headed Household			Female-headed Household			Male-headed Household		
	Coeff.		se	Coeff.		se	Coeff.		se	Coeff.		se
Ln (Area under improved maize)	0.270	***	0.096	0.268	***	0.069	0.451	***	0.083	0.322	***	0.050
Male adult labor	0.172		0.136	-0.024		0.077	-0.051		0.117	-0.086		0.056
Female adult labor	0.143		0.138	0.018		0.082	0.142		0.118	0.031		0.059
Land holdings in hectare	0.065		0.121	0.070		0.069	0.159		0.104	0.172	***	0.050
Household size	-0.225	***	0.076	-0.117	***	0.041	-0.224	***	0.066	-0.107	***	0.030
Year 2007	-0.979	***	0.309	-0.673	***	0.151	0.177		0.265	-0.202	*	0.109
Year 2009	-0.161		0.342	0.248		0.188	-0.300		0.294	-0.318	**	0.136
Rainfall over growing season	0.000		0.000	0.000		0.000	0.000		0.000	0.000	**	0.000
Coefficient of variation on rainfall	-0.627		1.295	-2.141	***	0.700	1.966	*	1.112	-1.290	**	0.505
Maize price prior to planting season(real 2009, kwcha)	0.015		0.014	0.007		0.007	0.023	*	0.012	0.002		0.005
Price of commercial fertilizer (real 2009, kwcha)	0.003		0.003	-0.001		0.002	-0.001		0.003	0.004	***	0.001
Constant	9.618		0.788	10.225	***	0.517	5.484	***	0.677	5.575	***	0.373
R2 – Overall	0.093			0.042			0.079			0.094		
Chi2	22065	***		61288	***		7858	***		29724	***	
Rho	0.383			0.346			0.454			0.427		
Number of sample	1066			2867			1066			2867		
Number of groups	450			1055			450			1055		

Notes as in Table 7

Table 9. Comparison of the Fixed Effects model estimations of income for the top and bottom wealth tercile

	Poorer households			Better-off households		
	Coefficient		Se	Coefficient		se
Ln (Area under improved maize)	0.296	***	0.093	0.167		0.189
Female-headed household	-0.042		0.316	0.040		0.467
Male adult labor	-0.054		0.122	0.019		0.143
Female adult labor	-0.011		0.125	0.206		0.149
Land holdings in hectare	0.213	*	0.113	0.154		0.135
Household size	-0.152	**	0.062	-0.096		0.077
Year 2007	-0.570	**	0.250	-0.544	*	0.301
Year 2009	0.038		0.339	0.840	**	0.418
Rainfall over growing season	0.000		0.000	0.000		0.000
Coefficient of variation in rainfall	-0.649		1.185	-2.214		1.381
Maize price prior to planting season(real 2009, kwcha)	0.025	**	0.012	-0.007		0.015
Price of commercial fertilizer (real 2009, kwcha)	0.001		0.003	-0.006		0.004
Constant	9.477	***	0.777	10.261	***	0.972
R2 – Overall	0.105			0.022		
Chi2	35421			23201		
Rho	0.467			0.497		
Number of sample	1313			1310		
Number of groups	736			723		

Notes as in Table 7

Table 10. Comparison of the Fixed Effects model estimation of income for the three regions of Malawi

	Northern region			Central region			Southern region		
	Coefficient		se	Coefficient		se	Coefficient		se
Ln (Area under improved maize)	0.267	**	0.128	0.231	**	0.093	0.243	***	0.085
Female-headed household	0.652		0.469	-0.039		0.289	-0.160		0.238
Male adult labor	0.071		0.135	-0.056		0.098	0.001		0.100
Female adult labor	0.005		0.162	0.068		0.103	0.038		0.103
Land holdings in hectare	0.137		0.131	0.195	**	0.088	-0.057		0.094
Household size	-0.181	**	0.071	-0.112	**	0.051	-0.078		0.054
Year 2007	-1.471	***	0.347	-0.187		0.187	0.139		0.361
Year 2009	1.165		0.735	0.340		0.336	0.138		0.254
Rainfall over growing season	0.002		0.001	0.000		0.000	0.000		0.000
Coefficient of variation in rainfall	6.267		4.261	-1.589		1.220	-1.112		1.032
Maize price prior to planting season(real 2009, kwcha)	-0.047	***	0.016	0.028	***	0.011	0.042	***	0.013
Price of commercial fertilizer (real 2009, kwcha)	0.003		0.004	-0.003		0.003	-0.004		0.003
Constant	8.302	***	1.938	9.140	***	0.741	9.112	***	0.684
R2 – Overall	0.145			0.051			0.049		
Chi2	16515.788			33808.423			35717.395		
Rho	0.311			0.286			0.305		
Number of sample	750.000			1464.000			1719.000		
Number of groups	250.000			488.000			573.000		

Notes as in Table 7

Appendix 1. Correlated Random Effect Probit model of access to Farm Input Subsidy Program (FISP)[a]

	Coeff.		Robust s.e
Age of household head	0.002		0.002
Education of household head (# of years)	0.018	**	0.008
Female-headed household	-0.022		0.112
Male adult labor	-0.004		0.041
Female adult labor	0.042		0.040
Household size	0.092	**	0.037
Cultivated area	0.060	**	0.030
Years household head lived in the village[b]	0.003	**	0.002
Member of parliament live in the community[b]	0.208	***	0.056
Village has farm credit organization	-0.002		0.056
Year 2007	0.970	***	0.092
Year 2009	1.259	***	0.106
North region	-0.207		0.142
Central region	-0.210	***	0.078
Rainfall over growing season	0.000	***	0.000
coefficient of variation on rainfall	-0.522		0.393
Maize price prior to planting season (real 2009, kwcha)	0.006		0.004
price of commercial fertilizer (real 2009, kwcha)	-0.002	**	0.001
Sandy soil	0.151	**	0.062
Clay soil	0.013		0.056
Constant	-0.997	*	0.575
Chi2	508.18	***	
Pseudo R2	0.101		
Number of observation	3933		

a- The mean of time varying variables are included as additional regressors in this correlated random effect model, but they are not reported here to save space.

b- These variables are instruments. The significance of the coefficients confirms our hope that these variables are appropriate instruments for selection to subsidy.

Appendix 2. Models for amount of improved maize adopted. Dependent variable is total area planted under improved maize seed[a]

	CRE Tobit			Cragg two-part model						Fixed Effect IV		
				Adoption			Amount					
	Coeff.		Bootstrap s.e	Coeff.		Bootstrap s.e	Coeff.		Bootstrap s.e	Coeff.		Se
Age of household head	-0.002	**	0.001	-0.004	***	0.001	0.001		0.002			
Education of household head	0.016	***	0.004	0.019	***	0.007	0.015	**	0.006			
Female-headed household	-0.107		0.072	-0.173		0.116	-0.160		0.100	-0.046		0.108
Male adult labor	0.047	*	0.027	0.089	*	0.049	0.050		0.048	-0.006		0.061
Female adult labor	-0.020		0.026	-0.073		0.047	0.046		0.044	-0.014		0.032
Household size	0.017		0.011	0.031		0.022	-0.004		0.019	0.024		0.023
Land holdings in hectare	0.271	***	0.031	0.064	*	0.034	0.524	***	0.047	0.256	***	0.083
Village has farm credit	0.091	***	0.028	0.171	***	0.049	-0.026		0.040			
Year 2007	-0.151	*	0.080	-0.632	***	0.141	0.332	**	0.147	0.468		0.643
Year 2009	-0.209	**	0.092	-0.187		0.158	-0.490	***	0.155	0.426		0.792
North region	0.023		0.063	0.228	*	0.126	-0.185		0.123			
Centeral region	0.008		0.040	-0.012		0.070	-0.023		0.072			
Rainfall over growing season	0.000	*	0.000	0.000		0.000	0.000		0.000	0.000		0.000
Coefficient of variation on rainfall	-0.279		0.255	0.290		0.419	-1.157	***	0.389	-0.442		0.383
Price of commercial seed (real 2009, kwcha)	-0.002		0.002	-0.011	**	0.005	0.008	*	0.004	0.003		0.005
Price of commercial fertilizer (real 2009, kwcha)	-0.002	***	0.001	-0.002		0.001	-0.003	***	0.001	-0.003		0.002
Plot soil type:sandy	-0.134	***	0.036	-0.179	***	0.052	-0.107	*	0.055			
Plot soil type: Clay	-0.077	***	0.028	-0.074		0.046	-0.124	***	0.044			
Access to subsidy(dummy)	0.879	***	0.152	1.278	***	0.239	1.040	***	0.277	-0.745		1.721
Generalized residual	-0.372	***	0.092	-0.367	**	0.151	-0.748	***	0.173			
Constant	-0.901	***	0.281	-0.492		0.548	-1.787	***	0.530	0.501		0.783
Chi2	717	***					584	***		85	***	
Log likelihood	-3655						-3227					
Number of observation	3933						3933			3933		

a-The Cregg and Tobit models are correlated random effect models and hence include mean values of regressors but are not reported here to simplify presentation.

[1] Refer SOAS *et al*. (2008) for detailed discussion of the subsidy program

[2] This is a general question for subjective valuation. The exact question put to the farmer was "Overall, how satisfied (content, happy) are you with your life?" and the choices rank from 'very unsatisfied' to 'very satisfied'

[3] See Appendix 1 for the estimation result from the first stage subsidy equation

[4] A qualitatively similar result was obtained for the own maize consumption equation.