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

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Summary. — This paper assesses rural households' decision to use improved maize varieties in Malawi and examines its impact on household welfare using a three-year household panel data. The distributional effect of maize technology adoption is investigated by looking at impacts across wealth and gender groups. We applied control function approach and IV regression to control for possible endogeneity of input subsidy and area under improved maize. We found that area under improved maize varieties is positively correlated with own maize consumption, income and asset holdings. We found evidence that improved maize adoption has a stronger impact on welfare of poorer households.

Key words — improved maize, technology adoption, input subsidy, food security, Malawi, Africa

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 during 1961–2010, 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). Own production of farmers covers on average between 6 and 7 months of household consumption in a normal year [Ministry of Agriculture and Food Security [MoAFS], 2011). Poverty is widespread in the country, particularly in rural areas where the poor account for 57% of the rural population according to the official estimate (NSO, 2012).[1]

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, W., O.D., & U.o., 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 35 years during 1970–2005, there have been only marginal increases in maize and rice productivity (MoAFS, 2011). Earlier studies, however, indicated high improved technology diffusion and hence high expectations of improved productivity (Heisey & Smale, 1995). The Government of Malawi believes that the major contributing factor to low productivity in the smallholder sector is low input use due to lack of resources (MoAFS, 2011). To ameliorate this, the government launched a Farm Input Subsidy Program (FISP) in 2005 explicitly

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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 while access to subsidized input did not affect the likelihood of modern maize planting, it has significant influence on the amount of improved maize planted. 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 0.48% increase in income, a 0.34% increase in the maize available for consumption, and a 0.24% increase in asset wealth. Improved maize adoption has more impact on 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 discussions, and conclude in Section 6 with highlights of the key findings and policy implications.

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). The majority of households are net buyers of maize; 56% of net buyers did not sell any maize in 2007 (SOAS *et al.*, 2008). On-farm storage losses are possibly high. There is evidence that maize produced in Malawi and many other countries in the region suffer from larger grain borer, which can cause up to 30% quantity loss after 6 months of storage (Boxall, 2002). Perhaps as a result, most households who buy maize, including net sellers, made their purchase during the lean season when prices are the highest.

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). 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 do not 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-Hurlé (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. The economic impact assessment studies of improved maize adoption (Alene *et al.*, 2009) and subsidy programs (Chibwana *et al.*, 2012; Dorward & Chirwa, 2013; Holden & Lunduka, 2010a, 2010b; Ricker-Gilbert & Jayne, 2012; SOAS *et al.*, 2008; Arndt, Pauw, & Thurlow, 2013; Buffie & Atolia, 2009; Filipski & Taylor, 2012; Lunduka, Ricker-Gilbert, & Fisher, 2013) showed positive results.

3. DATA AND DESCRIPTIVE STATISTICS

(a) *Data*

Data used in this study come from three nationally representative surveys of rural farm households in Malawi. The first wave of data comes from the Second Integrated Household Survey (IHS2), a nationally representative survey conducted during the 2002/03 and 2003/04 growing seasons that covers 26 districts in Malawi, collected by the National Statistical Office (NSO). The second wave of data comes from the 2006/07 Agricultural Inputs Support Survey (AISS1), conducted during the 2006/07 growing season, also collected by the NSO. Because of budget constraint only 3,485 of the households were in the re-sampled enumeration area in 2006/07. Of these 3,485 households, 2,968 were re-interviewed in 2006/07, which gives us an attrition rate of 14.8%. The third wave of data comes from the 2008/09 Agricultural Inputs Support Survey II (AISS2) conducted during the 2008/09 growing season, by Wadonda Consult. The AISS2 survey had a subsequently smaller budget than the AISS1 survey in 2006/07, so 1,642 of the households lived in enumeration areas that were revisited in AISS2. Of the 1,642 households in revisited areas, 1,375 were found for re-interview in AISS2, which gives us an attrition rate of 16.3% between AISS1 and AISS2. Therefore, we end up using a balanced panel of 1,375 households who were surveyed in all three waves for a total of 4,125 observations.

Potential attrition bias caused by households leaving the panel in different waves for systematic reasons is a major issue that must be addressed. Attrition rate is nearly 16% between each survey, so we test the robustness of our results using inverse probability weights (IPW). The IPW technique involves three steps: (i) use probit to measure whether observable factors in one wave affect whether a household is re-interviewed in the next wave; (ii) obtain the predicted probabilities (Pr_{it}) of being re-interviewed in the following wave; (iii) compute the IPW = ($1/Pr_{it}$) and apply it to the models estimated. For households originally sampled in IHS2, the IPW for household i in AISS1 = 1/PriAISS1 and the IPW in AISS2 = 1/(PriAISS1 * PriAISS2). (For more information on IPW see Wooldridge, 2010.) We multiply the IPW by the survey sampling weights in the first wave to control for the probability of the household being selected for interview from the population. We find that there is little difference in results when the models are weighted and when they are not, so attrition is not a major concern in this application. Our finding is consistent with other studies that use this data set and find little evidence of attrition (Ricker-Gilbert, Jayne, & Chirwa, 2011; Mason & Ricker-Gilbert 2013).

(b) *Descriptive statistics*

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 2004–09. 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 planted improved maize varieties. Significantly more households planted improved maize (64%) in 2009.

Table 1 shows the proportion of households who benefited from the Farm Input Subsidy Program (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.[2]

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 (about two-thirds) for maize cultivation. For improved maize seed users, 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 do not specify what percentage of the crops are purely improved maize when there is intercropping.

(i) *Who plants improved maize in Malawi?*

The socio-economic characteristics of improved maize adopters and nonadopters are reported in Table 3. Households planting improved maize are headed by younger and more educated farmers, perhaps because these households are more receptive to new ideas. In addition, improved maize adopters own more assets and have more adult labor. 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 improved maize planting decision. There are proportionately more female-headed households among nonadopters than there are in the adopters group. All the differences discussed are statistically significant at the 1% level.

An evaluation of the change in a household's improved maize seed use in the years 2004–09 shows that the probability of staying an improved maize technology adopter and/or moving toward adoption seems higher compared to the probability of discontinuing and nonadoption. While 66% of households who ever planted improved maize seed continue using the technology in the subsequent period and, only 48% of nonadopters remain so in subsequent periods.

(ii) *Improved maize seed technology adoption and its relation with household welfare*

Adopters of improved maize varieties earn significantly more income from crop production than nonadopters

Table 1. *Use of improved maize seed and access to input subsidy in the current sample*

Variable	2004	2007	2009
Households who planted any kind of maize	92%	93%	96%
Households who planted improved maize	56%	55%	64%
Households with access to subsidized input[a]	34%	65%	73%
Number of observations	1375	1375	1375

Source: Own computation from data.
[a] This refers to households who reported to have used subsidized input. The input subsidy program started in 2005 but there was some subsidy on fertilizer even in 2004.

Table 2. *Land holdings and maize planted (in hectares), 2004–09*

Variable	2004		2007		2009	
	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
Total 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
Improved maize as share of total maize planted (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 adopters and nonadopters of improved maize varieties*

Variable	Adopters	*t*-test	Nonadopters
Value of per capita[a] asset owned (in '000 MK)[b]	14.20	***	9.45
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 households (yes = 1)	0.23	***	0.33

Significance levels: *: 10%, **: 5%, ***: 1%.
Source: Own computation from data.
[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. 1 USD is equivalent to 140 MK. (SOAS *et al.*, 2008).

(Table 4). They earn about 18% more in total family or household income. Table 4 shows that nonadopters 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 use improved technology. Our data show that only about half of the households reported to have enough food consumption the last 12 months. This indicates that many farm 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 improved maize seed adopters lasts longer than that of nonadopters. Households' own evaluations of their welfare suggest that improved maize adopters may be better off. Proportionately more adopters report that they are "satisfied with their lives". We should not read too much into this, however, as two-thirds of the total households admitted to being dissatisfied with their lives. [3]

One may argue that, wealthier households are more likely to use improved maize seed as they are less liquidity constrained to purchase improved seeds and perhaps less risk averse. The positive correlation we see between improved maize technology adoption and welfare outcomes may, thus, be attributable to the impact of wealth on both improved technology adoption and welfare, rather than the effect of improved maize adoption on welfare. If planting improved maize indeed makes a difference for well-being, households with equal resources should experience different welfare outcomes depending on whether or not they plant improved maize. To test this, we compared welfare outcome of the poorest households disaggregated by

Table 4. *Household well-being measures for adopters and nonadopters of improved maize varieties*

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

Significance levels: *: 10%, **: 5%, ***: 1%.
Source: Own computation from data.
[a] Average annual income in 2009 MK.
[b] These statistics are from 2007 and 2009 surveys only (as reported by respondent for direct question).

their maize technology 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, staple production of poor adopters last longer than that of the nonadopters. These differences are statistically significant.

4. EMPIRICAL APPROACH

As stated in the introduction, this paper assesses: (1) the use of improved maize seed in Malawi; and (2) its impact on household welfare. There are some challenges in estimating the models for improved maize and welfare functions 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 nonseparability between production and consumption decisions. For example, the lack of access to credit causes some input prices to be marked upward by the shadow price of credit (Sadoulet & De Janvry, 1995).

Accordingly, in addition to relevant prices, our model of improved maize planted includes a vector of household, village, and plot characteristics as determinants. Let $\boldsymbol{M}$ 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 use improved maize seed and as such the variable is censored with 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 facing various constraints is at zero (Wooldridge, 2010). So M_{it} (area planted to improved maize variety) is given by:

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

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

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

where $\boldsymbol{P}_{it}$ refers to a vector of input and output prices. We expect input prices to negatively influence improved maize planting decision. 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 male and female family members, the education of the household head and farm size. We expect all the labor variables to contribute positively to the decision to use improved maize variety. The implication of imperfect factor markets is that households who have more labor and more skills will face fewer constraints when planting improved maize varieties. The vector $\boldsymbol{D}_{it}$ includes household demographic variables such as the age and gender of the household head and household size. We expect that households with more educated household heads are more likely to use 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 the decision to use improved maize seed varieties. 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.

The model above can be estimated using the tobit model framework which assumes that ε_{it} is normally distributed, $\varepsilon_{it}|\mathbf{x}_{it} \sim Normal(0, \sigma^2)$ (Tobin, 1958). But the tobit model imply that the direction of the effect of any explanatory variable on the decision to use improved maize seed is identical to the effect on the amount of improved maize planted. This is a limitation of the tobit model. A two-tier truncated normal hurdle model (Cragg, 1971) extends the standard tobit model by assuming that the adoption/use decision follows a probit model, while the amount/intensity decision has a truncated normal distribution. Adoption and intensity decisions are assumed to be independent in this model. In this paper we will adopt the

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

Welfare outcome	Poor adopters	*t-test*	Poor nonadopters
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

Source: Own computation from data.
[a] Households are grouped by their asset quartile.

more flexible double-hurdle (DH) model to estimate the improved maize planting decision.

The indicators of household welfare outcome for the purpose of this analysis are own ***maize consumption*** (maize available for consumption from own production); **income** (household income) and ***asset holdings*** (value of household asset holdings), all measured per adult equivalent. A more appropriate measure of welfare would have been consumption expenditure. Unfortunately, the AISS surveys do not collect data on consumption expenditure. The outcome equation is simple and relatively straight forward. We define own maize consumption (income or asset) as a function of improved maize planted ($\boldsymbol{M}_{it}$), 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 ($\boldsymbol{V}_{it}$).

$$Y_{it} = \alpha_0 + \boldsymbol{\alpha}_1 \boldsymbol{M}_{it} + \boldsymbol{\alpha}_2 \boldsymbol{D}_{it} + \boldsymbol{\alpha}_3 \boldsymbol{L}_{it} + \boldsymbol{\alpha}_4 \boldsymbol{R}_{it} + \boldsymbol{\alpha}_5 \boldsymbol{V}_{it} + c_i + \varepsilon_{it} \quad (4)$$

(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). Although there was inefficiency in targeting (Holden & Lunduka, 2012; Lunduka *et al.* 2013; SOAS *et al.*, 2008), the subsidies are officially designed for the poor farmers and as such access cannot be considered random. Even the inclusion and exclusion errors in targeting are unlikely to be 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 possible endogeneity of selection for input subsidy. Using more compact expression, we write the improved maize equation as follows:

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

The Smith and 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 access to the input subsidy as a linear projection of the exogenous variables, including the instruments (IV_{it}).

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

Accordingly, our estimation of improved maize variety adoption using the control function 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 improved maize equation along with the observed selection variable S_{it}. A significance test on the coefficient of the residuals tests for endogeneity of the input subsidy. We use bootstrapping in the second stage to adjust standard errors for the two-step procedure. The instruments that are used are "the *number of years the household lived in the village*" and "*a Member of Parliament resides in the village*." These two variables capture the social capital at an individual and village level that may influence access to the input subsidy by farmers. An earlier study shows that these variables are viable instruments (Ricker-Gilbert *et al.*, 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 equations. To address this we use the following procedure: (1) estimate improved maize planting decision using Cragg's DH model, (2) obtain expected values, (3) estimate Fixed Effect IV for the welfare equation where expected (predicted) values of improved maize planted serve as instrument for observed values. 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 equations. 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 panel models an important issue is how to handle the unobserved effect $\boldsymbol{c_i}$. 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 as there is no assurance that the unobserved heterogeneity will be orthogonal and uncorrelated to the other covariates. The Fixed Effects model allows correlation between the individual effects and the explanatory variables, which can be differenced out in the estimation process. We estimated Fixed Effects model for the welfare outcome equations as these are linear models.

The fixed effects estimator, which is the workhorse for linear models, is not easy to apply for nonlinear models because of the incidental parameters problem. For nonlinear panel data models, 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, 2010). Both the reduced form subsidy equation and the structural improved maize equations are estimated using the CRE estimator.

5. RESULTS

(a) *Improved maize adoption*

The number of panel households used for the estimation is 1,311 rather than 1,375 because of missing values for some of the regressor (giving us 3,933 observations in three rounds). Table 6 describes the variables used in the estimations and present descriptive statistics.

Table 7 shows the results from the Double Hurdle model. [4] The generalized residual from the first stage subsidy equation is included along with the observed subsidy indicator in the CRE models to test and control for the endogeneity of access to the input 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 access to the input subsidy is endogenous as expected and, therefore, our procedure was necessary. Appendix 1 shows the detailed results from the first stage subsidy equation.

Table 6. *Descriptive statistics of variables used in the econometric analysis*

	2003/2004			2006/2007			2008/2009		
	Median	Mean	Std. Dev	Median	Mean	Std. Dev	Median	Mean	Std. Dev
Household planted improved maize (yes = 1)	1.00	0.56	0.497	1.00	0.55	0.497	1.00	0.64	0.481
Area under improved maize (in hectares)	0.20	0.35	0.489	0.20	0.46	0.660	0.20	0.33	0.451
Household obtained subsidized input (yes = 1)	0.00	0.34	0.475	1.00	0.68	0.477	1.00	0.73	0.473
Age of household head	42.00	44.99	17.370	42.00	44.99	17.370	42.00	44.99	17.370
Education of household head (# of years)	4.00	4.52	3.831	4.00	4.52	3.831	4.00	4.52	3.831
Female-headed household (yes = 1)	0.00	0.25	0.433	0.00	0.27	0.445	0.00	0.29	0.455
Male adult labor (# of male adults under 65)	1.00	1.17	0.935	1.00	1.35	1.088	1.00	1.36	1.067
Female adult labor (# of male adults under 65)	1.00	1.23	0.756	1.00	1.40	0.880	1.00	1.44	0.958
Household size	5.00	4.83	2.388	5.00	5.34	2.369	5.00	5.52	2.445
Land holdings in hectare	0.81	1.06	0.946	0.81	1.01	0.844	0.81	1.15	0.939
Village has farm credit organization	0.00	0.37	0.482	0.00	0.37	0.482	0.00	0.37	0.482
Farm land contains sandy soil	0.00	0.21	0.406	0.00	0.21	0.406	0.00	0.21	0.406
Farm land contains mixed soil (soil between sandy and clay)	1.00	0.70	0.458	1.00	0.70	0.458	1.00	0.70	0.458
Farm land contains clay soil	0.00	0.30	0.460	0.00	0.30	0.460	0.00	0.30	0.460
Average cumulative rainfall during past five growing seasons at district level (in 100 cm)	862.68	952.98	213.541	857.78	884.11	150.812	835.16	897.82	133.176
Standard deviation of average rainfall over the past five growing seasons at district level (in 100 cm)	0.22	0.23	0.068	0.27	0.26	0.069	0.27	0.26	0.087
Average maize price 6 months prior to planting season at district level (kw/kg)	19.35	21.12	4.800	21.19	19.87	3.120	49.62	47.43	3.953
Price of commercial fertilizer during planting season	35.00	34.54	5.608	67.80	70.13	10.839	133.33	139.21	43.843
Household is in Northern region (yes = 1)	0.00	0.20	0.398	0.00	0.20	0.398	0.00	0.20	0.398
Household is in Central region (yes = 1)	0.00	0.36	0.481	0.00	0.36	0.481	0.00	0.36	0.481
Household is in Southern region (yes = 1)	0.00	0.44	0.497	0.00	0.44	0.497	0.00	0.44	0.497
Number of years household head lived in the village	29.00	31.30	21.349	32.00	34.76	21.378	34.00	36.76	21.378
Member of parliament lives in the village	0.00	0.36	0.480	0.00	0.34	0.473	0.00	0.12	0.328

Table 7. *Households' improved maize planting decision. Cragg's Double Hurdle model using the Correlated Random Effect method of estimation*[a]

	Probability of planting improved maize (Hurdle 1)		Area planted (land under improved maize) (Hurdle 2)	
	Coeff.	Bootstrap s.e.	Coeff.	Bootstrap s.e.
Age of household head	−0.003*	0.002	−0.001	0.002
Education of household head (# of years)	0.023***	0.007	0.015*	0.009
Female-headed household	−0.158	0.121	−0.219	0.180
Male adult labor	0.075	0.050	0.112*	0.059
Female adult labor	−0.085**	0.042	0.060	0.054
Household size	0.042	0.027	−0.004	0.030
Ln (land holdings in hectare)	0.060***	0.019	0.466***	0.108
Village has farm credit organization	0.191***	0.051	−0.129*	0.070
Year 2007	−0.432**	0.169	−0.316	0.308
Year 2009	0.030	0.239	−1.540***	0.394
Central region	−0.152	0.102	0.029	0.118
Southern region	−0.127	0.122	−0.094	0.166
Average cumulative rainfall over past five growing season	0.000	0.000	0.001	0.000
Standard deviation of average rainfall (in 100 cm)	0.151	0.428	−1.949***	0.516
Maize price prior to planting season (real 2009, kwcha)	−0.008**	0.004	0.006	0.006
Price of commercial fertilizer during planting season (real 2009, kwcha)	−0.002*	0.001	−0.002	0.001
Sandy soil	−0.104	0.072	−0.268***	0.093
Clay soil	−0.027	0.061	−0.168**	0.080
Mixed soil	0.122*	0.066	0.015	0.077
Access to subsidy	0.724	0.470	3.853***	0.911
Generalized residual	−0.038	0.284	−2.507***	0.568
Constant	−0.270	0.410	−2.229***	0.613
Sigma			0.817***	0.054
Chi2			566.68	
Prob > chi^2			0.000	
Loglikelihood			−3349	
Number of observations			3933	

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

[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.

The coefficient on access to subsidy is positive but not significant on the probit component of the equation. But access to the input subsidy is positively and significantly correlated with the area planted to improved maize varieties. This indicates that the subsidy is important in determining the extent of adoption rather than just the decision to use the new technology and suggests that farmers may not be able to invest significantly on expansion without financial support. This again seems to address the main concerns of the Government of Malawi by encouraging expanded use of modern varieties for increasing maize production. The new subsidy program was initiated to stimulate use of modern technologies by the poor.

Households with older household heads are less likely to use improved maize seed, possibly indicating risk-aversion and a technology mistrust behavior. But, the economic and statistical significances are not strong. Education of the household head is positively correlated with both the adoption/use decision and area planted to 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 planting and the amount of improved maize planted increases with land holding. This is as expected. Other things held the same, households who have more land can set aside larger land areas for planting improved maize. The probability of planting improved maize decreases with female labor availability. To the extent that improved maize varieties are labor demanding, we expect increase in availability of all labor to positively influence the adoption and use of improved maize seed. Perhaps this negative correlation arises because households with larger female labor are more likely to plant local maize which may be considered female crop (see Doss, 1999). As expected the amount of improved maize planted increases with household male labor and credit availability in the village. Higher prices for maize and fertilizer reduce the probability of improved maize planting, but did not affect the decision on the area to be planted. To check for robustness we also estimated the CRE tobit model. The results are largely similar. But Cragg's double-hurdle (DH) model fits the improved maize equation better. The likelihood ratio test rejects the tobit model in favor of the DH model.[5]

(b) *Improved maize adoption and household welfare*

We ran Fixed Effects models to estimate the relationship between improved maize technology adoption and household welfare. The selected indicators for the welfare outcomes are household per capita maize available for consumption from own production, 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, noncrop 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 instru-

Table 8. *Fixed Effects estimation of relationship between improved maize adoption and household welfare*

	Household income[a]		Assets[a]		Own maize consumption[a]	
	Coeff.	s.e.	Coeff.	s.e.	Coeff.	s.e.
Ln (area under improved maize)[b]	0.48***	0.109	0.24***	0.064	0.34***	0.070
Female-headed household	0.10	0.200	−0.37***	0.118	0.02	0.129
Male adult labor	−0.02	0.074	0.02	0.043	−0.07	0.047
Female adult labor	0.08	0.079	0.08*	0.046	0.03	0.051
Ln (land holdings in hectare)	−0.05	0.038	−0.01	0.022	0.07***	0.024
Household size	−0.13***	0.040	−0.15***	0.024	−0.12***	0.026
Year 2007	−0.65***	0.141	−0.27***	0.083	−0.07	0.091
Year 2009	0.08	0.194	−0.10	0.114	−0.26**	0.125
Average cumulative rainfall over past five growing season	0.00	0.001	0.00	0.000	0.00	0.000
Standard deviation of average rainfall (in 100 cm)	−1.72**	0.678	−0.47	0.398	−0.47	0.436
Maize price prior to planting season (real 2009, kwcha)	0.01**	0.007	0.00	0.004	0.01*	0.005
Price of commercial fertilizer-planting season (real 2009, kwcha)	0.00	0.002	0.00**	0.001	0.00**	0.001
Constant	10.67***	0.697	9.80***	0.409	5.78***	0.448
R^2 overall	0.029		0.037		0.087	
Prob > chi^2	0.000		0.000		0.000	
Rho	0.297		0.497		0.394	
Number of observations	3933		3933		3933	
Number of groups	1311		1311		1311	

Significance levels: *: 10%, **: 5%, ***: 1%.
[a] All outcome (dependent) variables are per adult equivalent and given in logarithmic terms.
[b] We control for possible endogeneity of improved maize adoption through a Fixed Effect estimation where the predicted improved maize area from the double-hurdle model is used as an instrument for observed values.

Table 9. *Comparison of the Fixed Effects model estimations of own maize consumption for male-headed and female-headed households*

	Female-headed households		Male-headed households	
	Coeff.	s.e.	Coeff.	s.e.
Ln (area under improved maize)	0.343***	0.101	0.337***	0.093
Male adult labor	−0.013	0.107	−0.078	0.057
Female adult labor	0.118	0.107	0.022	0.062
Ln (land holdings in hectare)	0.115**	0.049	0.065**	0.031
Household size	−0.215***	0.058	−0.104***	0.032
Year 2007	0.134	0.212	−0.128	0.105
Year 2009	−0.233	0.269	−0.269*	0.145
Average cumultive rainfall over past five growing season	0.000	0.001	0.000	0.000
Standard deviation of average rainfall (in 100 cm)	1.559	1.003	−1.467***	0.512
Maize price prior to planting season (real 2009, kwcha)	0.021**	0.010	0.005	0.005
Price of commercial fertilizer-planting season (real 2009, kwcha)	−0.002	0.002	0.003**	0.001
Constant	5.789***	0.890	6.105***	0.561
R^2 overall	0.093		0.092	
Prob > chi^2	0.000		0.000	
Rho	0.466		0.421	
Number of observations	1066		2867	
Number of groups	450		1055	

Notes as in Table 8.

ment for observed values. Table 8 reports the results from the fixed effects models.

We found that improved maize planted is positively and significantly correlated with per capita income, per capita own maize consumption and per capita asset holdings. The FE estimates show that controlling for other factors, a 1% increase in improved maize area is associated with a 0.48% increase in income, and 0.34% increase in own maize consumption and 0.24% increase in asset. 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).

Other significant covariates are land holdings, household size, rainfall variables and year dummies. As would be expected, households who have larger land holding have higher "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. Household size is negatively and significantly correlated with all the per capita 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. Households who live in villages with higher rainfall

Table 10. *Comparison of the Fixed Effects model estimations of own maize consumption for the poor and better-off households*

	Poor households (bottom asset quartile)		Better-off households (top asset quartile)	
	Coeff.	s.e.	Coeff.	s.e.
Ln (area under improved maize)	0.568***	0.214	0.377**	0.154
Female-headed household	−0.158	0.449	0.391	0.404
Male adult labor	−0.173	0.198	−0.099	0.126
Female adult labor	0.058	0.177	0.041	0.132
Ln (land holdings in hectare)	0.032	0.091	0.061	0.059
Household size	−0.227**	0.091	−0.020	0.073
Year 2007	0.234	0.335	−0.458*	0.241
Year 2009	0.081	0.506	−0.456	0.350
Average cumulative rainfall over past five growing season	−0.001	0.001	0.000	0.001
Standard deviation of average rainfall (in 100 cm)	0.179	1.716	−1.637	1.212
Maize price prior to planting season (real 2009, kwcha)	0.004	0.016	−0.008	0.012
Price of commercial fertilizer-planting season (real 2009, kwcha)	0.004	0.005	0.004	0.003
Constant	7.228***	1.872	6.203***	1.200
R^2 overall	0.072		0.078	
Prob > chi^2	0.000		0.000	
Rho	0.492		0.540	
Number of observations	982		981	
Number of groups	592		584	

Notes as in Table 8.

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. But households seem to have smoothened consumption as they have not registered lower maize consumption in 2007.

(c) *Who benefits more from adoption of improved maize technology*

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

Table 9 reports the results from a separate Fixed Effects estimation of own maize consumption for male-headed and female-headed households. The estimated coefficients show that use of improved maize variety increases own consumption for all households regardless of the gender of the household head. The marginal own consumption benefits per unit area of improved maize planted were however slightly higher for female-headed households, perhaps indicating the greater dependence of these households on own maize production. Given that we found no evidence of household-head gender difference in the improved maize adoption decision, it seems that all households have a potential to capture the same benefits from the use of improved maize technology.

Results from estimation of own maize consumption disaggregated by a households' wealth status are reported in Table 10. Wealth refers to the value of household durables and livestock owned by the household. The "poor households" group refers to the bottom quartile in the wealth distribution, while the "better-off households" group refers to the top quartile. The results indicate that improved maize adoption is positively and significantly correlated with consumption of maize from own production for both group. A percentage increase in the area under improved maize is associated with an increase in own maize consumption of 0.57% for households in the bottom asset quartile and 0.38% for households in the top asset quartile. This shows that poorer households are likely to benefit more in terms of consumption from planting improved maize varieties. This indicates that poorer households who cannot afford to purchase their staple food requirements will benefit most from an increase in own maize production for meeting their food security needs.

Given that our analysis indicates a positive impact of maize technology adoption and use on human welfare, it can be argued that Malawian rural households (both net sellers and net buyers) and the urban poor (from price effects) will benefit from wider diffusion of the technology. However, there may be also spillover effects of widespread adoption and use of improved maize varieties. The distributional effects of these benefits and the relative gains and losses among different rural and urban households will depend on elasticities of supply and demand. The econometric analysis here does not account for the economy-wide effects related to changes in food prices, urban–rural linkages and other multiplier effects. These indirect effects need to be investigated using an appropriate economy-wide modeling approach.

6. CONCLUSION

Malawi is one of the poorest countries in the world, with close to half of the rural population under poverty. 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 input 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 the decision to use improved maize seed and the link between adoption of improved maize and changes in selected household welfare indicators. We use an exceptionally rich three-year panel data collected during the period 2004–09 to systematically evaluate these effects. We estimated the decision to use improved maize technology 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 amount of improved maize planted increases with access to subsidized inputs, the education of the household head, land holdings, and male labor. Production risk in the form of higher rainfall variability discourages planting of improved maize. We found no significant 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 impacts of improved maize variety adoption are estimated using Fixed Effects models of household income, assets, and own maize consumption that control for endogeneity of the area under improved maize technologies. We found that a 1% increase in area under improved maize varieties is associated with a 0.34% increase in own maize consumption, 0.48% increase in household income and 0.24% increase in value of asset accumulation. Moreover, we found that an increase in improved maize planted is positively correlated with own maize consumption of both male-headed and female-headed households. We also found that both poor and better-off households benefit from improved maize planting with higher elasticity for the poorest households. This shows the importance of maize for poor families and how changes in maize productivity may contribute to ensuring food security and uplifting rural households out of extreme poverty.

The positive correlation between the use of improved maize technology and household welfare is an encouraging result, especially in view of the finding that male- and female-headed households are equally likely to use improved maize technology conditional on comparable access to services. The results in this study taken together lend evidence that the use of improved maize technology is good for improving the welfare of the poor and women farmers. Cost effective agricultural policies that help enhance access to and bridge the technology gap can significantly contribute toward improved food security in the rural areas.

NOTES

1. A new work challenging the poverty estimation method of NSO gave a smaller poverty rate (see Beck *et al.*, 2013).

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

3. 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”.

4. We estimated this using the command ***craggit*** in STATA. It could also be estimated by running a separate probit model for the planting decision and truncated normal regression model for the amount equation. Results are the same but the ***craggit*** command facilitates computation of expected values (refer Burke, 2009 for computation procedure).

5. The tobit model estimation results and the likelihood ratio can be obtained from the authors. Estimation result for a linear specification of the model with IV is also available upon request (Angrist, 2001 argue that using 2SLS is good enough for casual inference. See also Wooldridge (2010)).

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APPENDIX 1

See Table 11.

Table 11. *Correlated Random Effect probit model of access to Farm Input Subsidy Program (FISP)*[a]

	Coeff.	Robust s.e.
Years household head lived in the village[b]	*0.0030**	*0.002*
Member of parliament live in the community[b]	*0.2370****	*0.055*
Age of household head	0.0020	0.002
Education of household head (# of years)	0.0160**	0.008
Female-headed household	−0.0030	0.113
Male adult labor	−0.0650	0.043
Female adult labor	−0.0120	0.044
Household size	0.0230	0.021
Land holdings in hectare	0.1160***	0.032
Village has farm credit organization	0.0490	0.056
Year 2007	0.8940***	0.086
Year 2009	1.2380***	0.106
Central region	−0.0110	0.100
Southern region	0.0740	0.138
Average cumultive rainfall over growing seasons for past five growing season	0.0010**	0.000
Standard deviation of average rainfall (in 100cm)	−0.3760	0.401
Maize price prior to planting season (real 2009, kwcha)	0.0020	0.004
Price of commercial fertilizer during planting season (real 2009, kwcha)	−0.0020**	0.001
Sandy soil	0.1070	0.070
Clay soil	−0.0050	0.065
Mixed soil	−0.0180	0.069
Constant	−2.2730***	0.487
Chi2	512.2	
Prob > chi^2	0.000	
Loglikelihood	−2388.4	
Number of observations	3933	

Significance levels: *: 10%, **: 5%, ***: 1%.
[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 indicate that these variables are appropriate instruments for selection to subsidy.