Journal of Development and Agricultural Economics Vol. 4(14), pp. 393-403, December 2012
Available online at http://www.academicjournals.org/JDAE
DOI: 10.5897/JDAE12.029
ISSN 2006- 9774 ©2012 Academic Journals

Full Length Research Paper

Drivers of improved maize variety adoption in drought prone areas of Malawi

Samson P. Katengeza[1]*, Julius H. Mangisoni[1], Girma T. Kassie[2], Chloe Sutcliffe[3], Augustine Langyintuo[4], Roberto La Rovere[5] and Wilfred Mwangi[6]

[1]University of Malawi, Bunda College, Lilongwe, Malawi.
[2]International Maize and Wheat Improvement Centre (CIMMYT), Harare, Zimbabwe.
[3]University of Leeds, United Kingdom.
[4]Alliance for a Green Revolution in Africa (AGRA), Nairobi, Kenya.
[5]United Nations Development Programme (UNDP), New York, USA.
[6]International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya.

Accepted 22 March, 2012

This study identifies the determinants of adoption and adoption-intensity of improved maize varieties in Malawi. We estimated a double hurdle model based on household-level survey data collected in the districts of Balaka and Mangochi in 2008 and found that labour endowment, access to rural credit, livestock wealth, access to agricultural extension, farm size and access to off-farm employment all significantly increase the likelihood of adoption. Households where the head had membership of a social group were also found to be less likely to have adopted. The intensity of adoption was found to be negatively related to livestock wealth and fertilizer use. Conversely, the age of the household head, the labour endowment of the household and the proportion of household members engaged in off-farm activities were factors that were found to be positively related to intensity of adoption. The study suggests the need to enhance adoption and intensity of adoption of improved maize varieties in Malawi among other things improving access to rural finance through credit and improving access to agricultural extension. Agricultural extension enhances provision of timely and quality agricultural information which is vital to smallholder farmers' production and marketing decisions and hence, key to decisions to adopt new and improved technologies such as improved maize varieties.

Key words: Adoption, double-hurdle model, intensity of adoption, maize, Malawi.

INTRODUCTION

It would be difficult to overstate the importance of maize as a food crop in Malawi. Despite the fact that maize only started to replace sorghum as a staple food in Malawi a little over a century ago (Smale and Rusike, 1998), the crop now occupies such significance that it is synonymous with food in general (Smale, 1993), and it has (in line with the primacy of food security as a national concern) become a highly political crop (Chinsinga, 2011).

An agriculture account for 35% of Malawi's GDP and is central to the livelihoods of 85% of the population (Chirwa, 2010). Maize is grown by 97% of farming households and occupies over half of all smallholder cultivated land (Denning et al., 2009; Chirwa, 2010; Smale, 1993); yet, maize is predominantly a subsistence crop, with less than 20% of what is produced, ending up as marketed surplus (Chirwa, 2010). Maize has been reported to provide on average over 65% of the daily calories consumed by Malawians (Smale, 1993) and it has

*Corresponding author. E-mail: skatengezah@yahoo.co.uk. Tel: +265 888 705 351, +265 995 446 202.

been suggested that it makes up a higher share of the national diet in Malawi than in any other comparable African country (Takane, 2008). For most Malawians, eating maize is “seen as essential to having a good life”, and self-sufficiency in maize is a widely and highly held value (Levy, 2005).

Historically, food security in Malawi has been tenuous due to a variety of factors including the failure of productivity to keep pace with population growth, the impact of production shocks such as drought, and fluctuations in the level of support with which the agricultural policy environment has endowed farmers (Smale, 1993; Smale and Rusike, 1998; Harrigan, 2003; Mandala, 2005). Although full-blown famines are rare, household maize shortfalls are commonplace (Mandala, 2005), a fact mainly attributable to the increasing fragmentation of landholdings (Dorward and Chirwa, 2011) and the ubiquitous reliance on rain-fed agriculture (Cromwell and Kyegombe, 2005).

In a normal year, most rural households run out of their own maize stocks at least three months before the next harvest (Levy, 2005). Market prices for maize fluctuate considerably throughout the year so households tend only to resort to relying on purchased maize when they have no other option (Dorward and Chirwa, 2011). The adoption of improved, higher yielding maize varieties has long been recognized as a means to ameliorate food security and liberate smallholder land, thereby enabling crop diversification and enhanced market participation, yet surprisingly, historical uptake of these varieties has been slow (Denning et al., 2009; Smale, 1993).

The slow (and low) adoption of improved maize has persisted despite concerted efforts by Malawi’s Governments over the last four decades to stimulate uptake through the provision of subsidies and free agricultural extension services. Throughout the seventies and eighties, the country was able to produce a maize surplus and agricultural productivity grew in general terms, undergirded by a pervasive reliance on input subsidies to support the adoption of hybrid maize and fertilizer. 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 (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 (Balckie and Mann, 2005). Severe productivity shortfalls were forecast and despite donor reticence, government-led interventions were resumed, firstly, 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 Programme (Chinsinga, 2011). The reviews of these programs have been positive and encouraging (Buffie and Atolia, 2009; Simtowe et al, 2009; Chirwa, 2010; Holden and Lunduku, 2010) but levels of uptake remain limited, with only 58% of households growing some improved maize nationally (World Bank, 2006), and the level dropping to only 40% in the south (Chirwa, 2005)

It has been reported that smallholder farmers continue to maintain preferences for local (as opposed to improved) maize, despite its lower yield potential (Denning et al., 2009) because of perceptions that local varieties produce better quality flour, require less external inputs, and exhibit better pest resistance in storage (Smale, 1995; Smale and 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 (Peters, 1995; Kassie et al., 2011a). It was the early 1990s before national breeding attempts led to the release of varieties, with qualities better-suited to the needs of smallholders in Malawi. Some argue that subsequent swings in emphasis between the promotion of hybrid and open-pollinated maize have also confounded the adoption process (Chinsinga, 2011).

Various analysts have focused on the slow uptake of improved maize in Malawi (Smale, 1993; Langyintuo, 2005; Takane, 2008). Their findings suggest that farmers fail to adopt either because the varieties on offer do not meet their requirements or because they lack knowledge about the benefits of improved maize, or finally because they cannot adopt (despite wanting to) due to economic constraints. Thus, these analyses have dealt more with barriers to adoption than with the question of why some households adopt when others do not. Where studies have given consideration to the latter question, the household characteristics that have been deemed to be important are (Langyintuo, 2005) gender, membership in a farmers’ association, status as a beneficiary of a government or NGO program and receiving remittances, and (Smale, 1993) gender, credit-club membership and farm size. These findings indicate that factors related to household wealth are important determinants of adoption decisions. In other words, farmers make economic decisions based on the perceived potential profit and risk associated with the act of adopting (Aloyce et al., 2000).

Apart from the generally low level of adoption of improved maize varieties, it has been observed that even where farmers do grow improved maize, many continue to allocate some of their land to growing local maize which is preferred for household consumption (Takane, 2008; Smale, 1993). This fact highlights the importance of scrutinizing not only adoption but also intensity of adoption. Now that climate change threatens to worsen the impacts of drought on maize production for much of Sub-Saharan Africa (Slingo et al., 2005, Twomlow et al., 2008), hopes are pinned on the capacity of modern breeding techniques to produce maize varieties that can effectively tolerate drought (Brown and Funk, 2008; Toenniessen et al., 2008). Against this background, questions surrounding the adoption of improved varieties (particularly drought tolerant maize varieties) remain paramount both within Malawi and across Southern Africa. The aims of this study therefore are: to identify the determinants of adoption, assess adoption-intensity decisions in drought-prone areas of Malawi and seek to better inform strategies for drought tolerant seed dissemination in this region.

The rest of the paper is organized as follows: presentation of sampling and data collection procedures, analytical framework, and a description of the study districts; presentation and discussion of descriptive and inferential results. Finally, the research findings are summarized and conclusions drawn about the kinds of development intervention that could appropriately assist the sustained adoption of improved varieties amongst smallholders in Malawi.

METHODOLOGY

The study areas

Balaka and Mangochi districts are two of the 13 districts in the Southern Region of Malawi. Perched at an altitude of 625 m above sea level (m.s.l.), Balaka is bordered by Mangochi in the north, Ntcheu in the west, Machinga in the east and Mwanza in the South. Balaka district is divided into six Extension Planning Areas (EPAs). Each EPA has approximately eight sections. There are 532 villages and 91 Group village Headmen in the district. According to the Agricultural Extension and Development Officer (AEDO), the total population of the district is 314,000 people.

Balaka is predominantly in the rain shadow part of Malawi. The minimum level of rainfall registered is 700 mm and the maximum is 1100 mm, giving an average of 800 mm of rainfall for the district (Table 2). Rainfall in Balaka is determined by prevailing winds from the South East. The minimum temperature is 14°C and the maximum is 32°C. On average, Balaka has 35 rainy days per year, with frequent dry spells and droughts. The district has about 96,600 hectares (ha) of cultivable land and about 94% of the households do own farmlands. The land farmers own is typically acquired through purchase or inheritance. It is estimated that a typical household owns 0.8 ha of land in the district. The amount of land under annual crops such as maize, rice, sorghum, millet, pigeon peas, cotton, cassava and sweet potatoes is estimated at about 28,200 ha. Land under perennial crops is 10,300 ha. Grazing land in the district accounts for 31,800 ha and this land comprises wetlands and flood plains. Some land in the district is not suitable for cultivation due to rocks and poor access. This type of land is estimated at 26,700 ha. Land under forest cover is 23,300 ha.

Mangochi District is located at an altitude of 492 m above sea level (Table 1). The district is bordered by Lake Malawi in the North, Ntcheu and Balaka districts in the south-west and Dedza in the north-west and Mozambique in the east. Mangochi has 11 EPAs and 88 Sections. There are 725 villages in the district with a total population of about 778,300 people in 220,000 farm families. Mangochi has a minimum rainfall of 658 mm. The maximum amount of rainfall ever registered in the district is 1303 mm. On average, the district receives 983 mm of rainfall. Spatial and temporal differences in rainfall are due to the geographical position of the district in relation to the rain-bearing winds. The district topography is characterised by hills and valleys. Deforestation has reduced tree cover in the hills which makes the district prone to high winds and sudden changes in temperature and rainfall. Temperature in Mangochi ranges from 14.5 to 33.5°C.

In Mangochi District, the total cultivable land is 407,700 ha but the total land area for the district is 627,300 ha. The proportion of households that own land is 90%. A typical household owns 1.02 ha of land. Land under annual crops is 197,400 ha while land under permanent crops is 28,000 ha. Arable land accounts for 329,400 ha with 231,800 ha under smallholder farming and 97,600 under estate farming. The grazing land area is 75,500 ha. The grazing land areas are predominantly wetlands. The total cultivated land is 225,400 ha and land under forest is 155,600 ha. The amount of arable land potentially available for farming is 225,400 ha.

Sampling and data collection

Malawi is one of 13 African countries where the Drought Tolerant Maize for Africa (DTMA) initiative of the International Maize and Wheat Improvement Centre (CIMMYT) is being implemented. Balaka and Mangochi districts in the southern region of Malawi were randomly selected among the districts that fall in predetermined category (20 to 40%) of probability of failed season (PFS). PFS implies the probability of growing season failure as a result of insufficient soil water availability (either a too-short growing season, or a too-severe level of water stress within the growing period) (Thornton et al., 2006) and was considered here to homogenize exposure to drought that results in crop failures. The names of the villages in the two districts were listed, from which twelve were randomly selected. Finally, the farm families for all the twelve villages were listed and 155 households were randomly selected. The sample size in each of the villages was proportional to village size.

$$n_i = \frac{S_i \times 155}{N} \quad (1)$$

where: n_i is the sample size for village i; S_i is the number of farm families in village i; and N is the total number of farm families in all the 12 villages. Accordingly, 59.3% of the sample was drawn from the villages of Mangochi district and the remaining from that of Balaka.

Data collection was done by trained enumerators using a structured questionnaire in 2008. The variables of interest broadly included household characteristics, resource endowment, availability of and access to institutional services, enterprise choice and resource allocation, maize variety selection, adoption and preferences, production and marketing risks, and perceived trends in the different aspects of maize production.

Analytical framework

Adopters of an agricultural technology are those who have adopted a component or more of a technology and continued using it, whereas non-adopters are those who have never tried a technology (Feder et al., 1985; Doss, 2006). At a given point in time, the choice to adopt or to continue to use is a discrete decision. Such decisions are undertaken based on a perceived maximization of utility (Saha et al., 1994). Utility is however, latent and only the decision variable (adopting or not adopting) is observed. The decision of the respondent "*D*" takes on one of two values, 0 (not-adopting) or 1 (adopting). Equally important are decisions about the extent to which agricultural technologies are adopted.

The intensity of adoption is likewise an economic decision for farmers that is made on the basis of the resources they have available. We measure the intensity of adoption by assessing the proportion of maize-planted area allocated to improved maize varieties by each of the households. In this particular case, our formulation presumes that adopters will have a proportion of their land covered with improved maize that is greater than zero. There were, in fact, a few households who allocated no land to maize in the year of the survey. This results in observations with fully observed explanatory variables (*x*) and unobserved dependent variables (*y*). The implication is that our latent dependent variable (y^*), which denotes interest in improved maize varieties is not observed until the interest in the varieties exceeds some known constant threshold (*L*) that is, we observe y^* only when $y^* > L$. Decisions about adopting and about the intensity of adoption are interdependent and yet do not necessarily follow the same decision-making process. Accordingly, most of the factors that affect adoption decisions will also influence decisions about the intensity of adoption and vice versa.

There is a wealth of literature on the analysis of agricultural technology adoption decisions (Feder et al., 1985; Sanders et al., 1996; Sunding and Zilberman, 2000). The decision to adopt an improved maize variety (like any other agricultural technology) is influenced by a wide range of bio-physical, socioeconomic and technology-specific context dependent concerns. The vast literature on agricultural technology adoption has documented that demographic factors, technology characteristics, access to agricultural production and marketing information, farmer's experience and education, access to agricultural support services and social interactions all influence adoption decisions in one way or another (Suri, 2006; Alene et al., 2009; Tura et al., 2010; Johannes et al., 2010).

As cross-sectional rather than longitudinal data were used in the study, we cannot reliably establish causal relationships between factors and adoption decisions. However, the following assumptions influenced the analysis. The district in which the household was located, the age and sex of the household head, the level of family labour endowment, livestock wealth, access to credit and membership in farmers' social groups were expected to influence both adoption and intensity of adoption decisions. Average years spent in education by household members, access to agricultural extension services, farm size, and access to off-farm income-generating activities were assumed to influence and/or be correlated with adoption decisions, whereas attending agricultural extension field days, the proportion of household members involved in off-farm activities and fertilizer use were assumed to influence or be correlated with intensity of adoption.

Adoption and intensity of adoption decisions is complex and involve factors that are normally beyond the control of farmers, such as policy, institutional and environmental factors as well as household endowments, the agricultural business opportunities available, and the nature of the technology itself. Moreover, some of the factors that influence the continued use of the technology are linked to the user's experience in using it; the more farmers become habitualised to the use of a technology, the more they are likely to keep on using it. These phenomena generate modelling problems related to self-selection and endogeneity (Doss, 2006; Suri, 2006).

Adoption and intensity of adoption decisions continue to be relevant to those farmers who have already adopted. The two decisions, adoption and intensity of adoption, can be specified independently of each other using a binary model and a censored model, respectively. However, such a specification would provide inefficient estimates of the parameters of adoption and intensity models since it ignores the potential correlation between the un-observables (captured by the error terms) of the two decisions. This is because the decision to use the technology to a given extent is contingent on the decision to adopt.

Two considerations are important in this particular case. First, there is no theoretical background to support an assumption that the decision to adopt and the decision about the extent to adopt are made sequentially. The decisions seem to be made at the same time, as farmers would have allocated a fixed level of their resources to invest in the technology by the time they make the decision to adopt. Second, the intensity of adoption measured as the proportion of land allocated to improved maize will have observed "zero" values. The zero value represents a choice by the decision maker and is not a non-observed value of the response variable. This zero value can be considered simply as a corner solution to a constrained utility maximization problem (Humphreys, 2010). The "genuine" nature of the zero values leads to the question of whether the initial (adoption) decision affects the intensity of adoption which is affirmative in this case.

The simultaneity of the decisions and the meaningfulness of the zero values of the response variable of the second (intensity of adoption) decision narrow down our choice of analytical method to the double hurdle model over the less sound options of Heckit, Tobit, and Two-part models (Humphreys, 2010). Accordingly, we estimated a double-hurdle model (Cragg, 1971; Jones, 1992) whereby our outcome (intensity of adoption) equation is modelled with the selection (improved maize adoption) model.

The double-hurdle model is due to Cragg (1971) and is a parametric generalization of the Tobit model whereby two related decisions are assumed to follow two separate stochastic processes. In our case, the two decisions are the decision to adopt and the decision about the intensity of adoption. These are related decisions but they do not necessarily follow the same data generation process. The first decision variable (D) takes the value 1 for farmers who have adopted improved maize and takes the value zero for otherwise. The expected utility of adopting a technology (D_i^*) is latent however. Therefore, the first decision (adoption hurdle) of the households is formulated as:

$$D_i^* = z_i'\alpha + \varepsilon_i$$
$$D = \begin{cases} 1 \text{ if } D^* > 0 \\ 0 \text{ otherwise} \end{cases} \quad (2)$$

Not all improved maize adopters grow improved maize at the same level of intensity. As stated previously, the intensity of adoption is measured in terms of the proportion of farm area allocated to improved maize varieties. The intensity of adoption (intensity hurdle) of improved maize varieties is given as in a tobit-like function:

$$y_i^* = x_i'\beta + \upsilon_i$$
$$y^{**} = \begin{cases} y^{**} \text{ if } y^* > 0 \\ 0 \quad \text{otherwise} \end{cases} \quad (3)$$

The observed value of the proportion of land allocated to improved maize is therefore given by:

$$y_i = D_i y_i^* \quad (4)$$

If the models of both decisions are assumed to be linear in parameters and the random terms to be independently and normally distributed, the double-hurdle model is estimated with the maximum likelihood procedure that maximizes the log of the following likelihood function:

$$L = \prod_0 \left(1 - \Phi\left(\frac{x_i\beta}{\sigma_{\varepsilon_1}}\right).1 - \Phi(z_i\alpha)\right) \prod_+ \left(\Phi(z_i\alpha)\frac{1}{\sigma_{\varepsilon_1}}\phi\left(\frac{y_i - x_i\beta}{\sigma_{\varepsilon_1}}\right)\right) \quad (5)$$

where $\Phi(.)$ is the standard normal cumulative density function and $\phi(.)$ is the standard normal probability density function. The

Table 1. Agro-climatic description of the study areas.

Agro-climatic characteristics		Balaka	Mangochi
	North (Latitude)	140 59.295"	140 28.849"
District office	East (Longitude)	0340 57.448"	0350 16.296"
	Altitude (m.s.l.)	625	492
Minimum rainfall (mm)		700	658
Maximum rainfall (mm)		1100	1303
Average rainfall (mm)		800	983
Minimum temperature (℃)		140	14.50
Maximum temperature (℃)		32	33.50

matrices *x* and *z* are overlapping sets of explanatory variables for the two decisions. The two processes are non-separable and thus both parts of the likelihood function must be maximized simultaneously.

The stringent assumption of uncorrelated error terms has been relaxed by Jones (1992, 2000) and it is now possible to estimate double hurdle models with correlated random terms. The likelihood function of Jones' version of the double hurdle model is given as:

$$L=\prod_{0}\left[1-F_2\left(z_i\alpha,\frac{x_i\beta}{\sigma},\rho\right)\right]\prod_{+}\Phi\left(\frac{z_i\alpha+\frac{\rho}{\sigma}(y-x_i\beta)}{\sqrt{1-\rho^2}}\right)\frac{1}{\sigma}\phi\left(\frac{y-x_i\beta}{\sigma}\right) \quad (6)$$

This is the main model estimated in this study. Given the cross-sectional nature of our data and hence the possibility of conditional heteroscedasticity, we estimated the double hurdle model with a robust option to generate the Huber-White-Sandwich standard errors (Cameron and Trivedi, 2005).

RESULTS AND DISCUSSION

Characteristics of maize farming households

The characteristics of the sample households will be presented comparatively for adopters and non-adopters. Out of the total sample size of 155 households, 54.8% were found to be growing improved maize varieties in the year of the study. Most (69.5%) of our respondents were female and yet 64% of the households are male headed. Interactions with extension staff were more frequent (45.2%) than attendance at field days (only 3.9%). Fertilizer use was found to be high (93%) across the study areas. One of the important challenges farmers are facing is a lack of cash income. Accordingly, the majority (65.2%) of the households reported to have at least one member of the family engaged in off-farm activities. Only 15.5% of the households reported to have access to rural credit. About 21% of the households are members of social groups established mainly by the farmers themselves.

Pearson's chi-squared test revealed a significant relationship at the 1% level between the decision to adopt and two factors, namely: fertilizer use and the characteristic of having a household member in off-farm employment. Adoption and attendance at field days and adoption and the characteristic of a household being female-headed were found to be significantly related at the 5% level. In the case of adoption intensity, Spearman's correlation coefficient was calculated and revealed significant positive relationships with fertilizer use (at the 5% level) and attendance at field days (at the 10% level), as well as a negative relationship with the characteristic of the household being female-headed (at the 10% level). The average age of the heads of the sample households was found to be about 49 (SD = 15.71) years. The labour endowment of the households was estimated by computing man-equivalent units (MEU) [Conversion factors based on Storck et al. (1991)] of the households and the average MEU was computed to be 3.52 (SD = 1.768) MEU. The mean endowments of the other two important inputs, farm size, and livestock (in tropical livestock units - TLU) were found to be 1.25 (SD = 0.95) hectares and 0.412 (SD = 1.37) TLU, respectively. The differences between the means for average number of years in education of the household members, man equivalent units and farm were found to be statistically significant between adopters and non-adopters (Table 2).

Use of improved maize varieties in agricultural production

Maize varieties grown in the area

Despite the fact that these two districts are covered by government subsidy programs and there is active extension, the level of adoption of improved maize seems to be quite low justifying the assertions made by different observers (Smale and Jayne, 2003; Government of Malawi, 2004; World Bank, 2006). Only 20% of the maize land is covered with improved OP and hybrid maize varieties and more than 75% of the total seed purchase is of local varieties (Table 3). The input subsidy program of the government since 2005 to 2006 season might have changed these adoption figures significantly over the last three years and yet it would be rational to emphasize the need for trait-preference-based variety development and

Table 2. Descriptive statistics of important variables.

Parameter	Adoption	Intensity of adoption
	Pearson x^2	**Spearman correlation**
Female headed	4.903$^+$	-0.199*
Fertilizer use	7.080‡	0.169$^+$
Interaction with extension	2.57	
Member in off-farm income	10.286‡	
Credit access	1.919	0.091
Member of associations	2.237	0.086
Attended field day	5.619$^+$	0.107*
	Testing equality of means	
	Mean difference[b]	**t**
Age of household head (years)	-2.723	-0.952
Average years of education	0.521*	1.776
Labor (man equivalent unit)[a]	0.955‡	3.588

a, Assumption of equal variance was rejected and hence statistic is based on unequal variance; b, adopters minus non-adopters. ‡, +, and *, significance at 1, 5 and 10% levels.

Table 3. Proportion of farm land allocated to maize and maize varieties.

Variable	N	Mean	SD	Min	Max
Proportion of farm allocated to maize	155	69.76	26.60	0	100
Proportion of maize farm allocated to *Hybrids*	154	16.64	30.75	0	100
Proportion of maize farm allocated to *improved OPV*	154	3.22	13.73	0	100
Proportion of *local seed* out of total seed purchase	154	75.24	34.42	0	100
Proportion of *improved seed* out of total seed purchase	154	24.76	34.42	0	100

SD, Standard deviation; Min, minimum; Max, maximum.

a more aggressive and wider framework to change such scenarios (Holden and Lunduku, 2010).

Farmers' trait preferences were elicited and showed that yield potential is the most important varietal attribute that farmers (56%) are interested in. Also, of importance were storability, grain colour, early maturity, pest/disease resistance and drought (in the order listed). These preferences underline farmers' interests in the particular set of varieties they are growing. The most widely and frequently grown maize varieties are local maize, Kanyani (SC513), MH18, NSCM41, Makolo, and MH41 (Table 4). Apart from local maize, all are improved varieties known for their early maturity and high yield under farmers' conditions.

Adoption of improved maize varieties

The double hurdle model estimated showed that the decision to adopt improved maize in Malawi is influenced by different factors. Variations in district, labour power endowment, access to credit, membership in social groups, participation in field days, demonstration plot visits and discussions with extension agents about maize, farm size, livestock wealth, and access to off-farm activities were found to contribute to decisions about whether to adopt improved maize (Table 5). Households in Mangochi are mainly engaged in fishery and other off-farm income-generating activities. Compared to farming households in Balaka, the importance of maize is much lower. This could explain why farmers in Mangochi are less likely to adopt improved maize varieties than those in Balaka, ceteris paribus.

Households headed by individuals who are members of different social groups were also found to be less likely to adopt improved maize varieties compared to those headed by non-members. Social groups when serving as mediums of agricultural information exchange and dialogue can be expected to positively influence new technology adoption decisions. In the seventies and eighties, farmers' clubs were successfully organized in Malawi which enhanced access to and uptake of agricultural information and technology (Chirwa, 2007). These clubs were abandoned during the implementation of structural adjustment programs. It is possible that households in dire need of agricultural resources and who know about the opportunities the clubs created in the past might autonomously organize themselves into social

Table 4. Varieties being grown by farmers (% of farmers growing).

Variety	Farmers (%)	Variety	Farmers (%)
Local	17.34	Bantamu	1.11
Kanyani	15.31	DK8071	1.11
MH18	13.47	Kagolo	1.11
NSCM41	8.49	Mkango	1.11
Makolo	4.61	MH17	1.11
MH41	4.24	Masika	0.92
Pannar	3.87	Mkango	0.92
Pan 67	2.95	Sundwe	0.92
DK8033	2.77	Katswinn Pan	0.74
Pioneer	2.77	Njubua	0.55
DK8031	2.58	Others	10.15
OPV	1.29		

Table 5. Determinants of adoption and intensity of adoption of improved maize varieties.

Parameter	Adoption		Intensity of adoption	
	Coefficient	Robust standard error	Coefficient	Robust standard error
District (Mangochi=1)	-0.620^{+}	0.2690	0.08	0.109
Age of household head	-0.007	0.0090	0.006*	0.004
Sex of household head (female=1)	-0.065	0.3570	-0.257^{+}	0.118
Labour (man-day equivalent)	0.333^{+}	0.1320	0.055^{+}	0.022
Access to credit (yes=1)	2.740‡	0.3960	0.119	0.127
Member to a social group (yes=1)	-1.763‡	0.4920	0.106	0.111
Livestock wealth (TLU)	3.172‡	0.9670	-0.080‡	0.026
Average years of education	0.034	0.0820		
Access to extension activities (yes=1)	2.008‡	0.6130		
Attended field days (yes=1)			0.139	0.194
Farm size	0.384^{+}	0.1700		
Access to off-farm income (yes=1)	1.408‡	0.1790		
Proportion of hh members in off-farm activities			0.005‡	0.001
Uses fertilizer (yes=1)			-0.770‡	0.277
Constant	-3.060‡	0.676	-0.345	0.233
/athrho	17.086‡	0.205		
/lnsigma	-0.886‡	0.093		
Rho	1.000‡	0.000		
Sigma	0.412^{+}	0.038		
Lambda	0.412^{+}	0.038		
Number of observations	115	Uncensored observations		51
Censored observations	64	Log likelihood		-51.73

Wald test of independent equations (rho=0): $chi^2(1)$ = 6920.43 Probability>chi^2 = 0.0000. Double hurdle model (model with selection and censoring) - correlated errors.

groups in order to increase their access to resources including improved maize. In such a scenario, group members might lack the endowments for adoption more than non-group members. Another explanation could be that when such clubs serve as social gatherings for pleasure, they might result in a withdrawal of labour and time that would otherwise be spent in working towards accessing and using improved technologies. Whatever the explanation, the negative effect of social group membership on adoption was unexpected and it actually differs with findings of other related studies (Binam et al., 2004; Chirwa, 2007).

The labour endowment of the household is positively related to the adoption of improved maize varieties. The use of agricultural technologies such as improved seeds and fertilizer requires relatively more labour which could reveal why labour availability plays a significant role in shaping adoption behaviours in Malawi where maize production is carried out using traditional techniques that are heavily reliant on family labour (Chirwa, 2007; Johannes et al., 2010).

The importance of access to credit in enhancing farmers' adoption of agricultural technologies is well-known (Feder and Umali, 1993; Cornejo and Mcbride, 2002). Researchers have particularly emphasized that credit access will only be effective for the credit constrained who have access to remunerative consumption, production and investment opportunities but who are unable to pursue the opportunities because they lack financial resources (Simtowe et al., 2009). Malawian farmers have very limited access to credit mainly because of the high risk inherent in rain-fed agricultural production and because of the lack of farmer organizations (Chibwana et al., 2010). Therefore, the significance of the access to credit variable in positively influencing the decision to adopt improved maize shows the inherent demand for credit and its importance in facilitating the uptake of improved agricultural technologies.

In many African countries, publicly-funded, free agricultural extension services are the most reliable sources of information about improved agricultural technologies that farmers have access to. The importance of access to extension information cannot be overemphasized. Our findings show that farmers do make use of the technical information they acquire from extension institutions about different agricultural issues including improved maize. This result was expected and is in agreement with reported earlier works (Doss, 2006; Suri, 2006; Johannes et al., 2010).

Agricultural technologies have associated investment costs for farmers and those who are better-off are expected to be able to afford more than those who have less. Therefore, wealth is generally expected to have a positive correlation with the adoption of a technology. Farm size, livestock wealth, and access to off-farm income are all important components of the asset wealth of households in the study areas (Mangisoni et al., 2010; Kassie et al., 2011b). Households with more of these assets can therefore be considered to be endowed with buffer resources and hence they are less risk-averse in trying out new technologies.

Our results show that farm size is positively related to the decision to adopt improved maize. Generally, it is expected that farming households with bigger landholdings have an enhanced ability to purchase improved technologies and a greater capacity to cope with the loss if the technology fails (Feder et al., 1985). This is key in Malawi where farmland, both in terms of size and fragmentation, is the most important limiting factor in agriculture. Smale and Jayne (2003) noted that maize production is already operating at its land frontier with very little or no scope to increase the supply of land to meet the growing demand for food. About 70% of smallholder farmers in the country cultivate less than 1.0 hectare and the median area under cultivation is about 0.6 hectares (Alwang and Siegel, 1999).

As discussed, Malawian smallholders have serious farmland and credit constraints that limit their capacity to access the liquid capital needed to purchase improved agricultural technologies. Access to off-farm activities helps to relieve households from this important constraint and enables adoption. Our results support this argument in addition to earlier reports on the topic (Fernandez-Cornejo et al., 2005).

Finally, our results show that livestock wealth also positively influences the adoption of improved maize. This was expected, given that livestock ownership is an important livelihood asset. In analyzing improved chickpea variety adoption in Ethiopia, Asfaw et al. (2011) noted that ownership of livestock (and other assets) eases household access to improved seed and credit. It seems likely that livestock wealth translates to a source of income which can be spent on maize production. Beyond this, however, competition between the livestock enterprise and maize production seems to limit the intensity of adoption as described below.

Intensity of adoption of improved maize varieties

Although female-headed and male-headed households did not show any significant difference in adoption decisions, there is a significant difference in terms of their intensity of adoption. The result shows that female-headed households allocate less land to improved maize varieties than male-headed farming households. Female-headed households are apparently more resource constrained and also have less access to off-farm incomes (perhaps because domestic ties mean they have less mobility). This means that female-headed households are limited in their capacities to invest in new technology, other things being equal. This argument is further substantiated by the fact that households with a higher proportion of members engaged in off-farm activities are found to adopt improved maize more intensively than those with a lower proportion, since additional income can be used to purchase improved maize. The results also show that as labour endowment of the household increases, the intensity of improved maize adoption increases. This shows that labour has a positive marginal productivity when used in the production of maize using improved varieties. In this way, the high level of unemployed labour in rural Malawi in combination with the higher labour demand of improved maize production can lessen pressure on the agricultural labour market.

Fertilizer use was expected to be positively related to the intensity of adoption of improved maize varieties, particularly hybrids. However, our results show that households who applied fertilizer allocated significantly less land to improved maize than those who did not. Reports have repeatedly described fertilizer use in Malawi as both low and inappropriate (in terms of the recommended guidelines) (Dzimadzi et al., 2001; Sibale et al., 2001). Tchale and Sauer (2007) have indicated that this problem pertains across Sub-Saharan Africa for input applications to most food crops due to high relative increases in fertilizer prices. Yet, in the case of Malawi it has been reported that some improved varieties (for example, MH17 and MH18, which were released by the National Agricultural Research Station at Chitedze) yield more than local maize even in the absence of fertilizer, in which case it makes economic sense for farmers to grow these varieties even if they are unable to apply fertilizer (Heisey and Smale, 1995). As such, this result suggests a need for more focused agricultural information communication, especially on the wider issue of soil fertility management. It was also found that as livestock wealth increased, intensity of improved maize use decreased. An explanation for this might be that the continuous income that can be generated from keeping livestock might reduce the focus of households on the relatively more seasonal livelihood gains from crop production. Households may therefore prefer the strategy of allocating a greater proportion of their land and income to livestock production than to maize.

Conclusion

Maize is, and will remain the most important crop in the livelihoods of Malawians. The interventions that have been made by the Government of Malawi over the last four decades have rightly emphasized the provision of basic agricultural inputs for improving the productivity of smallholder maize farming. Despite these efforts, the adoption of improved high yielding maize varieties is still low. Apart from top-down interventions in the form of input subsidy packages, there are important household and farm level characteristics that drive adoption of improved varieties.

This study analysed the factors that are significantly related to the decisions made by households about whether to adopt or not and about the extent to which adoption is undertaken. Farmers in Mangochi (a district with a greater range of livelihood options) and households where the head had membership of a social group were found to be less likely to have adopted improved maize. On the other hand, labour endowment, access to rural credit, livestock wealth, access to agricultural extension, farm size and access to off-farm employment all significantly increased the likelihood of adoption of improved maize. The intensity of adoption (in terms of the proportion of the area planted to maize that was allocated to improved varieties) was found to be negatively related to fertilizer use, livestock wealth, and to the household having a female head. The age of the household head, the labour endowment of the household, and the proportion of household members engaged in off-farm activities were all found to be factors that related positively to intensity of adoption decisions.

Crucial observations from the analysis are the positive contributions of labour endowment, access to credit, access to extension, farm size, and access to off-farm activities. Malawian smallholder agriculture is characterized by small and highly-fragmented land-holdings (Chibwana et al., 2010), lack of access to rural financing (Simtowe et al., 2009) and low levels of literacy and numeracy which result in the inappropriate use of inputs, particularly fertilizer (Dzimadzi et al., 2001). These issues are dimensions that need to be duly considered in designing and implementing agricultural development interventions. Interventions need to be coordinated and should aim to harness the abundant availability of local, productive labour, increase access to rural financing, and improve the timeliness and quality of agricultural information communicated through extension services, in addition to creating off-farm employment opportunities that help to diversify the rural livelihood base.

Research also has to ensure improved varieties are generated with traits that are appropriate to the needs and desires of smallholders. The tendency for farmers to choose to grow local maize over improved hybrid and open-pollinated varieties is not only an issue of affordability. Farmers have trait preferences which form the basis of their selection of varieties. An important observation for Malawi is that farmers are interested in varieties which are flint because of their enhanced storability and their higher flour-to-grain extraction rate (Smale, 1993; Simtowe et al., 2009). Enhanced adoption of improved maize entails careful assessment of farmers' preferences and dedicated work by breeders to produce varieties that exhibit preferred characteristics.

REFERENCES

Alene AD, Menkir A, Ajala SO, Badu-Apraku B, Olanrewaju AS, ManyongVS, Ndiaye A (2009). The economic and poverty impacts of maize research in West and Central Africa. Agric Econ. 40:535–550.
Aloyce RM, Kaliba HV, Mwangi W (2000). Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania. J. Agric. Appl. Econ. 32(1):35–47
Alwang J, Siegel PB (1999). Labour shortages on small land holdings in Malawi: Implications for policy reforms. World Develop.. 27(8): 1461–1475.
Asfaw S, Shiferaw B, Simtowe F, Hagos M (2011). Agricultural technology adoption, seed access constraints and commercialization in Ethiopia. J. Develop. Agric Econ.3(9): 436-447
Balckie M, Mann CK (2005). The Origin and the Concept of the Starter Park. Book Chapter in Starter Parks: A Strategy to Fight Hunger in Developing Countries. CABI Publishing.

Binam JN, Tonye J, Wandji N, Nyambi G, Akoa M (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. Food Policy. 29(5): 531–45.

Brown ME, Funk CC (2008). Climate - Food security under Climate Change. Sci.319: 580-581.

Buffie EF, Atolia M (2009). Agricultural Input Subsidies in Malawi: Good, Bad Or Hard To Tell? FAO Commodity and Trade Policy Research Working p.28. Available at http://www.fao.org/es/ESC/.(Last accessed in October 2011).

Cameron AC, Trivedi PK (2005). Microeconometrics: Methods and Applications. Cambridge University Press, Cambridge

Chibwana C, Fisher M, Masters W, Shively G (2010). Measuring the Impacts of Malawi's Farm Input Subsidy Program. Paper presented at the Tri-annual meeting of the African Association of Agricultural Economist, Cape Town, South Africa, September. pp.19-23

Chinsinga B (2011). Seeds and Subsidies: The Political Economy of Input Programmes in Malawi. Ids Bulletin-Institute.Develop. Stud., 42: 59-68.

Chirwa E (2005). Adoption of fertilizer and hybrid seeds by smallholder maize farmers in southern Malawi. Develop. South Afri, 22: 1-12.

Chirwa EW (2007). Sources of Technical Efficiency among Smallholder Maize Farmers in Southern Malawi. AERC research paper 172. Afr Econ Research Consortium, Nairobi.

Chirwa TG (2010). Program evaluation of agricultural input subsidies in Malawi using treatment effects: methods and practicability based on propensity scores. MPRA Paper No. 21236. Accessed September 2011, available at: http://mpra.ub.uni-muenchen.de/21236/.

Cornejo J, McBride W (2002). Adoption of bioengineered crops, Agricultural Economics Report no. 810, Washington DC, USA.

Cragg JG (1971). Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. Econometrica, 39: 275-85.

Cromwell E, Kyegombe N (2005). Food security options in Malawi: good neighbours make good friends? Country Food Security Options Paper No. 2, Forum for Food Security in Southern Africa. Accessed September 2011, available at: www.odi.org.uk/food-security-forum

Denning G, Kabambe P, Sanchez P, Malik A, Flor R, Harawa R, Nkhoma P, Zamba C, Banda C, Magombo C, Keating M, Wangila J,

Sachs J (2009). Input Subsidies to Improve Smallholder Maize Productivity in Malawi: Toward an African Green Revolution. Plos Biology. 7: 2-10.

Dorward A, Chirwa E (2011). The Malawi agricultural input subsidy programme: 2005/06 to 2008/09. Int.J.Agric Sustain.. 9:232-247.

Doss CR (2006). Analysing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement. Agric Econ. 34: 207-219.

Dzimadzi C, Chinsinga B, Chaweza R, and Kambewa P (2001). Targeted Inputs Programme (TIP) 2000/01: Agricultural Communications. Final report of an evaluation commissioned by Ministry of Agriculture and Irrigation (Malawi) and the Department for International Development. DFID, UK.

Feder G, Just RE, Zilberman D (1985). Adoption of agricultural innovations in developing countries: A Survey. Econ Development and Cultural Change. 33(2):255-298.

Feder G, Umali DL (1993). The adoption of agricultural innovations: A review. Technology. Forecast and Social Change., 43: 215-39.

Fernandez-Cornejo J, Hendricks C, Mishra A (2005). Technology Adoption and Off-farm Household Income: the Case of Herbicide tolerant Soybeans. J. Agric. Appl. Econ. 37(3): 549-563.

GOM (Government of Malawi) (2004). Malawi's National Adaptation Programmes of Action (Napa) Under the United Nations Framework Convention on Climate Change (UNFCCC). First Edition. Ministry of Mines, Natural Resources and Environment. Environmental Affairs Department. Lilongwe, Malawi.

Harrigan J (2003). U-turns and full circles: Two decades of agricultural reform in Malawi 1981-2000. World Develop. 31: 847-863.

Heisey PW, Smale M (1995). Maize technology in Malawi.A green revolution in the making? CIMMYT Research Report, No. 4, Mexico City, Mexico.

Holden S, Lunduka R (2010). Impacts of the fertilizer subsidy program in Malawi: targeting, household perceptions and preferences. Norwegian University of Life Sciences, Ås.

Humphreys BR (2010). Dealing With Zeros in Economic Data.Accessed October 2011.Available at http://www.ualberta.ca/~bhumphre/class/zeros_v1.pdf.(Last accessed in October 2011).

Johannes TA, Vabi MB, Malaa DK (2010). Adoption of Maize and Cassava Production Technologies in the Forest-Savannah Zone of Cameroon: Implications for Poverty Reduction. World Appl.Sci J.11 (2):196-209.

Jones A (2000). Health econometrics. Handbook of health econ. 1:265–344.

Jones AM (1992). A Note on Computation of the Double-Hurdle Model with Dependence withan Application to Tobacco Expenditure. Bullet. Econ Res. 44(1):67–74.

Kassie GT, La Rovere R, Mwangi W, Erenstein O, Langiynato A, Sonder K (2011a). Drought Risk and Maize Production in Southern Africa – Lessons for Ethiopia.*In*: Adapting to Crisis: Ethiopian Agriculture in the 21st Century. Proceedings of the 13th Annual Conference of the Agricultural Economics of Ethiopia. November 2011, Addis Ababa, Ethiopia. pp. 99-124.

Kassie GT, Erenstein O, Mwangi W, La Rovere R, Setimela P, Langyintuo L (2011b). Characterizing Maize Production in Southern Africa: Synthesis of CIMMYT/ DTMA Household Level Farming System Surveys in Angola, Malawi, Mozambique, Zambia and Zimbabwe. CIMMYT: Harare, Zimbabwe.

Langyintuo A (2005). Maize production systems in Malawi: setting indicators for impact assessment and targeting. CIMMYT Zimbabwe.

Levy S (ed.) (2005). Starter Packs: A Strategy to Fight Hunger in Developing Countries? CABI Publishing.

Mandala EC (2005).The End of Chidyerano.Heinemann, Portsmouth, New Hampshire.

Mangisoni J, Katengeza S, Langyintuo A, La Rovere R, Mwangi W (2010). Characterization of Maize Producing Households in Balaka and Mangochi Districts in Malawi.CIMMYT, Nairobi, Kenya.

Peters PE (1995). Persistent drought and food security: Assessing the Inputs programme of 1994/5 and lessons for the drought inputs recovery programme of 1995/6. Harvard Institute for International Development.

Saha A, Love HA, Schwart R (1994). Adoption of emerging technologies under output uncertainty. Am. J. Agric Econ. 76 (4): 836-846.

Sanders J, Shapiro BI, Ramaswamy S (1996).The economics of agricultural technology in semiarid sub-Saharan Africa. The Johns Hopkins University Press, Baltimore.

Sibale PK, Chirembo AM, Saka AR, Lungu VO (2001). Targeted Inputs Programme (TIP) 2000/01: Food Production and Security. Final report of an evaluation commissioned by Ministry of Agriculture and Irrigation (Malawi) and the Department for International Development, DFID, UK.

Simtowe F, Zeller M, Diagne A (2009). The impact of credit constraints on the adoption of hybrid maize in Malawi. Rev. Agric. Environ. Stud. 90 (1): 5-22.

Slingo JM, Challinor AJ, Hoskins BJ, Wheeler TR (2005). Introduction: food crops in a changing climate. Philosophical Transactions of the Royal Society B-Biological Sciences, 360: 1983-1989.

Smale M (1993). Maize is Life: Maize Research and Smallholder Production in Malawi, U.S. Agency for International Development, Amex International.

Smale M (1995). Maize is life: Malawi's delayed green revolution. World Development, 23: 819-831.

Smale M, Jayne T (2003). Maize in Eastern and Southern Africa: 'Seeds' of Success in Retrospect. International Food Policy Research Institute, EPTD Discussion Paper No. 97.January.Available at http://www.fao.org/docs/eims/upload/166420/Smale,Jayne.pdf. (Last accessed in October 2011).

Smale M, Rusike J (1998). Malawi. In Morris, M. L. (Ed.) Maize Seed Industries in Developing Countries. Boulder, Colorado, Lynne Reiner Publishers, Inc.

Storck H,Emana B, Adenew B, Borowiecki A, Shimelis W/Hawariat (1991). Farming Systems and Farm Management Practices of Small holders in the HarargheHighlands.Farming Systems and resource Economics in the Tropics, Vol. 11, Wissenschaftsverlag Vauk, Kiel

KG, Germany.
Sunding D, Zilberman D (2000). The agricultural innovation process: Research and technology adoption in a changing agricultural sector, in B.L. Gardner and G.C. Rausser, eds., Handbook of agricultural economics. Vol. 1A, Amsterdam, Elsevier.
Suri T (2006). Selection and Comparative Advantage in Technology Adoption.Economic Growth Center Yale University. Centre Discussion. p. 944.
Available at http://isites.harvard.edu/fs/docs/icb.topic807162.files/suri_061212.pdf .(Last accessed in October 2011).
Takane T (2008). African Rural Livelihoods under Stress: Economic Liberalization and Smallholder Farmers in Malawi. Institute of Developing Economics, JETRO, Japan.
Tchale H, Sauer J (2007). The efficiency of maize farming in Malawi: A bootstrapped translog frontier. Cahiers d'Economieet Sociologie Rurales, 82: 8333-8356.
Thornton PK, Jones PG, Owiyo T, Kruska RL, Herrero M, Kristjanson P, Notenbaert A, Bekele N, Omolo A (2006). Mapping climate vulnerability and poverty in Africa.Report to the Department for International Development, Available at www.mahider.ilri.org. (Last accessed in October 2011).
Toenniessen G, Adesina A, Devries J (2008). Building an Alliance for a Green Revolution in Africa. Ann. N. Y. Acad. Sci. 1136:233-242.
Tura M, Aredo D, TsegayeT, La Rovere R, Girma Tesfahun, Mwangi W,Mwabu G (2010). Adoption and continued use of improved maize seeds: Case study of Central Ethiopia. Afr J. Agric. Res. August. 5(17): 2350-2358.
Twomlow S, Mugabe FT, Mwale M, Delve R, Nanja D, Carberry P, Howden M (2008). Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa - A new approach. Physics and Chemistry of the Earth. 33: 780-787.
World Bank (2006). Malawi Poverty and Vulnerability Assessment 2006: Investing in Our Future. Available at: http://www.worldbank.org. (Last accessed in September 2011).