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Research Article

Adoption of Improved Maize Seed Varieties in Southern Zambia

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Abstract: Maize is the principal agricultural crop produced by Zambian smallholder farmers for household consumption and sale. Their production strategy is therefore important in meeting food security and income needs. This study uses data collected from a survey of a random sample of farm households in southern Zambia to develop a Tobit regression model. The model identifies farm and farmer characteristics important for adoption of improved maize seed varieties as well as to determine the role of farmer perceptions of technology attributes in maize varietal adoption. The results indicate that expectations about output price and yield are important determinants of adoption. Other factors directly correlated with the probability of adoption include the status of being male-headed, farm size and membership to farmer organizations. Households with more wealth and educated heads were also significantly more likely to adopt improved varieties. Some of the policy implications of these findings are that intervention strategies should be designed and implemented to encourage poor households and those with low levels of formal education to participate in local farmer organizations. The positive interaction between membership to organizations and the adoption of technologies also suggests that group based extension approaches should be encouraged not only for their role in collective action but also for their positive impact on information diffusion and technology adoption.

Keywords: Adoption, farmer perceptions, maize, improved seed varieties, Zambia

INTRODUCTION

The vast majority of Zambians rely on agriculture as their principal means of livelihood. Agriculture and related agribusinesses are the largest employer (85%) and a major component of gross domestic product (about 15%) and export earnings (about 50%). Maize production is a very important source of food and farm income for smallholders, accounting for about 80% of their total value of crop production (Jayne *et al*., 2007). The crop is also a staple food for much of southern Africa. For many of these countries, its supply is essential to food security and domestic stability. Due to a low per capita income (US$ 350 in Zambia), the cost of maize is an important determinant in the cost of food.

A huge challenge facing Zambia is to increase maize productivity and incomes of smallholder farmers, both of which have remained very low. Rising productivity could improve the competitive position of maize in both rural and urban markets. Improving the competitive position of maize in Zambia is also justified by the growing recognition of the need for new strategies for developing agriculture in semi-arid areas that are prone to drought. Zambia experiences recurrent droughts, which tend to be severest in agro-ecological region I. Zambia has experienced 4 droughts in the last four decades. In the period 1976-2007, droughts were experienced in the 1986/87, 1991/92, 1994/5 and 2004/05 seasons (Environmental Council of Zambia, 2000; Mungoma, 2007; Thurlow *et al*., 2009). This challenge is unfortunately shared by most other countries in the region.

In response to this challenge, the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) have over the past two decades been working with national agricultural research institutes to adapt breeding techniques to Sub-Saharan Africa. Through this effort, more than 50 new maize hybrids and open-pollinated varieties have been developed and provided to the farmers through seed companies and Non-Governmental Organizations (NGOs). Varieties that are bred to tolerate drought can produce 20-50% higher yields during drought years than other maize varieties. However, the extent to which such varieties have been adopted remains unknown, even in the drought-prone regions.

Zambia has an integrated seed system that includes the formal and informal sectors and in which both public and private sectors play significant roles. Previously, the government played a controlling role in the entire chain from breeding to seed production and marketing, as well as quality control and certification.

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All this changed following economic liberalization of the 1990s. A number of private companies have since invested in seed breeding, production and marketing. These include Seedco, Zambia Seed Company (ZAMSEED), Maize Research Institute (MRI), Pannar Seed Company and Kamano Seeds Company. However, only ZAMSEED and MRI have locally based variety development programs while all other private companies promote externally bred varieties that have been tested and found suitable for Zambian conditions. Cotton companies such as Dunavant also promote locally developed varieties.

Non-Governmental Organizations (NGOs) have also become increasingly important in recent years, mainly in aspects of the seed system. These include handling seeds of “minor” crops, which do not attract private seed companies; operating in marginal and remote areas not serviced by the private sector; and implementation of input support programmes mainly in response to disasters (drought or floods) when farmers’ livelihoods are under threat. Their activities include, among others, seed distribution, training, promotion of local seed banks and seed production at community levels.

The government, however, remains in full control of seed certification and phytosanitary issues through the Seed Control and Certification Institute (SCCI), while also still playing an important role in research and plant breeding. The Zambia Agricultural Research Institute (ZARI) is a government institution which conducts crop research aimed at the development of improved varieties suitable to the different agro-ecological zones of Zambia. It is also responsible for the supply of breeder seed to other organizations/companies involved in seed production, as well as the supply of planting materials for vegetatively propagated crops like cassava and sweet potatoes. Other areas of research include soils and farming systems. ZARI is also responsible for the collection, characterization and preservation of plant genetic resources and the provision of quarantine and phytosanitary services.

In recognition of the limited local research capacity in the private sector, the government established autonomous agricultural research trusts to promote the capacity for research and variety development. These are the Golden Valley Agricultural Research Trust (GART) and the Cotton Development Trust (CDT). These Trusts are self-financing by generating funds through research and commercial farming. The SCCI is responsible for variety testing, release and registration; seed inspection and testing; and training of stakeholders to ensure that only good quality seed reaches the farmers. The SCCI also plays a central role in policy formulation and guidance as well as seed legislation and generally administers the Plant Varieties and Seeds Act for the smooth functioning of the seed trade.

During the past twenty years, the Zambia seed system has undergone a number of transformations. It has evolved from a situation where there was limited crop research to a situation where public research is providing virtually all the varieties now in use in the country. Remarkable progress has been made in developing a wide range of improved varieties and clones of traditional staple food crops such as maize, sorghum, pearl millet, cassava, sweet potatoes, cowpea and groundnuts. However, adoption rates and factors affecting the adoption of most improved seed remain unknown.

This study uses a Tobit model and data from a survey of maize-growing households to identify farm and farmer characteristics important for adoption as well as to determine the role of farmer perceptions of technology attributes in maize varietal adoption. Farmers also make subjective inter-varietal comparisons of certain key attributes before they can adopt the new varieties, which need to be understood and internalized in the design of programmes. Literature is, thus far, very scant on the determinants of adoption of drought tolerant improved varieties. This knowledge is important for identifying interventions that can effectively accelerate new technology adoption. Thus, the findings of this study are of interest to several development stakeholders, including relevant the government agencies (research, extension, policy and planning), seed companies and Non-Governmental Organizations (NGOs).

CONCEPTUAL FRAMEWORK

Farmers make choices of what to grow and which technologies to adopt with the goal to maximize their expected utility. In agriculture, they will look for production alternatives that will help them to reduce costs whilst taking full advantage of the benefits thereof. We can define the farmer’s optimization problem as:

$$\text{Max}\, E(U) = E\{[\alpha\pi_1 + (1-\alpha)\pi_2]A - C(\alpha, A); \rho, g\} \qquad (1)$$

where,

$E(.)$ = The expectations operator

$E(U)$ = The expected utility

α = The proportion of cultivated land area devoted to improved technologies

$\pi_1 = f_1(r_1, p_1, y_1)$ = Net revenue per hectare from fields on which the improved technologies are used

$\pi_2 = f_2(r_2, p_2, y_2)$ = Net revenue per hectare allocated to traditional technologie

A = The fixed quantity of land available to the household
$C(\alpha, A)$ = The cost function
ρ = A measure of risk preference
g = A vector of farm and household characteristics

Notice that both π_1 and π_2 are functions of yield (y) as well as input (r) and output (p) prices.

The optimal adoption rate, a^*, can be obtained by taking the first-order conditions of (1) with respect to and solving for α (Shapiro *et al*., 2002):

$$\alpha^* = f\left(\bar{\pi}_1, \bar{\pi}_2, \Sigma, A, \rho, g\right) \quad (2)$$

where, $\sum$ is a matrix of second and possibly higher-order moments of the joint probability distribution function. In general and in line with Eq. (2), adoption theory attempts to explain adoption using a set of variables drawn from five broad categories: prices of inputs and outputs, risk factors, quasi-fixed capital and shift factors (such as location). However, prices are rarely included in adoption models as they are regarded as implicit in the choice being modeled and are often further determined by farm size and location variables (Neven *et al*., 2006).

In general, three paradigms have guided the choice of covariates used in empirical adoption studies (Langyintuo *et al*., 2005):

- The innovation-diffusion
- The adopters' perception
- The economic constraints models

However, evidence has shown that none of these is by itself adequate in representing the adoption problem (Langyintuo *et al*., 2003; Ajayi *et al*., 2003). We select our covariates, x; with emphasis on all three paradigms (Table 1).

A number of risk factors and quasi-fixed capital are needed to help capture risk-sensitivity (size of the farm operation; and alternative, off-farm income), access to financial capital (size of operation; access to credit; education of the household head; education of most educated member), human capital (age of the household head; the two education variables described above; sex of the household; number of active male and female members supplying farm labour; and marital status of the household head), social capital (participation in farmer organizations, access to remittances, etc) and physical capital (asset endowment; degree of modernity of the main house). For most of these, ceteris paribus, a higher value is expected to increase the probability of adoption and, for adopters, the extent to which such practices have been adopted.

A number of variables representing the decision maker's perception with respect to the technology were also included in the model. This is because, ultimately, adoption of new technology will be determined by its suitability to the farmers, the profitability and risk associated with the new technology and the institutional capability to communicate to farmers about the new technology. Many individual farm and household characteristics affect technology adoption. Some households are more likely to be risk takers and early adopters of new technology than others. A key hypothesis is that farmer perceptions of technology-specific attributes or characteristics significantly influence technology adoption decisions.

METHODOLOGY

Data and data sources: This study uses data from the Zambia component of an Africa-wide study under the Drought Tolerant Maize for Africa (DTMA) project which was coordinated by the International Maize and Wheat Improvement Center (CIMMYT). Data were collected from Monze and Kalomo districts in Southern Province of Zambia. The districts were purposively selected with the goal to capture maize-based farming systems in an environment where the risk of drought was considered moderate to high. In both these districts, the probability of a failed season ranges from 40 to 60%. Monze district is located in agro-ecological region II where annual rainfall is 800-1000 mm and the growing season comprises 100-140 days (Bunyolo *et al*., 1995; Environment Council of Zambia, 2000). Kalomo is also located in agro-ecological region II. However, a small portion of the southern part of the district is located in agro-ecological zone I. Rainfall averages about 350 mm, which is far below the long term average for region II (Government of the Republic of Zambia, 2005, 2006a, b). Both districts, like most other places in the province, have experienced declining rainfall levels during the past two decades.

Ten villages were selected in each of the two districts and from each village, farmers were proportionately selected randomly based on the distribution of maize production households to give a total of 350 households for the survey. Fifty-eight % of the households were located in Monze District and the rest were located in Kalomo District. About 18% of the sample households were female headed. Structured questionnaires designed to capture information on a range of indicators related to household livelihood strategies and factors influencing the adoption of improved maize varieties were administered between June and August 2007.

The empirical model: Because of the discrete or partly-discrete nature of adoption decisions, they tend to be modeled in the limited dependent variable framework. Logit and probit models are popular in the adoption literature that seeks to model the probability of adoption. However, while explaining the probability of adoption well, logit and probit models are incapable of shedding any light on the extent or degree of adoption. This kind of information can be obtained if the dependent variable is partly binary and partly continuous. Such a variable represents both the decision to adopt at the censoring point and, once the technology has been adopted, the degree of adoption. Because not all maize producers use improved varieties and because even those who have adopted may not allocate all of their maize area to these varieties, the proportion of the maize area under improved varieties is likely to be censored at zero.

Tobin (1958) developed a framework for estimating models of censored dependent variables. The Tobit model, named after its inventor, is defined as:

$$y_i = \begin{cases} y_i^* & \text{if } y_i^* > 0 \\ 0 & \text{otherwise,} \end{cases} \qquad (3)$$

where $y_i^* = \hat{\beta}x + \mu_i$ is a latent variable, μ_i is an independently and identically distributed normal random error term with mean zero and constant variance σ^2 and x and β are vectors of covariates and parameters to be estimated, respectively. In effect, the Tobit model is a combination of a probit (at the censoring point) and a linear regression model (when above the censoring point). The estimates of a Tobit model approach those of Ordinary Least Squares (OLS) as the degree of censoring (number of censored observations) tends to zero and are inconsistent if the error term is heteroskedastic.

Equation (3) was estimated using the maximum likelihood methods, taking the two regimes jointly (Wooldridge, 2002; Greene, 2000). Heteroskedasticity was, however, significant in our cross-sectional data as indicated by a Breusch-Pagan/Cook-Weisberg test (χ_1^2 = 17, p-value<0.0001). To correct this problem and, thus, improve the efficiency of our estimates, we used robust standard errors.

Because the Tobit model is inherently nonlinear in the coefficients, its estimated parameters do not by themselves represent the marginal effects of the explanatory variables on the dependent variable. Instead, the marginal effects are functions of both the parameters and the data. Skipping the algebraic details, it has been shown (Wooldridge, 2002; Greene, 2000) that the marginal effect of a variable x_j on the dependent variable y can be computed as:

$$\frac{\partial E(y)}{\partial x_j} = F(z)\frac{\partial E(y \mid y>0)}{\partial x_j} + E(y \mid y>0)\frac{\partial F(z)}{\partial x_j} \qquad (4)$$

where F(z) is the standard normal cumulative distribution function evaluated at $z = x\beta/\sigma$, $E(y)$ is the unconditional expected value of y and $E(y|y>0)$ is the expected value of y given that y is above zero. Equation (4) implies that the overall effect of a small change in an explanatory variable can be decomposed into:

- The change in the number of hectares allocated to improved practices by those farmers that use these practices, weighted by the probability of adopting improved practices.
- The change in the probability of using improved practices, weighted by the number of hectares expected to be allocated to improved practices. This ability to unpack the overall effect, also referred to as the McDonald and Moffit (1980) decomposition, makes it a lot easier to interpret the marginal effects and has an inherent intuitive appeal.

RESULTS AND DISCUSSION

Table 1 presents farm and household characteristics and perceptions regarding improved varieties. The table also compares these across the two strata of farmers–adopters and non-adopters of the improved varieties. Most of the households were male-headed (82%) and had married heads (79%). They owned an average of 6.7 ha of land and cultivated just under half of it. A third of the households had heads that had attained secondary school or higher education level. Although more than half of the households participated in local farmer organizations, only 11% accessed credit in the 2005/06 season. More than three-quarters of the households felt that improved maize varieties matured earlier, had higher yield potential and tolerated water and moisture stress more than landraces.

When compared to non-adopters, adopters were more likely to be male-headed, to have educated heads and members and to be in farmer groups and the differences were statistically significant (Table 1). They also had significantly larger farm sizes, more male members in the active age group and were more likely to have houses with modern roofs (iron or asbestos sheets). Adopters also were more likely to perceive improved varieties as having higher yield potential and larger cobs and grains.

While these results indicate significant differences between adopters and non-adopters of improved varieties, they are unconditional and, thus, do not explain adoption. Table 2 presents the results of the Tobit model of adoption Eq. (3). Columns (1) and (2) present the parameter estimates and their standard errors, respectively. The marginal effects are split into their two components, as in Eq. (4) and are presented in Columns 3 and 4.

The tobit results show that the probability and degree of adoption of improved varieties of maize is directly related to the size of the farm holding and participation in farmer organizations. One more hectare

Table 1: Household and farm characteristics and perceptions about improved maize seed varieties

Variable description[a]	Full sample	Sub-samples: Non-adopters	Sub-samples: Adopters
	(1)	(2)	(3)
	350	59	291
	Mean		
Household and farm characteristics			
Male-headed households (%)	82.0	73.0	84.0*
Age of the HH head (years)	45.67	48.73	45.04
Households with married heads (%)	79.0	73.0	80.0
Head reached secondary school (%)	33.0	24.0	34.0*
Most educated: secondary school (%)	47.0	39.0	49.0
Modern roof on main house (%)	29.0	19.0	31.0**
Number of males aged 15-60 years	1.46	1.45	1.46
Number of females aged 15-60 years	0.78	0.61	0.81*
Farm size (ha)	6.70	4.34	7.18**
Cropped land area (ha)	3.03	2.98	3.04
Access to services and social capital			
Households receiving credit 2005/06 (%)	11.0	8.0	12.0
Participation in farmer groups (%)	51.0	37.0	53.0**
Access to extension officers (%)	63.0	63.0	63.0
HHs receiving agric input aid in 2005/06 (%)	5.0	7.0	5.0
HHs attending field days in 2005/06 (%)	25.0	24.0	25.0
HHs attending demonstrations in 2005/06 (%)	11.0	14.0	11.0
Farmer perceptions about improved seed (% of households)			
Improved seed is cheaper	16.0	10.0	17.0
Improved seed is readily available	34.0	37.0	33.0
Improved seed has higher grain price	26.0	20.0	27.0
Improved seed is more tolerant to field pests	55.0	61.0	54.0
Improved seed is more tolerant to storage pests	49.0	53.0	48.0
Improved seed is earlier maturing	85.0	78.0	86.0
Improved seed is having higher yield potential	79.0	69.0	81.0*
Improved seed is having more stable yields	7.0	7.0	7.0
Improved seed is more tolerant to water/soil stress	83.0	81.0	83.0
Improved seed is having larger cobs/grains	50.0	36.0	53.0**
Improved seed is more palatability	23.0	22.0	24.0
Improved seed is having better processing quality	56.0	49.0	57.0

Unequal-variance *t* tests: * = Sig at 10%; ** = Sig at 5%; *** = Sig at 1%; [a]HYV = High-yielding or improved varieties

Table 2: Tobit regression results on factors affecting adoption and use intensity of improved maize varieties

Variable description	Parameter estimate	Robust standard errors	Marginal analysis: Expected use intensity	Marginal analysis: Probability of adoption
	(1)	(2)	(3)	(4)
Intercept	0.583***	0.150	-	-
Sex of head, 1= male	0.307***	0.100	0.192	0.185
Age of head in years	-0.004**	0.002	-0.003	-0.002
Marital status, 1= married	-0.208**	0.090	-0.130	-0.126
Education of head, 1= secondary	0.074	0.052	0.046	0.045
Most educated, 1= secondary	0.039	0.053	0.025	0.024
Main house, 1= modern roof	0.034	0.050	0.021	0.021
Number of male members 16-59 years	-0.003	0.024	-0.002	-0.002
Number of female members 16-59 years	0.036	0.025	0.023	0.022
Farm size in ha	0.001**	0.001	0.001	0.001
Cropped area in ha	-0.014	0.011	-0.009	-0.009
Credit access, 1= got credit	0.009	0.083	0.006	0.006
Farmer organizations, 1= member	0.134***	0.050	0.083	0.081
Main extension source, 1= Ext officer	0.055	0.050	0.034	0.033
Perception, 1= HYV seed has lower price	-0.040	0.067	-0.025	-0.024
Perception, 1= HYV seed readily available	-0.064	0.056	-0.040	-0.038
Perception, 1= HYV grain fetches higher price	0.106*	0.057	0.066	0.064
Perception, 1= HYV more tolerant to field pests	-0.064	0.060	-0.040	-0.039
Perception, 1= HYV more tolerant to store pests	-0.012	0.059	-0.007	-0.007
Perception, 1= HYV is earlier maturing	0.112	0.084	0.070	0.068
Perception, 1= HYV has higher yield potential	0.114*	0.065	0.071	0.069
Perception, 1= HYV yields are more stable	0.077	0.100	0.048	0.047
Perception, 1= HYV tolerate soil/water stress	-0.016	0.073	-0.010	-0.009

Table 2: Continue

Perception, 1= HYV has bigger cobs/grains	0.022	0.053	0.014	0.013
Perception, 1= HYVs are more palatable	-0.033	0.056	-0.020	-0.020
Perception, 1= HYV better processing quality	0.003	0.058	0.002	0.002
Aid, 1= Received agric aid in 2005/06	-0.070	0.110	-0.044	-0.042
Field days, 1= attended in 2005/06	-0.107	0.065	-0.067	-0.065
Demonstrations, 1= attended in 2005/07	0.034	0.088	0.021	0.020
District dummy, 1= Monze	-0.130**	0.051	-0.081	-0.079
N	344			
Log pseudo likelihood	-218.2			
R-squared	0.11			
Goodness of fit F statistic	2.2700***			
Sigma	0.4070***			

Significance: * = 10%; ** = 5%; *** = 1%; Dependent variable: Proportion of maize area under improved varieties (hybrids or improved OPVs)

of land added to the farm raises the probability of adopting improved varieties by 0.1%. For those who have already adopted the technologies, an additional hectare is associated with a raised proportion of maize area allocated to improved technologies by 0.1%. Similarly, participation in farm organizations is associated with an increase in the probability of adoption by 8% while raising the average proportion among adopters of land allocated to improved varieties by 8.4%.

The sex of the household head also matters in explaining adoption of improved maize varieties with adoption favoring male-headed households. Male-headed households were 19% more likely to adopt than their female-headed counterparts. The decision-maker's perceptions about the output market price and the new varieties' yield potentials are also important factors. Those that perceived improved varieties as having higher yield potentials and likelihood to fetch higher grain prices were 7.1 and 6.6% more likely to adopt such varieties, respectively.

The results also interestingly show that households with married and elderly heads were less likely to adopt improved varieties than their counterparts. The finding that households with married heads are less likely to adopt is not surprising. It probably reflects the fact that the married people are more likely to be older than the single people. It is well established that the age of the household head affects the productive capacity of small-scale farmers (Rogers, 1983; Akinola, 1986). People who are predominantly below midlife could be regarded as potentially productive farmers with a greater capacity to adopt new technologies as compared to their older and married counterparts.

CONCLUSION

This study indicates that farmer expectations about output price and yield are important determinants of adoption. The results also suggest that farmers also seek specific varietal attributes, such as early maturity, yield potential, tolerance to water stress, pest/disease tolerance, better processing quality and cob/grain size. The finding that farmer perceptions of technology-specific characteristics significantly condition technology adoption decisions is consistent with recent evidence in the literature, which suggests the need to go beyond the commonly considered socio-economic, demographic and institutional factors in adoption modeling (Feder *et al.*, 1985; Feder and Umali, 1993).

Farmer and farm characteristics found to significantly influence varietal adoption decisions include the status of being male-headed, farm size and membership to farmer organizations. As expected, households with educated heads and/or more wealth were also significantly more likely to adopt improved varieties.

The empirical results of this study are useful in the design of policy strategies or interventions that will assist in increasing the adoption and utilization of improved technologies such as drought tolerant maize varieties among smallholder farmers. Adoption of these drought tolerant maize technologies will help to increase agricultural productivity and hence improve food security in Zambia. For instance, the findings on farmer characteristics and membership to organizations have important policy implications in favor of group-based approaches to agricultural extension. Given that the majority of the rural people are poor and have lower levels of formal education, intervention strategies can be designed and implemented to encourage poor households and those with low levels of formal education to participate in local farmer or credit organizations. The positive interaction between membership to organizations and the adoption of technologies also suggests that group based extension approaches should be encouraged not only for their role in collective action but also for their positive impact on information diffusion and technology adoption.

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