Staff Paper

Department of Applied Economics and Management
Cornell University, Ithaca, New York 14853-7801 USA

Adoption of Improved Maize Seed by Smallholder Farmers in Mozambique

Helder Zavale, Edward Mabaya, and Ralph Christy

Adoption of Improved Maize Seed by Smallholder Farmers in Mozambique

Helder Zavale, Edward Mabaya, Ralph Christy [1]

Abstract

The objective of this paper is to investigate factors influencing the adoption of improved maize seed by smallholder farmers in Mozambique. The data used in this study were obtained from a national random sample of 4,908 smallholder farmers conducted by the Ministry of Agriculture and Rural Development in 2002. Using Probit and Logit models, the main factors influencing adoption of improved maize seed were identified. The results of this analysis indicate that fifteen out of twenty five factors are significantly found to be the determining factors influencing the probability of adopting improved maize seed. To increase the likelihood of adopting improved maize seed, policy makers should put more emphasis on improving rural infrastructures and providing better education.

INTRODUCTION

Despite the enormous potential of Mozambique's natural resource available for a healthy growth rate of the agricultural sector, the performance of the agricultural sector is relatively low. Though the poverty rate has declined from 69 percent in 1996 to 54 percent in 2002, many rural households depending on agriculture are still poor. Since the 1960s, the maize production in Mozambique has increased rapidly. As shown in figure 1, expansion in cultivated area is the main source of maize production growth. Achievements of production increase by bringing more land into cultivation will no longer work because fragile uncultivated land has increased. Since 1960, unlike cultivated area, maize yield has decreased slightly, and average maize yield in Mozambique is lower that yield achieved in the Southern African in particular and in Sub Saharan Africa in general.

---

[1] Graduate Student, Research Associate, and Professor respectively in the Department of Applied Economics and Management at Cornell University, Ithaca, New York 14853. The corresponding author is Helder Zavale who can be reached by email at hz49@cornell.edu.
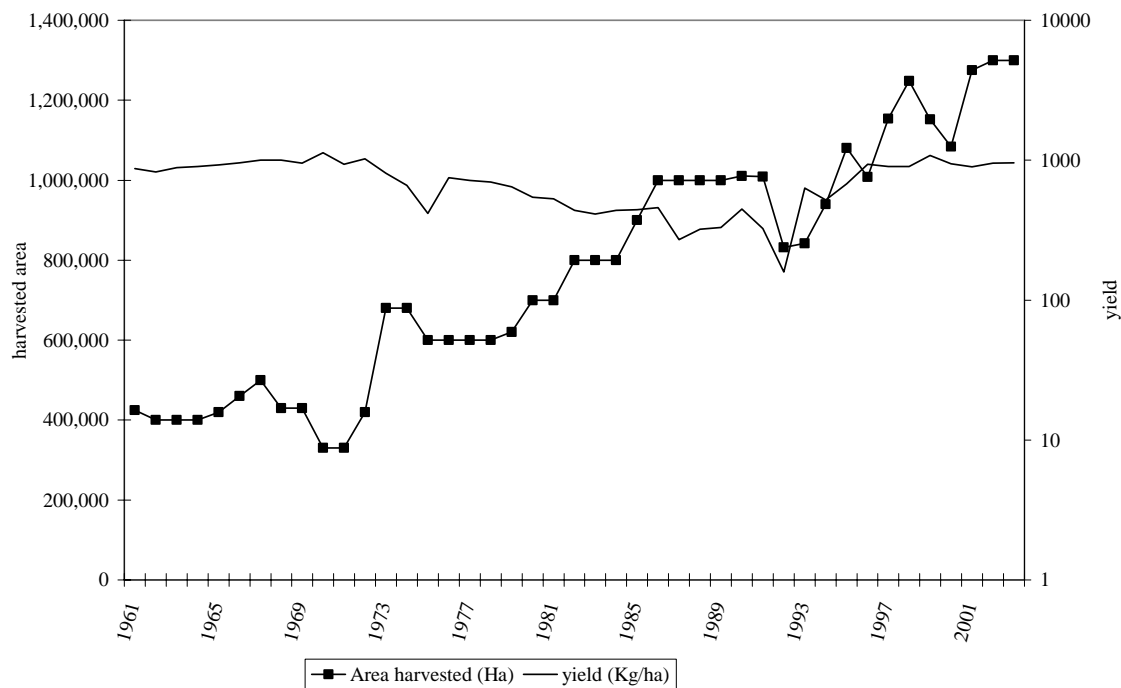
Figure 1 Production and yield of maize from 1961 to 2003 in Mozambique

Typical maize yields (generally intercropped) ranged between 400 and 800 Kg/hectare in Monapo, between 250 and 600 Kg/hectare in Ribaue, and between 200 and 400 Kg/hectare in Angoche, while CIMMYT quotes average maize yields of between 830 and 3,000 Kg/hectare among low input smallholders in the Southern Africa. On the other hand, the Mozambican population expanded from 12.1 million in 1980 to 18.1 million in 2001, and it is estimated to be 22.7 million in 2015. In face of current demographic trends, Mozambique has to improve its agricultural productivity urgently to alleviate its poverty incidence (Howard et al., 2001; Haggblade et al., 2004). Productivity can be increased through improved varieties and better management; however, productivity benefits will not be realized unless substantial improvements are made in seed production and distribution.

Maize is one of the staple food and one of the most important crops produced in Mozambique. It occupies thirty-five percent of the total cultivated area and is grown by seventy-nine percent of the total number of holdings. Given the relative importance of maize in the

subsistence agriculture in Mozambique, this paper has as its central objective to determine the factors influencing the adoption of improved maize seed by smallholders.

This paper is structured as followed. In the following section, we describe the data used in estimating the adoption models. After presenting the Probit model used to analyze smallholder farmers' decisions to adopt improved maize seed, we report the estimation results from this model. The final section focuses on the implications of our findings for both public policy and private strategies.

DATA

The data used in this study came from a national agricultural survey. The survey is nationally representative and was conducted by the Ministry of Agriculture and Rural Development (MADER) in the agricultural year 2001-2002. This national sample survey is widely known as *TIA - Trabalho de Inquerito Agricola*. The survey collects a wide range of detailed information on various aspects of household economy, including income, expenditures, production, capital stock, land use, and demographic characteristics.

Table 1 Farm holdings by size, 2000/2001

	Holding size			Total
	small	medium	large	
Number of farm holdings	3,054,106	10,180	429	3,064,715
Total cultivated area (ha)	3,736,577	67,726	62,064	3,866,368
Average cultivated area (ha)	1.22	6.65	144.67	1.26
Most common range of cultivated area (ha)	0.5 – 1.0	5.0 – 10.0	20.0 – 50.0	0.5 – 1.0
Percentage of cultivated area under basic food crops	84.4	74.2	14.8	84.7
Percentage of cultivated area under horticultural crops	5.2	8.7	2.5	5.2
Percentage of cultivated area under "cash crops"	4.3	4.7	82.8	5.6
Percentage of farm holding				
Use fertilizers	2.7	11.0	32.9	2.7
Use pesticides	4.5	10.3	36.1	4.5
Use animal traction	10.8	71.8	32.2	11.0
Use irrigation	3.9	16.9	35.4	3.7

Source: INE, Agricultural and Livestock Census, 1999/2000

In Mozambique, there are three categories of farm holdings[2]: small, medium, and large. Data from the Agricultural and Livestock Census presented in Table 1 shows that Mozambique has approximately 10,000 medium, 400 large holdings, and more than 3 million small holdings. The average cultivated area of these holdings is 1.26 hectares and about 84 percent of which is devoted to basic food crops (maize, rice, millet, cassava, sorghum, and pulses). The distribution of cultivated area is highly skewed. Maize, the main food crop, is grown predominantly by the smallholders. Horticultural and commercial cash crops make up approximately 10 percent of the small holdings' cultivated area.

Mozambique's agricultural sector is characterized by a large number of small holdings with primarily rain-fed subsistence production based on manual cultivation techniques and little use of purchased inputs. It can be seen from table 1 that only 2.7, 3.7, and 4.5 percent of the total holdings use fertilizers, irrigation, and pesticides, respectively. Acquisition and use of purchased inputs can be facilitated by access to credit. The results of the Agricultural and Livestock Census 1999 – 2000 show that only 4 percent of the small and large holdings had access to credit, mostly from informal sources.

Table 2 summarizes the sample statistics of the explanatory variables of the adoption model. This table illustrates that the household size of a typical maize grower is on average 5.6 members. This household size is bigger than the Mozambique's average household size estimated to be 4.8 members. Regarding gender, only 24 percent of the sampled households are female-headed. The average age of the household head is about 43.9, which is slightly higher than the life expectancy, 42.0, of the population of Mozambique. With respect to formal education, many household heads are uneducated and the average household head's years of schooling is 2.8. The low level of literacy has implications for technological adoption and other interventions aimed at enhancing agricultural productivity. Table 2 shows that only about 16 and 5 percent of the sampled households received extension service from both government and NGOs and belonged to an agricultural association, respectively.

---

[2] Holding is defined as an economic entity of agricultural and livestock production under single management. Small holdings are those farms with less than 10 hectares of cultivated area, less than 10 heads of cattle, less than 50 goats, sheep, or pigs, and less than 5, 000 poultry. Medium holdings are those farms with between 10 and 50 hectares of cultivated area, between 10 and 100 heads of cattle, between 50 and 500 goats, sheep, or pigs, and between 5, 000 and 20, 000 poultry. Large holdings are any farms that have one or more component higher than the medium holding limit.

Table 2 Descriptive statistics of the explanatory variables of the adoption model

Variable	Definition	Mean	Standard Deviation
HHSIZE	Household size	5.60	3.33
SEX	Gender of the household head (male = 1; otherwise = 0)	0.761	
AGE	Age of the household head (years)	43.88	14.89
EDUC	Highest formal schooling completed by household head (years)	2.80	4.02
DISTANCE	Distance to county seat (Km)	27.00	16.61
JOB	Household head had off-farm employment = 1; otherwise = 0)	0.326	
NORTH	Household located in northern macro agro-ecologic zone = 1; otherwise = 0	0.442	
CENTRAL	Household located in central macro agro-ecologic zone = 1; otherwise = 0	0.305	
EXTENS	Household had contact with extension service = 1; otherwise = 0	0.155	
ASSOC	Household belonged to an agricultural association = 1; otherwise = 0	0.052	
INFO	Household received price information = 1; otherwise = 0	0.319	
FERTIL	Household used fertilizer = 1; otherwise = 0	0.053	
PESTIC	Household used pesticide = 1; otherwise = 0	0.071	
IRRIG	Household used irrigation = 1; otherwise = 0	0.155	
TRACTION	Household used animal traction = 1; otherwise = 0	0.200	
ELECTRIC	Household had access to electricity = 1; otherwise = 0	0.080	
CREDIT	Household had access to credit = 1; otherwise = 0	0.117	
MARKET	Household had access to market = 1; otherwise = 0	0.269	
SEED	Household had access to seed store = 1; otherwise = 0	0.190	
COTTON	Farm household grew cotton = 1; otherwise = 0	0.067	
TOBACCO	Farm household grew tobacco = 1; otherwise = 0	0.047	
DROUGHT	Household affected by drought in the last 2 years = 1; otherwise = 0	0.896	
FLOOD	Household affected by flood in the last 2 years = 1; otherwise = 0	0.770	

In Mozambique, agricultural inputs are not available to farmers or availability of these inputs is spatially limited due to lack of infrastructures, limited access to credit, low purchasing power, inappropriate agricultural input policies, and sometimes environmental constraints. The findings presented in table 2 indicate that only 5, 7, and 16 percent of the surveyed households used fertilizer, pesticide, and irrigation respectively. One fifth of the households use animal traction and only about 7 and 5 percent grew cotton and tobacco respectively.

METHODS

Adoption of agricultural technology is influenced heavily by technical, economic, social, and physical aspects of farming. Since the pioneering study of Griliches (1957), logistic curve, based on the assumption that the adoption increases slowly at first and then rapidly to move toward a maximum level, is the widespread procedure used to evaluate the rate of adoption. The logistic model has two specifications: fixed and dynamic. The dynamic specification is more

realistic than fixed specification because farmers learn by doing and do not simply decide whether or not to permanently adopt an improved variety.

The farmers' decision in one period is highly correlated with the previous decisions; therefore, farmers' decisions need to be followed over time (Doss, 2003; Moser and Barrett, 2003). Both fixed and dynamic specifications of logistic model require availability of panel data. However, as Doss (2003) points out, when panel data are unavailable, cross section data can answer important questions about technology adoption. Cross-section analysis can provide information on the patterns of adoption, farmers' decision-making process, and farmers' preferences.

The Tobit model, based on the normal distribution, is preferably used to analyze adoption when the rate of application of a new technology is available. However, when the adoption variable is categorical (usually adoption or non-adoption) instead of continuous and truncated (rate of application), other analytical techniques are required. The most common analytical techniques used in this case are Logit and Probit models. Many studies (Nkamleu and Adesina, 2000; Hintze et al., 2003; Payne et al., 2003; Asfaw and Admassie, 2004) have investigated the factors that influence farmer's adoption of new technologies utilizing either Probit or Logit models.

Probit and Logit models are based on the normal and logistic cumulative distribution function, respectively. Both models are quite similar, the main difference being that the logistic distribution has slightly fatter tails. In this study, the Probit model was chosen. The farmer's decision on seed adoption depends on the criterion function,

$$Y_i^* = \gamma^{'} Z_i + \mu_i$$

Where Y_i^* is an underlying index reflecting the difference between the utility of adopting and the utility of not adopting improved seed, γ is a vector of parameters to be estimated, Z_i is a vector of exogenous variables which explain adoption, and μ_i is the standard normally distributed error term. Given the farmer's assessment, when Y_i^* crosses the threshold value, 0,

we observe the farmer using improved seed. In practice, Y_i^* is unobservable. Its observable counterpart is Y_i, which is defined by

$$Y_i = 1 \quad \text{if } Y_i^* > 0 \text{ (Household i used improved seed), and}$$
$$Y_i = 0 \quad \text{if otherwise}$$

In the case of normal distribution function, the model to estimate the probability of observing a farmer using improved seed can be stated as

$$P(Y_i = 1 \mid x) = \Phi(x'\beta) = \int_{-\infty}^{x'\beta} \frac{1}{\sqrt{2\pi}} \exp(-z^2/2) dz$$

Where,

P is the probability that the ith household used improved seed, and 0 otherwise;

x is the K by 1 vector of the explanatory variables;

z is the standard normal variable, i.e., $Z \sim N(0, \sigma^2)$; and

β is the K by 1 vector of the coefficients to be estimated.

RESULTS

LIMDEP 8.0 software was used to derive estimates for the maximum likelihood function of the adoption model. The overall goodness of fit of adoption model is good. The null hypothesis that all coefficients with the exception of the intercept are simultaneously equal to zero is robustly rejected at 1 percent level of significance. Similarly, the Wald statistic indicates that all coefficients are simultaneously statistically different from zero at 1 percent level of significance, indicating a good fit of the adoption model. Thus, the explanatory variables are influential in determining the probability of adoption of improved maize seed by the surveyed households. Finally, the percentage of correctly predicted responses is 71 percent, which is within the range of other studies. Both Probit and Logit model provide similar results (see table 3).

Table 3 Measures of goodness of fit of adoption model

	Probit model		D.F.	Logit model		D.F.
Log likelihood	-2,085.79			-2,086.14		
Restricted log likelihood	-2,237.03			-2,237.03		
Likelihood ratio index	0.06761			0.06745		
Likelihood ratio	302.50	***	25	301.79	***	25
Wald	8.42	***	25	8.31	***	25
Percentage of correct prediction	70.6			70.6		
Number of observations	3,603			3,603		

D.F. = degree of freedom
*** Statistically significant at the 1% level

Table 4 presents the estimates of the adoption model for improved maize seed estimated by maximum likelihood. For comparative purpose, Probit and Logit model were estimated, and as theoretically anticipated, the Probit and Logit estimated marginal effects are very similar. The results of the Probit model are summarized in table 4 and discussed in this section. See appendix A for results of Logit model. Due to collinearity, the variables, drought and flood in the last two years, were excluded in the adoption model for the southern region. These two dummy variables have value of 1 for all the observations in the south.

Fifteen of the twenty five parameter estimates were statistically significant. Household size; age; education; off-farm employment; location (southern, central, and northern agro-ecological zone); access to extension service, credit, seed stores, and electricity; use of pesticide, fertilizer, and irrigation; and farming of traditional cash crops (cotton and tobacco) are the determining factors influencing the probability of adopting improved maize seed in Mozambique.

From the coefficients of the adoption model, one can see that household size, an indicator of availability[3] of farm labor, is significantly associated with the decision of adopting improved maize seed. The positive sign of this variable indicates that larger households are more likely to adopt improved maize seed, as expected. However, when the model is run by region, household size is only statistically correlated to adoption decision in the northern region of the country.

---

[3] As argued by Doss (2001), it is important to note that a farmer may gain access to labor by mobilizing household labor and through the market. Further, the seasonal availability of labor considerably influences the decision of adopting new technology.

Table 4 Coefficient estimates for the adoption model estimated by maximum likelihood

	Expected sign	North Coefficient			Central Coefficient			South Coefficient			All sample Coefficient		
Constant		-0.345			-0.998			0.086			0.234		
Distance	-	-0.008	***	-(0.002)	0.004	*	(0.001)	-0.001			-0.001		
Household size	+	0.052	***	(0.015)	0.009			0.011			0.020	***	(0.007)
Gender	+/-	-0.003			0.052			-0.008			0.001		
Age of household head	+	-0.022			-0.024			-0.006			-0.015	*	-(0.005)
Age squared	-	0.000			0.000			0.000			0.000		
Years of schooling	+	0.012			0.012			0.014			0.011	**	(0.004)
Off-farm employment	+	0.198	***	(0.059)	0.019			0.310	***	(0.123)	0.162	***	(0.057)
Extension service	+	-0.071			-0.062			-0.238			-0.129	**	-(0.044)
Association	+	0.102			0.324			-0.345	**	-(0.133)	-0.032		
Price information	+	-0.094			0.006			0.296	***	(0.118)	-0.025		
Use of fertilizer	+	0.386	***	(0.125)	-0.204			0.084			0.244	**	(0.089)
Use of pesticide	+	0.412	***	(0.134)	0.655	***	(0.249)	-0.087			0.188	*	(0.068)
Use of irrigation	+	0.294	***	(0.093)	0.250	***	(0.090)	0.080			0.140	***	(0.050)
Use of animal traction	+	0.002			-0.339	***	-(0.108)	0.185	**	(0.073)	0.012		
Electricity access	+	0.523	***	(0.177)	0.003			0.275	**	(0.109)	0.343	***	(0.127)
Credit access	+	-0.312	***	-(0.082)	-0.354	*	-(0.110)	-0.144			-0.266	***	-(0.087)
Market access	+	-0.099			-0.040			0.216	**	(0.086)	-0.036		
Seed store access	+	0.076			0.225	**	(0.079)	0.069			0.106	*	(0.038)
Paved road access	+	-0.015			0.013			-0.014			-0.001		
Cotton farming	-	-0.399	***	-(0.100)	-0.391	**	-(0.121)	-8.015			-0.212	*	-(0.070)
Tobacco farming	-	-0.465	***	-(0.113)	-0.145			-0.471			-0.288	**	-(0.093)
Drought last 2 years	+/-	0.205	***	(0.057)	0.306						0.140		
Flood last 2 years	+/-	-0.146	***	-(0.042)	0.598	***	(0.171)				-0.091		
North	-										-0.679	***	-(0.228)
Central	-										-0.456	***	-(0.150)
Log likelihood		-800.03			-644.59			-589.55			-2,085.79		
Chi squared		99.51	***		58.09	***		81.78	***		302.50	***	
Observations		1,592			1,100			911			3,603		

* Statistically significant at the 10% level; ** Statistically significant at the 5% level; and *** Statistically significant at the 1% level
Marginal effects for significant variables in parentheses

The effect of experience of the farmer, measured by the age of the household head, on the decision to adopt improved maize seed was found to be statistically significant and negative at national level. Although not statistically significant, the sign of this variable is consistent across all regions. Empirical evidence has revealed that the age can be either positively or negatively related to the decision of adopting new technology. The results of this study reveal that older farmers are less likely to adopt improved maize seed than younger ones. Furthermore, the findings show that the age-squared variable is not statistically significant, which suggests that the likelihood of taking risk associated with new technology is not different between younger and older farmers.

With respect to education, it is theoretically argued that education enhances the ability of farmers to acquire, synthesize, and quickly respond to disequilibria, thereby increasing the probability of adopting an innovation. As expected, the education variable has a positive impact on the decision of using improved maize seed. Empirical results of most of the studies support this finding. However, the results by region show that education of farmers does not have a significant impact on the adoption decision in none of the three regions.

Off-farm employment is another often-mentioned determinant of improved seed adoption. Feder, Just, and Zilberman (1985) argue that off-farm income can help overcome a working capital constraint or may finance the purchase of a fixed-investment type of innovation. Consistent with previous studies, the results of this study indicate that off-farm employment and the adoption of improved maize seed are positively correlated. It is worth pointing out that this variable is not statistically significant in the central region although the expected sign was detected.

A number of theoretical and empirical studies have revealed that capital in the form of either accumulated savings or access to capital markets is necessary to finance many new agricultural technologies. Those studies have found that access to credit and decision to adopt new agricultural innovation are positively associated (Feder et al., 1985). Somehow surprising, table 4 shows that in Mozambique, the more the farmers gain access to credit, the smaller the probability of adopting improved maize seed. However, it should be pointed out that several empirical studies have found similar results. In Mozambique, formal financial institutions are reluctant to give loans to poor rural households, characterized by low levels of assets ownership, because of their lack of collaterals, high transaction costs associated with the small loans, the risk of income shocks (weather fluctuations, susceptibility to pests, and commodity prices), and moral hazard problems. Thus, these financial institutions give

especially loans to households involved in off-farm income generating activities. As a result, households accessing credit may not depend solely on agriculture as their major source of livelihood.

Also, the decision to adopt improved maize seed is affected by risk factors. Two types of risk are related to improved seed adoption: subjective and objective. Subjective risk is associated with uncertainty faced by the farm households when making decision to adopt new and unfamiliar technology and objective risk arises due to weather fluctuations, susceptibility to pests, uncertainty regarding timely availability of essential inputs, and so on. Kosarek, Garcia, and Morris (2001) argue that farmers may be unwilling to invest in a high yielding variety if they are uncertain that the new variety will outperform their current variety. Further, if farmers fear that the potential benefits of the new variety might not be realized because of the uncontrollable factors such as adverse weather, they also do not invest in the new variety even if they are sure that the yields of the new variety are higher.

Access to extension services, association membership, and access to price information are the variables employed in this study to measure the extent to which farm households surveyed are exposed to information. Empirical evidences by Nkamleu and Adesina (2000), and Asfaw and Admassie (2004) among others suggest that these variables should be positively correlated to the adoption of improved agricultural inputs. Only in the south, association membership and access to price information are significantly associated with the decision to adopt improved maize seed. Association membership is negatively correlated to adoption decision, while price information is positively. This result is due to the fact that the agro ecological condition are unsuitable for maize production in the south and farmers belonging to agricultural associations are devoted to the production of other crops such as vegetables, rice, and cassava.

Surprisingly, findings on the access-to-extension variable reveal that the effect of this variable on the likelihood that households will adopt improved maize seed is negative and statistically significant. This finding is inconsistent with the hypothesis that extension services should emphasize on educating farmers about the potential benefits of improved technologies; however, similar results have been revealed in empirical studies of agricultural productivity in developing countries. In developing countries, poor performance of extension services in agriculture is due to bureaucratic inefficiency, deficient program design, and publicly operated information delivery systems. However, in the case of Mozambique, it is important to point out that Sasakawa-Global 2000 (SG 2000) program helped increase the awareness of improved maize technologies by establishing demonstration plots, providing

improved maize seed and fertilizer on credit at low rates of interest, and giving extension assistance to farmers somehow involved in the SG 2000 program.

With respect to the incidence of drought and flood in the last two years, these variables were not found to have a statistically significant influence on the adoption of improved maize seed at national level. Yet, incidence of droughts and floods has a significant impact on the likelihood of adopting improved maize seed in the north and central. In the North, farmers affected by floods are less likely to adopt improved maize seed, while ones affected by droughts are more likely. By contrast, in the central, incidence of floods increases the likelihood of adopting improved seed. Because adoption of improved varieties is affected by agro-ecological conditions that are local specific, location of the farm is another factor related to risk. It is expected that the probability of adopting improved maize seed differs across macro agro-ecological zones due to the wide diversity of the climate and ecology within macro agro-ecological zones[4]. To capture the impact of macro agro-ecological zones on adoption, two location variables were used.

Farm households located in the northern and central macro agro-ecological zone are 22.8 and 15.0 percent respectively less likely to adopt improved maize seed than ones located in the southern. This result is interesting because the variable with the largest impact on the likelihood of adopting improved maize seed is whether or not the farm household is located in the northern macro agro-ecological zone. A possible explanation to this result is that the location variable can be understood as an interaction amongst agro-ecological conditions, infrastructure, and agricultural policies.

Indeed, the results of the study by Mucavele (2000) reveal a comparative advantage of producing maize in the northern and central macro agro-ecological zone. Also, this study shows that the maize policy may have introduced some distortions which are subsidizing the maize production in the southern and taxing it in the northern and central macro agro-ecological zones. In addition, the southern macro agro-ecological zone is generally characterized by better infrastructure conditions compared to the northern and central macro agro-ecological zones.

Availability of complementary inputs such as fertilizer, pesticide, and water is an essential factor taken into consideration when smallholder farmers make decision to adopt high yielding seed varieties. According to Feder, Just, and Zilberman (1985), it is obvious that high yielding seed varieties will not be adopted by most smallholder farmers if both seed

---

[4] For details on the description of each macro agro-ecological zone, see Mucavele (2000)

and fertilizers are not available. Also, it is generally known that the achievement of the potential benefits of high yielding seed is conditioned for the application of some fertilizers or pesticides. As expected, use of fertilizer, pesticide, and irrigation had a significantly positive impact on the adoption of improved maize seed. Similarly, surveyed farm households having access to seed stores are more likely to adopt improved maize seed. Although access to seed stores is not statistically significant in the north and south, the sign of this variable is consistent across all regions.

Furthermore, the results summarized in table 4 also show that farm households farming traditional cash crop (cotton and tobacco) are less likely to adopt improved maize seed. This finding is probably because these farm households are committed to the production of traditional cash crop and do not focus on the production of food crops as maize due to the fact that they are normally located in concessionary areas where the main goal of the concessionaires is to grow either cotton or tobacco. Moreover, the farm households growing traditional cash crop have to sell the production of cash crop to the concessionaires and reimburse the concessionaires for the agricultural inputs they received as credit at the planting time. Farming of traditional cash crops does not have a significant impact on the adoption of improved maize seed in the south because these crops are not main crops in this region due to inapt agro ecological conditions and very few farmers grow these crops in the south. Only 0.4 and 1.3 percent of the farmers located in the south grow cotton and tobacco respectively.

Another key factor in explaining adoption decisions is infrastructure. Infrastructure is to some extent related to marketing costs and influences both demand and supply of seed in particular and of agricultural inputs in general. Three explanatory variables were employed as indicators of access to infrastructure: access to paved road, market, and electricity. Another infrastructure variable used in this study is distance to county seat. Only one of the infrastructure variables (access to electricity) was found to be positively and statistically associated with the decision to adopt improved maize seed. A change of 12.7 percent in the probability that a farm household adopts improved maize seed is due to access to electricity. It is important to point out that as expected, access to market significantly increases the probability of adopting improved maize seed in the south. This variable increases the likelihood of adopting improved seed in the south by 9 percentage points.

IMPLICATIONS FOR PUBLIC POLICY AND PRIVATE STRATEGIES

New agricultural technologies have the potential to increase productivity. However, increases in productivity due to technological innovation could not be achieved if new technologies are not combined with appropriate and complementary enhancements in agricultural institutions and human capital. Also, it is largely recognized that agricultural output growth is not only influenced by technology enhancements but also by the efficiency with which available technologies are utilized. This study analyzes the maize seed industry in Mozambique by investigating the determinants of the adoption decision of improved maize seed.

Empirical evidence suggests that adoption of improved maize seed is jointly determined by demand-side and supply-side factors. Among other factors, profitability of the technology, availability of seed, and risk consideration influence farmers' decision to adopt improved seed. On the other hand, supply of seed is affected by economic factors such as recovery of production and distribution costs, cost of research; industry structure; and institutional arrangements that govern the behavior of seed companies. It is clear that if the diffusion of improved technologies is to be accelerated, policy makers should ensure an environment in which it is profitable not only for seed companies to produce and sell high-yielding varieties but also for farmers to adopt these varieties.

The results of this study indicate that household size; years of formal schooling; off-farm employment; use of fertilizer, pesticide, and irrigation; and access to electricity and seed stores are positively associated with the decision of adopting improved maize seed. Age of the head of household; geographic location (central and northern macro agro-ecological zones); access to extension services and credit; and farming of traditional cash crops (cotton and tobacco) were found to have a negative and significant influence on the decision to adopt improved maize seed.

An interesting empirical result is that the factor with the largest impact on the likelihood of adopting improved maize seed is whether or not the farm household is located in the northern macro agro-ecological zone. Household maize producers located in this macro agro-ecological zone are 23 percent less likely to adopt improved maize seed than ones located in the southern macro-ecological zone. To increase the likelihood of adopting improved maize seed by smallholder farmers in Mozambique, the results of this study suggest that policy makers should put much emphasis on improving rural infrastructures and providing better education.

On the supply side, to foster the emergence of a flourishing seed industry, policy makers should promote the development and growth of the private sector, give incentives for the continuing role of the public sector in research activities, provide better marketing infrastructures to enhance the efficiency of the seed marketing channels, and promote commercialization of the maize sector. Taking into account factors that influence adoption of improved seed, seed companies in Mozambique should develop dynamic marketing plans to improve the farmers' satisfaction and awareness of the benefits of high-yielding seed varieties.

References

Adesina, Akinwumi A.;David Mbila;Guy Blaise Nkamleu; et al. 2000. Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon. *Agriculture, Ecosystems and Environment* 80 (3):255-65.

Asfaw, Abay and Assefa Admassie. 2004. The role of education on the adoption of chemical fertiliser under different socioeconomic environments in Ethiopia. *Agricultural Economics* 30 (3):215-28.

Doss, Cheryl R. 2003. Understanding Farm Level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa. CIMMYT Economics Working Paper 03-07, Mexico, D.F.: CIMMYT.

Feder, Gershon;Richard E. Just; and David Zilberman. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development & Cultural Change* 33 (2):255-98.

Godoy, Ricardo;Jeffrey R Franks; and Mario Alvarado Claudio. 1998. Adoption of modern agricultural technologies by lowland indigenous groups in Bolivia: the role of households, villages, ethnicity, and markets. *Human Ecology* 26 (3):351-69.

Greene, William H. 2003. *Econometrics Analysis*. Fifth ed. Upper Saddle River, New Jersey: Prentice Hall.

Haggblade, Steven;Peter Hazell;Ingrid Kristen; et al. 2004. African agriculture: past performance, future imperatives. In *Building on successes in African agriculture* Focus 12, edited by International Food Policy Research Institute (IFPRI) 2020 vision. Washington, DC: IFPRI 2020 vision.

Hintze, L. H.;M. Renkow; and G. Sain. 2003. Variety characteristics and maize adoption in Honduras. *Agricultural Economics* 29 (3):307-17.

Howard, Julie;Jan Low;Jose Jaime Jeje; et al. 2001. Constraints and Strategies for the Development of the Seed System in Mozambique. Research paper series 43E, Maputo, Mozambique: Ministry of Agriculture and Rural Development, Directorate of Economics.

Kosarek, Jennifer L.;Philip Garcia; and Michael L. Morris. 2001. Factors explaining the diffusion of hybrid maize in Latin America and the Caribbean region. *Agricultural Economics* 26 (3):267-80.

LIMDEP 8.0. Econometric Software. 15 Gloria Place, Plainview, New York.

Moser, Christine M and Christopher B Barrett. 2003. The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar. Working Paper 2003-20, Ithaca, New York: Department of Applied Economics and Management, Cornell University.

Mucavele, Firmino Gabriel 2000. Analysis of comparative advantage and agricultural trade in Mozambique. Technical Paper 107, Maputo, Mozambique: USAID.

Nkamleu, Guy Blaise and Akinwumi A. Adesina. 2000. Determinants of chemical input use in peri-urban lowland systems: bivariate probit analysis in Cameroon. *Agricultural Systems* 63 (2):111-21.

Payne, James;Jorge Fernandez-Cornejo; and Stan Daberkow. 2003. Factors Affecting the Likelihood of Corn Rootworm Bt Seed Adoption. *AgBioForum* 6 (1&2):79-86.

Weir, Sharada and John Knight. 2000. Adoption and diffusion of agricultural innovations in Ethiopia: the role of education. Working paper series 05, Oxford: Center for the Study of African Economies.

Zavale, Helder. 2005. Analysis of the Mozambique's Maize Seed Industry: Factors Influencing the Adoption Rates of Improved Seed and Determinants of Smallholders' Cost Efficiency. Masters thesis, Department of Applied Economics and Management, Cornell University, Ithaca.

Appendix

Appendix A. Coefficient estimates for the adoption model estimated by maximum likelihood (Logit)

	Expected sign	North Coefficient			Central Coefficient			South Coefficient			All sample Coefficient		
Constant		-0.518			-1.951			0.160			0.391		
Distance	-	-0.014	***	-(0.002)	0.006	*	(0.001)	-0.002			-0.003		
Household size	+	0.089	***	(0.015)	0.014			0.018			0.032	***	(0.007)
Gender	+/-	-0.020			0.083			-0.021			-0.003		
Age of household head	+	-0.038			-0.038			-0.010			-0.024	*	-(0.005)
Age squared	-	0.000			0.000			0.000			0.000		
Years of schooling	+	0.021			0.020			0.023			0.019	**	(0.004)
Off-farm employment	+	0.342	***	(0.059)	0.031			0.507	***	(0.126)	0.268	***	(0.057)
Extension service	+	-0.133			-0.097			-0.387			-0.222	**	-(0.045)
Association	+	0.156			0.537			-0.559	**	-(0.132)	-0.066		
Price information	+	-0.151			0.011			0.490	**	(0.122)	-0.036		
Use of fertilizer	+	0.677	***	(0.130)	-0.272			0.136			0.409	**	(0.091)
Use of pesticide	+	0.659	**	(0.126)	1.105	***	(0.259)	-0.147			0.305	*	(0.067)
Use of irrigation	+	0.504	**	(0.093)	0.399	**	(0.087)	0.125			0.228	**	(0.049)
Use of animal traction	+	-0.023			-0.562	***	-(0.106)	0.308	**	(0.076)	0.023		
Electricity access	+	0.861	***	(0.173)	0.000			0.446	**	(0.111)	0.553	***	(0.125)
Credit access	+	-0.526	***	-(0.077)	-0.610	*	-(0.110)	-0.230			-0.444	***	-(0.086)
Market access	+	-0.162			-0.060			0.351	**	(0.087)	-0.050		
Seed store access	+	0.130			0.374	**	(0.080)	0.112			0.176	*	(0.038)
Paved road access	+	-0.016			0.019			-0.028			-0.004		
Cotton farming	-	-0.648	**	-(0.091)	-0.689	**	-(0.123)	-30.510			-0.346	*	-(0.068)
Tobacco farming	-	-0.842	***	-(0.112)	-0.275			-0.798			-0.493	**	-(0.093)
Drought last 2 years	+/-	0.366	**	(0.057)	0.795						0.239		
Flood last 2 years	+/-	-0.253	**	-(0.042)	1.014	**	(0.166)				-0.145		
North	-										-1.117	***	-(0.225)
Central	-										-0.751	***	-(0.147)
Log likelihood		-800.00			-644.44			-589.47			-2086.14		
Chi squared		99.56	***		58.38	***		81.94	***		301.79	***	
Observations		1,592			1,100			911			3,603		

* Statistically significant at the 10% level; ** Statistically significant at the 5% level; and *** Statistically significant at the 1% level
Marginal effects for significant variables in parentheses

APPENDIX B: Correlation matrix of the variables employed in the adoption model

	DISTANCE	HHSIZE	SEX	AGE	AGE1	EDUC	JOB	NORTH	CENTRAL	EXTENS	ASSOC	INFO	FERTIL	PESTIC
DISTANCE	1.000													
HHSIZE	0.010	1.000												
SEX	0.065	0.213	1.000											
AGE	-0.063	0.141	-0.045	1.000										
AGE1	-0.059	0.108	-0.042	0.983	1.000									
EDUC0	-0.023	0.104	0.213	-0.090	-0.084	1.000								
JOB	0.018	0.004	0.183	-0.171	-0.171	0.063	1.000							
NORTH	0.064	-0.199	0.026	-0.204	-0.197	-0.074	-0.005	1.000						
CENTRAL	0.189	0.112	0.055	-0.011	-0.011	0.013	0.039	-0.590	1.000					
EXTENS	-0.022	0.062	0.078	0.014	0.012	0.050	-0.004	0.025	0.034	1.000				
ASSOCIAT	-0.069	0.077	0.013	0.047	0.045	0.052	0.007	-0.025	-0.042	0.175	1.000			
INFO	0.011	0.016	0.119	-0.120	-0.122	0.041	0.076	0.160	0.059	0.186	0.043	1.000		
FERTIL	-0.058	0.036	0.060	-0.018	-0.022	0.032	0.003	0.093	-0.094	0.187	0.129	0.052	1.000	
PESTIC	-0.015	0.078	0.080	0.008	0.003	0.050	-0.004	0.047	-0.050	0.155	0.114	0.118	0.335	1.000
IRRIGAT	-0.101	0.100	-0.002	0.060	0.054	0.075	0.009	-0.158	-0.027	0.093	0.106	-0.017	0.262	0.161
TRACTION	-0.076	0.172	0.039	0.162	0.159	0.065	-0.016	-0.272	-0.058	0.051	0.086	-0.133	0.115	0.045
ELECTRIC	-0.115	0.050	-0.020	0.047	0.038	0.128	-0.009	-0.121	-0.074	0.060	0.110	0.017	0.086	0.069
CREDIT	-0.119	0.018	-0.012	0.044	0.039	0.044	-0.061	-0.015	-0.106	0.117	0.125	-0.005	0.112	0.121
MARKET	-0.015	0.009	-0.025	-0.015	-0.014	0.075	-0.033	0.038	-0.143	0.030	0.057	0.030	-0.006	0.007
SEEDSHOP	-0.072	0.024	0.001	-0.003	-0.003	0.023	-0.010	-0.084	0.116	0.047	0.039	0.016	-0.010	0.023
ROAD	-0.092	0.028	-0.041	0.026	0.023	0.071	-0.009	-0.107	0.016	0.026	0.063	0.020	0.027	0.007
COTTON	0.084	0.027	0.088	-0.024	-0.023	-0.015	-0.001	0.102	0.028	0.103	0.022	0.151	0.066	0.521
TOBACCO	-0.039	0.010	0.049	-0.007	-0.010	0.014	0.026	0.101	-0.020	0.092	0.030	0.029	0.309	0.080
DROUGHT	0.144	0.047	0.051	0.085	0.081	0.039	0.056	-0.351	0.192	-0.025	0.014	-0.068	-0.038	-0.037
FLOOD	0.088	0.101	0.021	0.126	0.117	0.022	0.057	-0.526	0.267	-0.027	0.018	-0.176	-0.158	-0.051

Appendix B (continued)

	IRRIGAT	TRACTION	ELECTRIC	CREDIT	MARKET	SEEDSHOP	ROAD	COTTON	TOBACCO	DROUGHT	FLOOD
IRRIGAT	1.000										
TRACTION	0.236	1.000									
ELECTRIC	0.090	0.019	1.000								
CREDIT	0.097	0.111	0.138	1.000							
MARKET	-0.034	-0.079	0.401	0.082	1.000						
SEEDSHOP	0.041	-0.034	0.105	0.063	0.081	1.000					
ROAD	0.030	-0.011	0.201	0.036	0.172	-0.013	1.000				
COTTON	-0.032	-0.075	-0.063	0.048	-0.035	-0.010	-0.083	1.000			
TOBACCO	0.074	0.009	-0.052	0.061	-0.044	-0.055	-0.069	0.008	1.000		
DROUGHT	0.061	0.170	0.007	0.056	0.014	-0.044	-0.032	-0.036	-0.070	1.000	
FLOOD	0.041	0.162	0.062	-0.046	-0.033	-0.037	-0.027	-0.055	-0.148	0.442	1.000

OTHER A.E.M. STAFF PAPERS

SP No	Title	Fee (if applicable)	Author(s)
2005-02	Farm Savings Accounts: Examining Income Variability, Eligibilitiy, and Benefits		Gloy, B., LaDue, E. and C. Cuykendall
2005-01	Market Opportunities for New Sauerkraut Products		Cuellar, S. and W. Uva
2004-01	Medicaid, County Property Levies, and Property Tax Levies on New York Farmland		Bills, N.
2003-04	A Brief Overview of Mozambique's Rural Development and the Role of US Assistance		Kyle, S.
2003-03	Political and Economic Prospects for Mozambique and Angola		Kyle, S.
2003-02	We're Rich!! Or Are We? Oil and Development in Sao Tome e Principe		Kyle, Steve
2003-01	Marketing New York Wine in New York City		Presler, T.
2002-04	Impacts of Trade Liberalization on the New York Horticultural Sector		G. B. White, N. L. Bills, and I. Schluep
2002-03	Insights Into the Economic Viability of a New CEA System Producing Hydroponic Lettuce		Ilaslan, G., G.B. White, and R.W. Langhans
2002-02	Health Care and Genesee County, New York: Economic Implications of Reduced Hospital Services		Bills, N. and D. Kay
2002-01	Questions Cooperative Directors Should Be Asking Management		Anderson, B. and B. Henehan