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Full Length Research Paper

Adoption and continued use of improved maize seeds: Case study of Central Ethiopia

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The literature on agricultural technology is limited on the issue of the continued use of an agricultural technology after it is adopted. This paper analyzes the factors that explain adoption as well as continued use of improved maize seeds in one of the high potential maize growing areas in central Ethiopia. Using a bivariate probit with sample selection model approach, the study provides insights into the key factors associated with adoption of improved maize seed and its continued use. The result revealed that human capital (adult workers, off-farm work and experience in hiring labor), asset endowment (size of land owned), institutional and policy variables (access to credit, membership in cooperatives) all strongly influence farmers' decisions to adopt improved maize varieties, while continuous use of the seed is influenced by the proportion of farmland allocated to maize, literacy of the household head, involvement in off-farm work, visits by extension agents, farmers' experience, household land size, and fertilizer usage. Accordingly, policies and interventions that are informed about such factors are required to accelerate adoption and continued use of improved maize seeds in order to increase farm yields and remedy shortage of food and fight food poverty and insecurity more effectively and more sustainably.

Key words: Adoption, continued use, improved maize seeds, Ethiopia.

INTRODUCTION

One effective way to increase agricultural productivity is through wider adoption of new farming technologies (Minten and Barrett, 2008). The substantial improvement in productivity of cereal crops in Ethiopia in the mid 1990's, following extensive promotion of improved agricultural technologies by Sasakawa Global 2000 (SG2000)[1], verifies this hypothesis. In the Bako area of central Ethiopia, the average productivity of maize increased from 1.6 tons/ha in 1993 to more than 5.4 tons/ha in 1996 mainly by means of higher adoption of improved seed and fertilizer (SG2000, 2002; Takele, 2002). However, in recent years, maize productivity has either remained constant or has shown a declining trend. Productivity of maize, declined by about 14% in 2007 (from 2.8 tons/ha in 2006 to 2.4 tons/ha in 2007), after stagnating over the previous three consecutive years. This decline in maize productivity is partly explained by farmers' disadoption of new agricultural technologies. In Bako area, for example, the use of improved seed declined from 74.3 tons in 2006 to 63.9 tons in 2007, amounting to a 14% fall in seed use (DOARD, 2008).

The adoption of new technologies, such as fertilizer, improved seed, etc. is central to agricultural growth and poverty reduction efforts. For instance, a study in Mexico showed that adoption of improved maize varieties

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[1] An international NGO working since almost two decades in Africa to promote agricultural growth and food security through demonstration and promotion of packages of agricultural technologies.

improves household welfare (Becerril and Abdulai, 2010). Similarly, in sub-Saharan Africa, adoption of improved maize was indicated to have positive outcomes (Alene et al., 2009). However, very low adoption of productivity enhancing technologies has dwarfed efforts to reduce rural poverty (World Bank, 2008).

Studies on agricultural technologies have been mainly concerned with factors influencing adoption of new technologies (Feder et al., 1985; Sunding and Zilberman, 2001). Only few have investigated reasons why farmers discontinue using technologies (Carletto et al., 1999; Neill and Lee, 2001; Oladele, 2005; Aklilu and Graaf, 2007; An, 2008). These studies show that ownership of farm assets, institutional factors and market conditions can explain the decision to continue or not to continue using agricultural technologies.

Adoption of improved technologies will neither improve food security nor reduce poverty if barriers to their continued use are not overcomed (Oladele, 2005). Rogers (2003) reported two types of reasons for discontinuing a technology use on the part of farmers; that is, replacement discontinuance, where farmers discontinue using the existing technology in order to adopt a superior one, and disenchantment discontinuance, where a decision to discontinue a technology, with or without replacement, is due to dissatisfaction with its performance.

Discontinuation of use of improved agricultural technology is evident within Ethiopia. Tenkir et al. (2004) indicated that about 40% of farmers who tried new inputs discontinued using them. The authors reported the adoption rates to be 92.4% for maize seeds and 86% for chemical fertilizers. With regard to adoption of improved maize seeds, several studies in Ethiopia (NEGASAI, 1997; Degu, 2000; Feleke, 2006) showed that extension service, access to credit and market, respectively are the main factors influencing the adoption of improved maize seed. Feleke (2006) also emphasized that access to credit is a powerful policy option in raising the probability of the adoption of improved maize seeds.

Furthermore, Alemu et al. (2008) investigated performance of maize seed system in three drought prone districts of the Rift valley in Ethiopia and found that there is a limited dissemination of improved varieties to farmers in spite of extensive variety development by the public sector. However, these studies did not account for farmers who adopt improved seed at one season and discontinue it afterwards. This paper attempts to explain why farmers adopt (or not adopt) and keep using (or stop using) improved maize seed technology, based on the case of the Bako area of central Ethiopia. Insights generated by this study are expected to help in better informing appropriate policy instruments to sustain the adoption of agricultural technologies in Ethiopia. It contributes to the literature on adoption and diffusion by focusing on the issues and conditions for continued use of a technology.

The paper is structured as follows. First is description of of the study area. The second part describes in detail the data used in the study, the theoretical and empirical frameworks, and the variables and hypotheses. Next is presentation of the results and discussion and finally conclusions and implications.

THE STUDY AREA

The study was conducted in Bako district, located about 250 km west of the capital - Addis Ababa, in the central part of Ethiopia. The district has mean annual temperature of 20.4°C and mean annual rainfall of 1217 mm, the main rainy season is from May to September and elevation ranging from 1500 to 2000 m above mean sea level. Although there are crops like sorghum, tef[2] (*Eragrostis abyssinica*), noug (*Guizotia abyssinica*) and pepper, the Bako area is mainly known for maize production. Based on the Ethiopian agricultural enumeration survey, in Bako, the maize cultivated area accounts for about 50% of the total cropped area (which was 22640 ha) and 60% of the land under cereal crops (CSA, 2003). Farmers in the area produce maize for home consumption and for selling. Improved maize cultivars have been introduced in the district by Bako Agricultural Research Center (BARC) and SG2000.

METHODOLOGY

Data

The main source of data for this study is a survey conducted on a sample of farmers in Bako area in April 2008. Secondary data on yield, use of improved seed and the institutional environment are obtained from agricultural development offices and the BARC. A two-stage sampling technique is used to select the sample. At the first stage, a total of 15 kebeles[3] out of 28 are purposively selected. At the second stage, sample households are selected using systematic random sampling. A sample of 120 households is drawn from the 15 kebeles in proportion to the population size in each kebele. This sample size is within orders of sample sizes in similar studies conducted in the area and elsewhere (Negatu and Parikh, 1999).

Analytical considerations

According to Doss (2006), an adopter is a farmer who has adopted a component or more of a technology and continued using it, whereas non-adopters are those who have never tried a technology. Defining adoption in this way assumes that once households adopt a technology, they will keep using it. It is, however, apparent that farmers might try a technology and decide to (or not to) continue using it. Therefore, in this study we define adopters as farming households that have used improved maize seed at least once over recent years. An adopter is a continuous user only if he or she uses improved maize seed every season since the time he or she first adopted the improved seed.

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[2] Tef is an endemic crop to Ethiopia and is the most important staple food in the country.

[3] Kebele is the smallest administration unit in Ethiopia.

The adoption of a technology and its continued use are outcomes of interdependent decisions. The decision to adopt improved maize seed can be influenced by, among others, total land size, access to credit, extension, among others. Since adoption occurs before continuation or discontinuation of a technology, variables that are stable overtime are the ones assumed to affect technology adoption (Neill and Lee, 2001). The hypotheses are that continued use of improved maize is influenced by area allocated to maize, access to extension on complementary technologies and credit. The decisions on adoption and on whether to continue using a technology or not, is complex and involves factors that are normally beyond the control of farmers, such as policy, institutional factors, environmental factors as well as the household endowments, the type of farm business, and the technology itself.

Moreover, some of the factors that influence the continued use of technology are linked to the experience in using it; the more the farmers know a technology, the more they keep using it. These phenomena generate modeling problems related to self selection and endogeneity (Doss, 2006). The decisions of adopting and continuing the use of improved maize seeds are relevant to those farmers who adopted it in the first place. The two decisions, adoption and continued use, can be specified independently of each other using probit or logit models[4]. However, such a specification would provide inefficient estimates of the parameters of adoption and continuation models since it ignores the potential correlation between the unobservables (captured by the error terms) of the two decisions. This is because the decision to use technology continuously is contingent on the decision to adopt. Such modeling can be accomplished by a bivariate probit with sample selection (Neill and Lee, 2001; Wooldridge, 2002; Greene, 2008). The model employed in this case is similar to the Heckman's selection model except that the probit model appears in both the selection decision (technology adoption) and the outcome decision (technology continuation).

Adoption of improved maize seeds occurs if the expected net marginal benefit of adoption exceeds zero (Saha et al., 1994). Moreover, a household decides to continue using improved maize seeds in a particular year only if the use of the technology can generate a net gain (Carletto et al., 1999). However, since the gain could also be in utility terms it might not be observable. What is observed is the choice to adopt or not to adopt a technology and, conditional on adoption, the choice to continue using it or to discontinue it.

Bivariate probit model of technology adoption and continuation

The unobservable, perceived utility 'y_j^*' from adoption depends on a vector of explanatory variables 'x' so that the binary outcome $y_j = 1$ arises when the latent variable $y_j^* > 0$. In this case, we observe y_2 (continuation of technology use) if and only if y_1 (adoption) = 1. The outcome of the decision represented by the first probit equation is fully observed but we have a censored sample in the second equation representing continued use of the technology, because only a subset of original farmers are involved. This censoring of observations implies the importance of taking into account self selection at the adoption decision making stage to ensure proper estimation of model parameters. The standard bivariate probit model with additive errors, can be specified as

$$y_1^* = x_1'\beta_1 + \varepsilon_1, \quad y_1 = 1 \ if \ y_1^* > 0, 0 \ \text{otherwise}, \tag{1}$$

$$y_2^* = x_2'\beta_2 + \varepsilon_2, \quad y_2 = 1 \ if \ y_2^* > 0 \ \text{and} \ if \ y_1^* > 0, 0 \ \text{otherwise}, \tag{2}$$

where x and β are vectors of explanatory variables and coefficients to be estimated, respectively. Estimation by maximum likelihood is straightforward given the additional assumption that the correlated errors are jointly normally distributed and homoskedastic (Cameron and Trivedi, 2005), with the following further assumptions

$$E[\varepsilon_1 \mid x_1, x_2] = E[\varepsilon_2 \mid x_1, x_2] = 0 \tag{3}$$

$$\text{Var}[\varepsilon_1 \mid x_1, x_2] = \text{Var}[\varepsilon_2 \mid x_1, x_2] = 1 \tag{4}$$

$$\text{Cov}[\varepsilon_1, \varepsilon_2 \mid x_1, x_2] = \rho. \tag{5}$$

Accordingly, three types of observations and associated probabilities can be specified:

$$y_1 = 0: \quad prob(y_1 = 0) = \Phi(-x_1\beta_1), \tag{6}$$

$$y_1 = 1, y_2 = 0: prob(y_1 = 1, y_2 = 0) = \Phi(x_1\beta_1) - \Phi_2(x_1\beta_1, x_2\beta_2, \rho), \tag{7}$$

$$y_1 = 1, y_2 = 1: prob(y_1 = 1, y_2 = 1) = \Phi_2(x_1\beta_1, x_2\beta_2, \rho), \tag{8}$$

where Φ is the univariate normal distribution, and Φ_2 is the bivariate normal distribution. The log-likelihood function to be maximized is based on these probabilities and can be specified as:

$$\ln L = \sum_i^N \{y_{i1}y_{i2} \ln \Phi_2(x_1\beta_1, x_2\beta_2; \rho) + y_{i1}(1 - y_{i2})\ln[\Phi(x_1\beta_1) - \Phi_2(x_1\beta_1, x_2\beta_2; \rho)] + (1 - y_{i1})\ln\Phi(-x_1\beta_1)\}, \quad i = \text{number of observations}. \tag{9}$$

The model parameters are estimated by maximizing this log likelihood function with respect to the yet unknown parameters.

Variables and further discussion

An overlapping set of variables related to household, farm and institutional characteristics are used to specify the estimated models. Adult equivalent[5], total land size owned, number of plots owned and access to formal credit sources appear only in the adoption decision model. Similarly, the number of male and female family members, proportion of land allocated to maize cultivation, access to irrigation facilities from own plots, indebtedness to formal credit sources, practice of saving, number of visits by development agents, awareness of all other components of the maize technology package, and continuous use of fertilizer appear only in the continued use model.

The variables that appear in both models are literacy of household head, soil fertility, plot ownership, size of land owned, and livestock wealth in tropical livestock units (TLU)[6], involvement

[4] These are among the most widely used members of generalized linear models in the case of binary dependent variables.

[5] The conversion factors used are adapted from Storck et al. (1999).

[6] The conversion factors used are adapted from Jahnke et al. (1982).

Table 1. Continuous descriptors of sample households.

Variable	Adopter						Non-Adopter	
	Continued use		Discontinue		All adopter			
	Mean	Standard deviation	Mean	Mean	Mean	Standard deviation	Mean	Standard deviation
Male family members	4.04	1.76	2.70	1.27	3.55	1.72	2.00	1.32
Female family members	3.61	1.71	3.39	2.00	3.53	1.82	1.89	1.36
Adult equivalent	6.07	2.14	4.82	2.08	5.60	2.20	3.19	1.52
Total livestock units	5.27	4.20	2.91	2.60	4.39	3.85	1.59	2.26
Total land owned (ha)	4.83	2.95	2.87	1.86	4.10	2.76	1.85	1.42
Proportion of farmland allocated to maize	1.35	2,15	0.56	0.64	0.26	0.36	1.05	1.78
Number of plots owned	3.00	1.59	2.59	1.45	2.85	1.55	2.44	1.94
Number of visits by the Development agents	4.16	8.17	1.10	2.19	3.02	6.76	-	-
Distance from office of development agent (h)	0.37	0.42	0.66	0.74	0.48	0.57	0.50	0.54
Distance from nearest town market (h)	0.55	0.46	0.70	0.66	0.61	0.54	0.70	0.66
Total no.	70		41		111		9	

of the household head in off-farm activities, involvement of another family member, experience in hiring farm labor, distance from development agents' office, distance from the nearest town market, and membership in a primary cooperative.

Human capital endowments, usually captured by family size and composition and education are the main factors influencing the technology adoption and continued use decisions of households. Family size and composition influence such decisions from both labor supply and consumption demand sides. Availability of labor within the household, as measured in number of adult household members, is taken into account.

The human capital assets (education, skills, and training) of the household head affect the profitability of modern technology, as they reflect unobservable productive characteristics of the decision maker, such as farming skills and entrepreneurship (Carletto et al., 1999). Education increases the ability of farmers to obtain, process, and use information relevant to the technology leading to greater use of new technologies (Wozniak, 1997). However, the literature on the relationship between education and adoption is not definitive, for example Weir and Knight (2000) show that education is associated more with timing of adoption rather than with adoption itself.

Access to farm assets such as land, or livestock, is expected to enhance continued use of modern technologies. Sain and Martinez (1999) argued that the larger the farm size the less binding is the financial and land constraints faced by a farmer. Ownership of livestock promotes adoption and continued use of improved maize seed since it generates income to finance the inputs associated with the technology and reduces the risks that may arise from crop failure (Nega and Sanders, 2006). Inadequate infrastructure; that is, roads and lack of seed, is another external factor affecting technology adoption and continued use. Households living near major towns have good access to both physical infrastructure and seed supplies, and can purchase seed from the market, hence are expected to continue using adopted technologies.

Institutional factors and policy variables that include the extent of competitiveness of credit and labor markets, access to extension, and access to land make up the other set of determinants of adoption and continued use. Extension provides farmers with information on availability and properties of the new technology and technical skills for using it (Wozniak, 1997). Improved seed varieties are unaffordable to poor peasants since they require using complementary inputs like fertilizer whose price is rising from time to time. Access to credit, by helping farmers to finance the acquisition of improved seed and fertilizer could enhance adoption and continued use of an agricultural technology.

The effect of access to sufficient land is expected to be positive on both technology adoption and continuation. Farmers who do not own sufficient land may not be able to capture the full returns from investments in new technology, and thus, will be less willing to use new technology. This is either because they must share the increased product with a land leaser or as they might not have the minimal land size for economically competitive maize production.

RESULTS AND DISCUSSION

Descriptive statistics

The data show that only 7.5% of the sample households have never grown improved maize varieties. About 63% of the sample households have been using the improved seeds since they first adopted them, whereas the remaining 37% have disadopted the improved seeds. Accordingly, adoption rate of maize seed in the study area is more than 92% while discontinuance is about 37% (Table 1).

Those households which discontinued using the improved seeds were asked to state the reasons why they could not continue using the improved maize seed. Most farmers (61.5%) identified high price of seed and fertilizer as reasons for discontinuance, mainly due to lack of financial resources. Since prices of seed and fertilizer are the major components of cost of production, a rise in input cost may render farm activities unprofitable; this is in line with the disenchantment theory of disadoption (Rogers, 2003). Another major factor that farmers mentioned as a constraint is lack of credit. Partly because of defaulting problems, farmers have found it increasingly difficult to get credit from official sources.

Farmers obtain improved seed from different sources.

Table 2. Discrete descriptors of sample households.

Variables	Levels	Frequency			
		Adopters			Non-adopters
		Continue user	Discontinue user	Total	
Main plot fertility	Very fertile	5	4	9	2
	Fertile	32	10	42	2
	Infertile	33	27	60	5
Literacy of the household head	Literate	50	20	70	6
	Illiterate	20	21	41	3
Has irrigation on own plots	Yes	26	3	29	2
	No	44	38	82	7
Received credit from formal sources	Yes	19	12	31	0
	No	51	29	80	9
Indebted to lenders	Yes	24	19	43	1
	No	46	22	68	8
Saves money	Yes	20	11	31	0
	No	50	30	80	9
Off farm activities - head	Yes	22	10	32	4
	No	48	31	79	5
Off farm activities - family member	Yes	17	8	25	2
	No	53	33	86	7
Aware of all technology components	Yes	59	30	89	3
	No	11	11	22	6
Experience in hiring labor	Yes	54	15	69	1
	No	16	26	42	8
Member of a cooperative	Yes	65	29	94	3
	No	5	12	17	6
Farm land owned is sufficient	Yes	20	11	31	4
	No	50	30	80	5

Cooperatives are the major sources of improved maize seed. More than 80% of the sampled household reported that they obtain seed from nearby local primary cooperatives. This implies the importance of membership and/or access to the cooperatives. About 81% of sample households are members of cooperatives, while this number rises to 93% for adopters who continue to use improved maize seeds. On the contrary, only 33.3% of non-adopters are members of cooperatives (Table 2). There is also a large informal market for maize seeds since suppliers from the formal sector cannot satisfy the existing demand as the sector is not fully developed. There is also an interesting difference between adopters and non-adopters in terms of their distance to nearest town markets measured in walking hours, as adopters are relatively closer to seed and output markets (0.61 h) as compared to non-adopters (0.70 h) (Table 1).

The summaries in Tables 1 and 2 further show that households that have adopted improved maize seeds are better off in terms of livestock wealth and average land holding as compared to non-adopters. Non-adopters allocate on average a higher proportion of their land to maize as compared to adopters in general but a lower proportion as compared to those adopters who are using the improved seeds continuously. In terms of access to the development agents (the major source of extension services), adopters have better access as it takes less time for them to reach for the development agents (Table 1).

Comparing continuous users with those who discontinue, it is evident that the latter have more female family members (improved varieties traditionally require more male agricultural labor tasks) and are located farther from the development agents and town markets (Table 1). Again, more than half of those who discontinue are illiterate, most of them have never hired farm labor, and a third of them are not members of cooperatives (Table 2).

Estimation results

The bivariate probit with selection model was found to be valid as the likelihood ratio test of independent equations strongly rejects the null hypothesis that the random terms of the adoption and continued use of equations are not correlated. This implies that ignoring the selection into approved status would render the estimates of a univariate probit equation for continued use of improved maize seeds equation biased and inconsistent. The estimation results showed that adult equivalent, total land owned, access to credit from formal sources, involvement of the household head in off-farm activities, experience in hiring farm labor, and cooperative membership positively and significantly influence the decision to adopt improved maize varieties. Only literacy of the household head was found to affect the decision to adopt negatively. At the second stage, proportion of farm area allocated to maize, literacy of the household head, involvement of a family member in an off-farm activity, number of development agents' visits to the household, experience in hiring farm labor, sufficiency of land owned to sustain the household, and continued use of fertilizer are found to be positively and significantly influencing the continued use of improved maize varieties. The only factor that negatively influences the continued use of improved seed is the number of female family members (Table 3), as their role in maize production in Ethiopia is limited, mainly to weeding.

Adoption of improved maize seeds

Adult equivalent was found to be significantly and positively influencing the likelihood of adopting improved maize. This implies that increase in family size positively influences, through increases in the availability of labor, the decision to adopt improved maize varieties. The size of farmland owned by the household is associated with the decision to use improved maize varieties, since land is the scarcest production resource in this part of the country.

Households headed by literates are relatively less likely to adopt improved maize varieties in the study area. This is against the conventional expectation but locally, it can be related to the fact that the relatively more educated household heads are youngsters and that land ownership among the youth is minimal, hence are land constrained. It was similarly reported in Ethiopia that education influences timing of adoption but not whether to adopt an agricultural innovation (Weir and Knight, 2000).

Access to credit from formal sources was found to be positively and significantly influencing the decision to adopt improved maize varieties. This is expected as farming households rarely have sufficient means to buy the improved maize seeds and other associated components, magnifying the importance of cash credits that can be used to purchase the technologies to be adopted. Credit access has mostly been reported to have a similar result in earlier research (see Pattanayak et al., 2003 for a summary). However, access to credit by itself is not enough and should be provided in such ways that clients will be able to repay in time without staying indebted for long, thus ending up abandoning the livelihood improving technologies.

Related to access to cash through credit is the involvement of the household head or other family members in off-farm economic activities. Participation of the household head in off-farm activities increases the likelihood that the household adopts improved maize varieties. Similarly, households with experience in hiring labor are more likely to adopt improved maize varieties than those who have not hired labor. Ouma et al. (2002) reported a positive influence of labor hiring on the adoption of maize seed and fertilizer in Embu, Kenya.

Being a member of a cooperative positively influenced, as expected, the decision to adopt improved maize varieties. This is related to the access to inputs and information that cooperatives create for members, as discussed above.

Continued use of improved maize seeds

A number of female family members were found to be negatively influencing the continued use of improved maize varieties, once they have been adopted. This is apparently related to the labor supply implications of more female family members in the household. Improved maize production obviously requires more labor (that is, for sowing with line planting, more land preparation and application of inputs) than traditional production, which typically involves sowing with broadcasting and less application of inputs.

The proportion of farmland allocated to maize influenced the decision to use improved maize varieties

Table 3. Bivariate probit with selection - estimation results.

Continued use of improved maize (Outcome equation)		
Variable	**Coefficient**	**Robust standard error**
Male family	0.125	0.110
Female family	-0.203^{++}	0.096
Tropical livestock units	-0.043	0.052
Proportion of farmland allocated to maize	0.243^{+}	0.136
Main plot - very fertile (dummy)	0.055	0.599
Main plot – infertile (dummy)	-0.324	0.310
Literate household head (dummy)	0.618^{+++}	0.238
Indebted to lenders (dummy)	-0.215	0.172
Saves money (dummy)	0.196	0.182
Off-farm activity – head (dummy)	0.154	0.212
Off-farm activity – family member (dummy)	0.455^{++}	0.207
Aware of all technology components (dummy)	-0.294	0.283
Number of visits by the development agents	0.034^{++}	0.017
Experience in hiring labour (dummy)	0.613^{+++}	0.175
Distance from nearest town market (hours)	0.185	0.290
Member of a cooperative (dummy)	-0.228	0.279
Land owned - sufficient (dummy)	0.779^{+++}	0.267
Uses fertilizer continuously (dummy)	1.998^{+++}	0.404
Has irrigation on own plots (dummy)	0.329	0.317
Improved maize adoption (selection equation)		
Variable	**Coefficient**	**Robust standard error**
Adult equivalent	0.633^{+++}	0.232
Tropical livestock units	0.258	0.172
Total land owned (ha)	0.401^{++}	0.197
Main plot - very fertile (dummy)	-0.056	0.472
Main plot – infertile (dummy)	-0.043	0.339
Literate household head (dummy)	-1.140^{++}	0.555
Received credit from formal sources (dummy)	1.686^{+}	0.897
Off-farm activity – head (dummy)	1.309^{+}	0.730
Off-farm activity – family member (dummy)	-0.775	0.598
Distance from development agents' office (h)	-0.051	0.563
Experience in hiring labor (dummy)	0.948^{++}	0.415
Distance from nearest town market (h)	0.095	0.703
Member of a cooperative (dummy)	0.662^{++}	0.335
Land owned - sufficient (dummy)	-0.501	0.475
Number of plots owned	-0.194	0.215
/athrho	-14.285	1.254
Rho	-1.000	0.000

Wald test of independent equations ($\rho = 0$): $chi^2(1)$ =129.79 prob > chi^2 = 0.0000
+++, ++, and + significant at 1, 5 and 10% levels of statistical error respectively.

continuously. The relative share of maize shows the importance attached to the crop, hence the decision to continuously produce it. Despite the fact that household heads that are relatively educated are less likely to adopt the improved maize varieties, they were found to be more likely to continue using the variety if they adopt it once.

Engagement of a family member in an off-farm activity also influences positively the decision to use improved maize varieties continuously. This can be associated with the possibility that cash generated from off-farm activities can be used in purchasing required inputs to continue growing improved maize varieties.

Access to extension has been widely reported to positively influence adoption and continued use of agricultural technologies (Feder and Umali, 1993; Knowler and Bradshaw, 2007). Similarly, the frequency of visits by development agents of the bureaus of agriculture was found to be significantly influencing the decision to use improved maize varieties. The development agents have a number of services they render to the community that includes, *inter alia*, advices on crop management, crop pest control, and availability of agricultural inputs. Extension services would inform and build the capacity of farmers, increasing their knowledge and reducing their uncertainty in decision-making.

Experience in labor hiring was also found to be important in positively influencing the decision to continue growing improved maize. Like in the adoption case, access to the labor market encourages the continued use of improved seeds. Households that have enough land to sustain the family were found to be more likely to keep using improved maize. This highlights the importance of land ownership for continued use of agricultural technologies.

Continuous use of fertilizer positively influences the continued use of improved maize. This clearly shows that adopting another component of the improved technology package increases the chance that households use the essential component of the package for long.

Conclusions and policy Implications

In developing countries like Ethiopia, widespread adoption of yield-enhancing agricultural technologies is one way to eradicate poverty and to ensure food security. However, adoption of new technologies is not sufficient to meet this national need. In addition it must be ensured that farmers use the technology in a sustainable manner.

This study represents one step towards understanding the process of post-adoption behavior of farm households implying that technology adoption requires close follow up and monitoring to ensure that households continue using it, and using it appropriately. This paper provides insights into the key factors associated with the adoption and continuous use of improved maize seeds; the results reveal that human capital, asset endowment, and institutional and policy variables all affect the decisions of farmers.

The econometric results demonstrate the importance of family size – both as supplier of labor and as a consumer of maize, involvement of the household head in off-farm activities – as a source of income that can be invested in improved maize technologies, and that of the experience of hiring labor as an indicator of the exposure to the labor market influencing the adoption decisions of households. Size of total farmland owned and membership to cooperatives were also found to be important. The importance of land ownership in Ethiopian agriculture in general and in the study area can not be over-emphasized. Similarly, the empowerment that cooperatives bring for farming households in terms of creating access to market and information is vitally important.

One time trial or use of an agricultural technology can hardly change livelihoods, reinforcing the need that technologies are used on a continuous basis. The proportion of land allocated to maize and the perception that the land owned is sufficient to sustain livelihoods are found to be important factors in determining continuous use of improved maize. Likewise, literacy of the household head, engagement of a family member in off-farm activities, and household's access to the labor market was also important in positively influencing the continuous use of improved maize seeds once adopted.

Using complementary technologies, in this case fertilizer and access to extension services, also increases the likelihood that improved maize seeds are used continuously. Targeted capacity building activities that enable female family members to contribute in the process of producing and marketing maize might possibly play an important role in making maize more of a "women's crop", and thus facilitating the continuous use of improved seeds.

Appropriate strategic interventions that consider such factors are required so that improved maize seeds can be adopted and continuously used to increase farm yields and help fighting food insecurity. The government extension system needs to address the factors which affect the decision to use a technology continuously. However, the extension system in Ethiopia has some limitations for doing so, including a top-bottom approach for disseminating knowledge, capacity limitations, lack of specialists, etc. An effective and efficient extension system can render an innovation sustainable and useful for economically and spatially disadvantaged groups, thus, contributing towards alleviating poverty and reducing inequality among rural communities. How to break the vicious circle of poverty through effective promotion of agricultural knowledge on a sustainable basis is an important question for policy-makers in poor countries. Agenda for future research include a dynamic analysis of the adoption and continued use of technology. In other words, further research is required, using panel (multi-year) data for proper analysis, to extend and demonstrate the dynamic processes that influence farmers' decisions to adopt a technology and use it continuously.

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