

DETERMINANTS OF ADOPTION AND INTENSITY OF USE OF IMPROVED MAIZE VARIETIES IN THE CENTRAL HIGHLANDS OF ETHIOPIA: A TOBIT ANALYSIS

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This study employed a Tobit model to examine factors that influence the adoption and intensity of utilisation of improved maize varieties in the West Shoa Zone in the central highlands of Ethiopia. The estimated results indicate that level of education, household labour, farm size, extension services, farm income, and timely availability of improved maize seeds significantly influence the adoption and intensity of use of improved maize. It also showed that the impact of off-farm income and age of the household head on adoption and intensity of use of improved maize seed was insignificant.

1. INTRODUCTION

Agricultural productivity in Ethiopia is known to be the lowest among African countries (FAO, 1996). Ethiopia also has faced severe food shortages within the past two decades and is on constant threat of famine. One major reason for the low agricultural productivity in Ethiopia is the low rates of adoption of improved agricultural production technologies. Since agricultural research innovations have no value if they are not taken by the end users, identification of the factors determining adoption of improved technologies will help improve the effectiveness of research and extension services and agricultural policy to increase productivity of traditional farmers. There have been few studies conducted to determine the rate of adoption of improved agricultural technologies in Ethiopia. However, to the knowledge of the authors, very limited analysis has been done of factors influencing the intensity or extent of utilisation of the technologies once they are introduced. The existing domain of research and development endeavours so far seem to be unable to provide adequate empirical explanation as to why small-holders in Ethiopia usually fail to adopt the desired level of recommended technologies. The main objective of this study is therefore to identify the socio-economic and institutional factors that influence the adoption and extent of utilisation of improved maize seed in the West Shoa Zone in the central highlands of Ethiopia. The selection of maize was based on its importance as a major food staple in the country, and because of the relatively better data

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available on maize for the present analysis. Maize being a major food staple, this analysis should also contribute to improved food security in the country.

2. ETHIOPIA'S AGRICULTURAL SECTOR

The agricultural sector of Ethiopia is dominated by small-scale and resource poor farmers who produce 90 to 95 percent of all cereals, grains, pulses and oilseeds. Agriculture provides the livelihood for more than 85 percent of the population and employs more than approximately 85 percent of the economically active labour force (CSA, 1997). The productivity of Ethiopian agriculture is one of the lowest in the world. Yield per hectare of cereals for 1996 was 1.36 tons (FAO, 1996) and declined to 1.18 tons in 1998 as compared with the global average of 3.98 tons per hectare (FAO, 1998). Ethiopian farmers used, on an average, 7 kg of soil nutrients per hectare. In 1996/97, out of a total of 6.9 million hectare under cereal crops, only 0.2 million hectares were planted with improved seeds, 0.004 million hectares were irrigated, about 0.6 million hectares were under some type of pest control and chemical fertilizer was limited to only 2.5 million hectares (CSA, 1997). Expansion of cropping areas to marginal land and pasturelands has been the principal cause of soil erosion, land degradation, and reduction in livestock numbers.

Maize is the most important food crop in the study area and has the highest yield per hectare, with an average yield of 1.93 tons per hectare. According to the CSA (1997), during the 1996/97 main production season, the area under maize was 20% of the 6.8 million hectares of the cultivated land.

To improve the economic welfare of their population many developing countries used modern agricultural technologies. However, this has not been the case for Ethiopian farmers, because of their continued reliance on traditional farming practices and insufficient technical and institutional support facilities, such as credit, extension, marketing, etc. These have greatly impeded the development and growth of the agricultural sector. Consequently, the country has faced severe food shortages in the last two decades. The growing population and the scarcity of suitable arable land necessitates agricultural intensification to be an important means in meeting the increasing demand for food. The use of improved cultivars, use of irrigation, minimisation of post harvest losses, better pest management techniques and use of some type of chemical fertilisers are among the possible means of enhancing agricultural production in Ethiopia (Mulat, 1996).

3. EMPIRICAL STUDIES ON THE ADOPTION OF AGRICULTURAL TECHNOLOGIES

Adoption of technological innovations in agriculture has attracted the attention of development economists and policy makers since it is commonly believed that introduction of new technology increases productivity (Feder *et al*, 1985). The decision of whether or not to adopt a new technology hinges upon a careful evaluation of a large number of technical, institutional and socio-economic factors. Adoption analysis, in general, presupposes that innovations exist and the study of the adoption process evaluates the reasons or determinants of whether and when adoption takes place.

Defined as the process of spreading of a new technology within a region, diffusion represents the cumulative process of adoption measured in successive times (Rogers, 1983). The introduction of agricultural innovations into a given geographical area at a given period of time is usually carried through private and public initiatives. The rate of diffusion depends, among other things, on extension communication and the extent to which farmers discuss agricultural issues among themselves routinely (Fliegel, 1984).

Many studies have in one way or the other evaluated the factors affecting the adoption of new technology (Feder *et al*, 1985; Hassan *et al*, 1998; Adesina & Baidu-Forson, 1995; Baidu-Forson, 1999; Itana, 1985; Nkonya *et al*, 1997 and Shakya & Flinn, 1985). Most of these studies have focused on the relationships of key variables to the adoption behaviour of farmers. A review of previous studies is important as it provides some conceptual and theoretical basis for identifying the relevant variables to be included in the analysis. Given the complexity of the adoption decision and the volume of empirical literature on adoption and diffusion of agricultural innovations, it was decided in this study, to summarise the findings of selected studies on the association between adoption decision and factors that influence adoption, particularly in underdeveloped countries. Hassan *et al*, (1998), for Kenya, Adesina and Baidu-Forson (1995) for Burkina Faso, Baidu-Forson (1999), for Niger, and Itana (1985), for Ethiopia, reported that farmer's age is negatively related to adoption and hence implying that the older the farmer the lower is the probability of adoption. According to their analyses, this may be because conservativeness (risk aversion) increases with age, which may be one cause of low adoption of agricultural technologies. Freud *et al*. (1996) in the case of Ghana and Cote d'Ivoire, have found that farmer's age and adoption of modern varieties of cocoa are not at all related, whereas, Hossain and Croach (1992), revealed that the probability of adoption of new farm practices increases with farmer's age in Bangladesh.

According to Welch (1971), both formal and informal education contribute to total agricultural output among other things. Education increases the ability of farmers to use their resources efficiently and the allocative effect of education enhances farmer's ability to obtain, analyse and interpret information. Several studies reviewed by Feder *et al* (1985) indicate that education level enhances farmers' ability to acquire, interpret and use information, including information about agricultural technologies and hence leads to earlier and faster adoption. Hossain and Croach (1992), in the case of Bangladesh, reported that farmers with higher level of education have higher probability of adopting improved farming practices than those with lower level of education. The level of education enhances the decision-making capabilities to adopt a new agricultural technology. Nkonya *et al* (1997), in the case of Tanzania, and Itana (1985) in the case of Ethiopia indicated that education is an important factor positively affecting the process of adoption of improved maize varieties.

Family size has been identified to have a positive and significant effect on adoption of fertiliser technology (Itana, 1985 and Yohannes *et al.* 1990), since large rural households have more labour. On the other hand, Shakya and Flinn (1985) found that family size has an insignificant influence. Greene and Ng'ong'ola (1993) reported that off-farm employment opportunities, due to the larger size of the household, significantly influence fertiliser adoption decisions in Malawi.

From the above it is evident that there is no consistency in the findings of the cited literature. However, the above- mentioned studies are indicative of which factors influence the adoption process such as age, education level, family size, farm size, farm income, off farm income, farmers' access to credit, agricultural extension services and availability of improved seeds.

4. THEORETICAL FRAMEWORK

The observed adoption choice of an improved agricultural technology is hypothesised to be the result of a complex set of inter-technology preference comparisons made by farmers. It is common to examine factors affecting adoption and intensity of use of new agricultural technologies by estimating a probit or logit models of the above mentioned variables on areas planted with improved seed and/or receiving fertiliser (Nkonya *et al*, 1997). Area planted with improved variety of maize will thus represent a censored distribution since some farmers will assume a value of zero for not adopting (non-users). Accordingly, there is a cluster of households with zero adoption of the improved technology at the limit. The application of Tobit analysis is

preferred in such cases because it employs both data at the limit as well as those above the limit. According to McDonald and Moffit (1980), the Tobit model is specified as follows: Let I be the intensity of the use of an improved technology (HMY), I^* is equal to an index reflecting the combined effect of the explanatory variables hindering or promoting the use of an improved technology, I^* is not observable and is recorded as zero for not having area under high- yielding variety. I^* can be expressed as:

$$I^* = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \dots + \beta_n\chi_n + \mu_i = f(\chi_i)$$

$$I = \begin{cases} I^*, & \text{if } I^* > 0 \\ 0 & \text{if } I^* \leq 0 \end{cases} \tag{1}$$

Equation (1) represents a censored distribution of intensity of use of a technology where χ is a vector of explanatory variables, β a vector of Tobit maximum likelihood estimates, μ_i the independently and normally distributed error term assumed to be normal with mean zero and constant variance σ . The value of I for all non-users equals zero. Following Tobin (1958), the expected intensity of use of a given technology, $E(I)$, is:

$$E(I) = \chi\beta F\left(\frac{I_m}{\sigma}\right) + \sigma f\left(\frac{I_m}{\sigma}\right) \tag{2}$$

Where χ as defined above,

$$F\left(\frac{I_m}{\sigma}\right)$$

is the cumulative normal distribution function at

$$\left(\frac{\chi\beta}{\sigma}\right), f\left(\frac{I_m}{\sigma}\right)$$

is the value of the derivative of the normal curve at

$$\left(\frac{\chi\beta}{\sigma}\right), \left(\frac{I_m}{\sigma}\right)$$

is the value of the normalised index at the *mean* values of all explanatory variables and represents the Z scores for the area under the normal curve. β is

a vector of Tobit maximum likelihood estimates, and σ is the standard error of the error term. The marginal effect of an explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(I)}{\partial \chi_i} = F\left(\frac{I_m}{\sigma}\right) \beta_i \tag{3}$$

The change in the probability of using a technology as independent variable X_i changes is:

$$\frac{\partial F\left(\frac{I}{\sigma}\right)}{\partial \chi_i} = f\left(\frac{I_m}{\sigma}\right) \frac{\beta_i}{\sigma} \tag{4}$$

And, the change in the intensity of use of a technology with respect to a change in an explanatory variable among users is:

$$\frac{\partial E(I^*)}{\partial \chi_i} = \beta_i \left[1 - \frac{I_m}{\sigma} \frac{f\left(\frac{I_m}{\sigma}\right)}{F\left(\frac{I_m}{\sigma}\right)} - \frac{f\left(\frac{I_m}{\sigma}\right)^2}{F\left(\frac{I_m}{\sigma}\right)^2} \right] \tag{5}$$

5. THE EMPIRICAL MODEL AND RESULTS

To examine the intensity of use of improved maize varieties, the number of hectares of land planted to improved maize (HMV) is specified as a function of socio-economic and institutional factors as follows:

$$HMV_i = \beta_0 + \beta_1 AGE + \beta_2 EDUC + \beta_3 LBR + \beta_4 FS + \beta_5 AES + \beta_6 FINC + \beta_7 OFINC + \beta_8 AVMS + \mu_i \tag{6}$$

Variables included controlling for social factors are age of the household head (AGE), education level of the head of the household (EDUC) and household Labour (LBR) defined as members of the household who are ten years or older. The economic factors considered are farm size (FS), farm income (FINC), and off-farm income (OFINC). The influence of institutional factors is accounted for through availability of improved variety of maize (AVMS) and access to agricultural extension service (AES) measured as the number of visits per month by an extension agent during the cropping season. Availability of improved maize seed was measured as a dichotomous

variable, with the value of 1 for timely and adequate availability and zero otherwise, whereas off-farm income took the value one if a member of a household has off-farm employment and zero otherwise. The dependent variable was specified to be the area under improved maize (HMV).

This study relies on secondary data collected during the 1998/99 cropping season from a random sample of 110 farmers from the Sasakawa Global 2000 project. The Tobit maximum likelihood estimation procedure was used to estimate equation (6). The Tobit maximum likelihood gives consistent and efficient estimates (McDonald & Moffit, 1980). Table 1 reports the estimated results. The estimation procedure was performed using SHAZAM and E-Views softwares.

Table 1: Tobit model results of the adoption and intensity of use of improved variety of maize

Variable	ML-estimate	Std. Error	p-value	Change in probability $\frac{\partial F\left(\frac{I}{\sigma}\right)}{\partial \chi_i}$	Total Change $\frac{\partial E(I)}{\partial \chi_i}$	Change among users $\frac{\partial E(I^*)}{\partial \chi_i}$
Constant	-0.571	0.1572	0.0003			
AGE	-0.0031	0.0028	0.2799	-0.004	-0.003	-0.002
EDUC	0.0307	0.0171	0.0732	0.039	0.030	0.017
LBR	0.0609	0.0151	0.0001	0.077	0.060	0.034
FS	0.2154	0.0731	0.0032	0.273	0.211	0.122
AES	0.0638	0.0169	0.0002	0.081	0.063	0.036
FINC	0.0002	0.0000	0.0150	0.001	0.0002	0.0001
OFINC	0.0510	0.0426	0.2312	0.0650	0.050	0.029
AVMS	0.1939	0.0581	0.0008	0.246	0.190	0.110
Log of Likelihood=2.99 Censored observations 42 Uncensored observations 68 Predicted probability of Y >limit = 0.98 Jarque-Bera=22.695 (p=0.000)				$\frac{I_m}{\sigma} = 2.05$ $F\left(\frac{I_m}{\sigma}\right) = 0.98$	$\sigma = 0.15$ $f\left(\frac{I_m}{\sigma}\right) = 0.19$	

The estimated parameter for age of the farmer (AGE) is statistically insignificant and has the expected negative sign. Level of Education (EDU) of the head of the household has a positive and significant influence on the adoption and use of improved maize variety with each additional year of

schooling increasing the probability of adoption by 3.9 per cent. Household labour (LBR) has a positive influence on the number of hectares of land planted to improved variety of maize. Each additional unit of labour increases the probability of adoption by 7.7 percent. Moreover, on average, each additional labourer has increased the number of hectares of farmland planted to improved variety of maize by 0.06 for the entire sample and by 0.034 for users.

As anticipated farm size (FS) has a positive and significant influence on the adoption and use of improved variety of maize with each additional hectare of land increasing the probability of adoption of improved maize by 27.3 percent. On average, each additional hectare of land farmed has increased the number of hectares of land planted with improved maize by 0.211 for the entire sample and by 0.122 for users.

Off-farm income has a positive but insignificant effect on the adoption and intensity of use of improved maize seed. A plausible explanation for this is that there are little or no opportunities for off-farm employment in the study area and families rely heavily on farm income to acquire many of the required inputs. Extension services (AES) measured in number of visits per month by the extension agent to a farmer during the cropping season positively and significantly influenced the adoption and intensity of use of improved maize. Each additional visit by the extension agent to a farmer increased the probability of adoption by 8.1 per cent. On average, each additional visit has also increased the number of hectares of land planted with improved seed by 0.06 for the entire sample and by 0.04 for users.

Availability of maize seed (AVMS) at the right time and in the required quantity has the expected positive and significant influence on adoption and level of use of improved maize in the study area. Provision of improved maize seed to farmers in the required quantity and at the right time increases the probability of adoption of the seed by 24.6 per cent. Moreover, provision of improved maize increases the number of hectares planted with improved variety of maize, on average, by 0.19 for the entire sample and by 0.11 for users. The results are the reflection of the situation in the study area in particular and in Ethiopia in general about the supply of improved seed. Quite often improved seeds are in short supply and hence adoption becomes a question of provision of the recommended quantities. Moreover, there is a problem of timely provision of seeds.

The negative and insignificant influence of the age variable is in line with Hassan *et al*, (1998) and Itana, (1985). An additional member aged ten or older

in the family increases the availability of labour thereby increasing the probability of using the improved variety, which is labour intensive. The larger the farm the higher is the probability of adoption and intensity of use as more land is available to allocate to the variety vis-à-vis other crops. Farm income is another important factor which influences farmers' decision to adopt improved varieties as it enables farmers to acquire seeds and other inputs at the right time. Moreover, both visits by extension agents and availability of improved seed increase the probability of adoption and intensity of use as expected.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The study confirmed the importance of farmers' access to resources, extension services, and availability of improved maize seed. This is implied by the fact that farm income is a significant factor differentiating users from non-users and hence has implications for changing the existing input credit scheme, which requires farmers to settle 25-50 per cent down payments. Such requirement may be beyond the capacity of the resource poor farmers and thus represents a hindrance to adoption of improved agricultural production technology. The study results seem to suggest that creating more opportunities for off-farm employment and income will enhance the financial ability of smallholder farmers to acquire external inputs. The fact that extension services are making a difference, it follows that policy makers need to focus on targeting resource poor farmers who represent the farming communities in many areas of the country. At the same time, availability of improved seed proved to be a major constraint for adoption, a fact that calls for improvements in improved seed delivery to effectively cope with the demands of small farmers.

REFERENCES

- ADESSINA, A.A. & BAIDU-FORSON, J. (1995). Farmers perceptions and adoption of new agricultural technology: Evidence from Burkina Faso and Guinea. *Journal of Agricultural Economics*, 13:1-9.
- AMEMIYA, T. (1984). Tobit models: A survey. *Journal of Econometrics*, 24:3-61.
- BAIDU-FORSON, J. (1999). Factors Influencing Adoption of Land-enhancing Technology in the Sahel: Lessons from A Case Study in Niger. *Journal of Agricultural Economics*, 20:231-139.

CENTRAL STATISTICAL AUTHORITY (CSA). (1997). Statistical abstract of Ethiopia. Addis Ababa.

FAO. (1996). *FAO production yearbook*. Rome, Italy.

FAO. (1998). *FAO production yearbook*. FAO, Rome, Italy.

FEDER, G.R., JUST R.E. & ZILBERMAN, D. (1985). Adoption of agricultural innovations in developing countries: A Survey. *Economic Development. and Cultural Change*, 33:255-298.

Fliegel, F.C. (1984). Extension communication and the adoption process. In: *FAO, A Reference Manual*, 2nd ed. Rome.

FREUD, E.H., PHILLIPE P. & JACQUES R. (1996). Innovation in West African smallholder Cocoa: Some. conventional and non-conventional measures of success. In: *Food Security and Innovations: Successes and Lessons Learned*, International Symposium, Hohenheim, Germany:131-146

GREEN, D.A.G. & NG'ONG'OLA, D.H., (1993). Factors affecting fertiliser adoption in less developed countries: An application of multivariate logistic analysis in Malawi. *Journal of Agricultural Economics*, 1:99-109.

HASSAN, R.M., KIARIE, N., MUGO, N., ROBIN, O. & LABOSO, A. (1998). Adoption and performance of maize in Kenya. In: Hassan, R.M. (ed.) *Maize Technology Development and Transfer: A GIS Approach to Research Planning in Kenya*. CAB international, London.

HOSSAIN, S., ALAMGIR, M. & CROACH, R. (1992). Patterns and determinants of adoption of farm practices: Some evidence from Bangladesh. *Agric. Systems*, 38:1-15.

ITANA A. (1985). *An analysis of factors affecting the adoption and diffusion patterns of package of agricultural technologies in subsistence agriculture*. Unpublished MSc. Thesis, Addis Ababa University.

MCDONALD, J.F. & MOFFIT, R.A. (1980). The use of Tobit analysis. *Review of Economics and Statistics*, 62:318-320.

MULAT, D. (1996). Constraints to the efficient and sustainable use of fertiliser in Ethiopia. In: Mulat D., et al. (eds.) *Sustainable Intensification of Agriculture in*

Ethiopia. Proceedings of the Second Annual Conference of the Agricultural Economics Society of Ethiopia. Addis Ababa.

NKONYA, E., SCHROEDER T. & NORMAN, D. (1997). Factors affecting adoption of improved maize seed and fertiliser in Northern Tanzania. *Journal of Agricultural Economics*, 4:1-12.

POLSON, R.A. & SPENCER, D.S.C. (1991). The technology adoption process in subsistence agriculture: The case of Cassava in South Western Nigeria." *Agricultural Systems*, 36:65-77

RAHM, M.R. & HUFFMAN, W.E. (1984). The adoption of reduced tillage. The role of human capital and other variables. *American Journal of Agricultural Economics*, 66:405-413.

ROGERS, E.M. (1962). *Diffusion of innovations*. Free Press of Glencoe, New York.

ROGERS, E.M. (1983). *Diffusion of innovations*. 3rd Edition, Free Press, New York.

SASAKAWA GLOBAL 2000. (1995). *Annual report of the Sasakawa Global 2000 agricultural project in Ethiopia*. Crop Season 1994. Addis Ababa, Ethiopia.

SASAKAWA GLOBAL 2000. (1995). *Sasakawa Global 2000 African Country programme data sheets*.

SHAKYA, P.B. & FLINN, J.C. (1985). Adoption of modern varieties and fertilizer Use on Rice in the Eastern Terrai of Nepal. *J. of Agricultural Economics*, 36: 409-419.

TAKELE, G. (1996). Sasakawa Global 2000 Project. In: Mulat Demeke et al. (eds.). *Sustainable Intensification of Agriculture in Ethiopia*. Proceedings of the Second Annual Conference of the Agricultural Economics Society of Ethiopia. Addis Ababa, Ethiopia.

TOBIN, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica*, 26:26-36.

VAN DEN BAN & HAWKINS, H.S. (1988). *Agricultural extension*. John Wiley and Sons, Inc., New York.

WELCH, F. (1971). Education in production. *Journal of Political Economy*, 7.