Journal of Research in Economics and International Finance (JREIF) Vol. 1(2) pp. 39-49, August 2012
Available online http://www.interesjournals.org/JREIF
Copyright © 2012 International Research Journals

Full Length Research Paper

Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach

Hassen Beshir*[1], Bezabih Emana[2], Belay Kassa[3] and Jema Haji[3]

[1]*Wollo University, Department of Agricultural Economics, Ethiopia, [2] SID Consult, Addis Ababa, Ethiopia
[3]Haramaya University, School of Agricultural Economics and Agribusiness, Ethiopia

Accepted August 3, 2012

The objective of the study was to assess the determinants of the probability of adoption and intensity of use of inorganic fertilizer in two districts of south Wollo zone, in Ethiopia. The study employed cross-section data to analyze the effect of farmers' demographic, socioeconomic and institutional setting, market access and physical attributes on the probability and intensity of use of inorganic fertilizer. A double hurdle model was employed using data collected from randomly selected 252 farmers between July 2009 and November 2009. Secondary data were also used to complement the primary data. The study depicted low utilization of inorganic fertilizer which was 29.6% and 19%of total cultivated crop land in Ethiopia and south Wollo, respectively. The results of the study provided empirical evidence of a positive impact of extension and credit services, age, farm land size, education, livestock, off/non-farm income and gender in enhancing the adoption of inorganic fertilizer. Physical characteristics like distance from farmers' home to markets, roads, credit and input supply played a critical role in the adoption of inorganic fertilizers as proximity to information, sources of input and credit supply and markets save time and reduce transportation costs. Therefore, the results of the study suggest that the probability of adoption and intensity of use of inorganic fertilizers should be enhanced to meet the priority needs of smallholder farmers and to alleviate the food shortage problem in the country in general and in the study area in particular.

Keywords: Adoption, inorganic fertilizer, technology, double hurdle model, intensity of use.

INTRODUCTION

The economic development of Ethiopia is highly dependent on the performance of its agricultural sector. Agriculture contributes 53% of the country's Gross Domestic Product (GDP), 85% of all exports (coffee, livestock and livestock product and oil seeds) and provides employment for 85% of the population (FAO, 2007). Agriculture provides also raw material for 70% of industries in the country (MOFED, 2006). The bulk of agricultural GDP for the period 1960-2009 had come from cultivation of crops (90%) and the remaining (10%) from livestock production (FAO, 2007; MOFED, 2010). The industrial sector is small in size contributing, on average, only about 13% of the GDP.

The growth rate of agriculture and GDP is low for several decades mainly due to severe weather fluctuation, inappropriate economic policies and low adoption of improved agricultural technologies and prolonged civil unrest. The average growth rate of the agricultural sector was 1.7%, 3.8% and 5.5% during the Imperial period (1960-1974), socialist period (1975-1990) and the Ethiopia People's Revolutionary Democratic Front (EPRDF) period (1991-2009), respectively. The growth rate of GDP fluctuates with the growth rate of agriculture. The major crops produced in the country include cereals, pulses and oil seeds with 72%, 12% and 7% of area coverage and 69%, 9% and 3% of production,

*Corresponding Author Email:hassenhussien@gmail.com

respectively (CSA, 2009a). Data from the Central Statistical Agency indicate that the major cereals produced in the country include *Teff,* wheat, barley, maize and sorghum. The same source shows that the yield of cereal crops on the average is 1.55 tons per hectare.

The yield of crops in general and cereals in particular is very low because of low utilization of improved technologies. For instance, the amount of inorganic fertilizer applied in the 2008/09 cropping season was 423,000 tons. During the same period, the total area fertilized with inorganic fertilizer for all crops was about 29.6% of total cultivated area in Ethiopia (CSA, 2009b). The cultivated area covered with improved variety was about 3.4% of total cultivated land. Hence, Ethiopian smallholders' typically produce with their indigenous seed and are characterized by low adoption of improved technologies. Because of the low productivity agricultural sector, Ethiopia has become highly dependent on food import in that domestic food production and supply have consistently been the national demand (FAO, 2007). For instance, the country received 674,000 metric tons of cereals in the form of food aid in 2006 alone (FAO, 2007).

In the northeast Ethiopia where this study is conducted, crop and livestock production are highly integrated as a means to generate income, cope up with market and environmental risks and meet household consumption requirements. However, the production and productivity of crops and livestock is very low resulting in food insecurity. The average cultivated area with inorganic fertilizer was 19% of the total cultivated area while the average cultivated area with improved seed was also 2.6% of the total wheat cultivated in the study area (CSA, 2009b). Due to low use of improved practices the productivity of all crops is below the national average. For example, the yield of cereals in Ethiopia was 1.55 ton per hectare for traditional practices but more than 3.0 tons per hectare using improved technologies.

Though, there have been quite different types of adoption studies related to improved agricultural technologies in Ethiopia. More precisely, there have been various empirical studies conducted to identify determinants of adoption of agricultural technologies in Ethiopia, (for instance, Asfaw et al., 1997; Tesfaye and Alemu, 2001; Tesfaye et al., 2001; Mergia, 2002; Kiflu and Berhanu, 2004), to the best of the authors' knowledge there were no similar studies undertaken in the study area. Moreover, since adoption is dynamic, it is imperative to update the information based on the current technologies being adopted by farmers. The general objective of the study is to identify the determinants of the adoption of inorganic fertilizers technology in two districts of south Wollo, north east highland of Ethiopia.

The rest of the paper is presented as follows. Section two develops the analytical framework and methodologies used in the study. Section three presents and discusses the empirical results of the study. Finally, section four brings the major findings, draw conclusions and make recommendations of the study to improve smallholders' agricultural productivity through adoption of chemical fertilizers technology.

METHODOLOGY

Description of the study area

This study was carried out in South Wollo. South Wollo is located in the North East part of Ethiopia. South Wollo is one of the eleven administrative zones of the Amhara National Region State. It is situated between the Eastern highland plateaus of the region and the North Eastern highland plateaus of Ethiopia. It is divided into 20 administrative districts and has two major towns (Kombolcha and Dessie) and 18 rural districts. Among the eighteen rural districts, Dessie Zuria and Kutaber are selected for this study.

South Wollo has steep edges of a mountain wall in the Western edge of great East African rift valley. This is acting as a vast retaining wall which drops abruptly into the low, arid and hot Afar depression. There are great differences in elevation of the mountain complexes and these are now left with a bare broken surface due to the undulating topography, reckless large scale felling of trees, unscrupulous cultivation practices from time immemorial. South Wollo is located between latitudes $10^0$10'N and $11^0$41'N and longitudes $38^0$28' and $40^0$5'E. According to Central Statistical Agency's population census in 2007, the total population of South Wollo was 2,519,450 of which 50.5% were females and 88% were rural dwellers (CSA, 2008). The total land area in South Wollo, Dessie Zuria and Kutaber are 1,773,681 hectares, 180,100 hectares and 72,344 hectares. The proportion of cultivated land area accounts for 39%, 20% and 35.3% for Dessie Zuria, Kutaber and South Wollo, respectively.

Sampling procedure

Dessie Zuria and Kutaber were selected purposively based on their accessibility and relevance of the study. Multistage random sampling was used for the selection of the sample respondents. In the first stage of sampling, 6 Farmers' Associations (FAs) were selected randomly from a total of 54 FAs. As the numbers of Farmers Associations in Dessie Zuria (28) were equal to that of Kutaber (26), three Farmers Associations were selected from each district using simple random sampling procedure. In the second stage, a total of 252 farmers were selected using probability proportional to sample size sampling technique.

Table 1. Distribution of sample farm household heads by farmers' association and district

Name of District	Name of FA	Total household* head		Sample farm household heads		
				Female	Male	Total
		Male	Female	Number	Number	Number
Dessie Zuria	Tita	686	182	7	27	34
	Bilen	1,179	161	8	45	53
	Endod Ber	688	102	4	27	31
Kutaber	Boru	490	123	5	20	25
	Beshlo	797	201	8	32	40
	Alasha	1,297	458	18	51	69
	Total	5,137	1,227	50	202	252

Source: *Kebele Administration Office (Personal Communication),

Data collection and sources

A structured questionnaire was designed, pre-tested and refined to collect primary data. Experienced enumerators were recruited and trained to facilitate the task of data collection. Farm visit, direct observation and informal interview were undertaken both by the researcher and the enumerators. The secondary data were extracted from studies conducted and information documented at various levels of Ministry of Agriculture and Finance and Economic Development Offices in the study.

Analytical models

Econometric specification of agricultural technology adoption model

Different researchers used different models for analyzing the determinant of technology adoption. In principle, the decisions on whether to adopt and how much to adopt can be made jointly or separately (Berhanu and Swinton, 2003). The Tobit model was used to analyze under the assumption that the two decisions are affected by the same set of factors (Greene, 2003). Tobit is an extension of the probit model and it is one approach to deal with the problem of censored data (Johnston and Dinardo, 1997). In the double-hurdle model, on the other hand, both hurdles have equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of them (Teklewold *et al.*, 2006). Empirical studies have also indicated that a variable appearing in both equations may have opposite effects in the two equations. The double-hurdle model, developed by Cragg (1971), has been extensively applied in several empirical studies such as Burton et al. (1996), Newman *et al.* (2001), Berhanu and Swinton (2003) and Teklewold *et al.* (2006).

As already noted, in this study a double hurdle model is used to identify factors affecting the probability of adoption and intensity of use of inorganic fertilizers. The double-hurdle model is a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the level of adoption of technology. The double-hurdle model has an adoption (D) decision with an equation:

$$D_i = 1 \ldots if \ldots D_i^* > 0 \ldots and$$
$$D_i = 0 \ldots if \ldots D_i^* \leq 0 \quad (1)$$
$$D_i^* = \alpha' Z_i + U_i$$

being D_i* a latent variable that takes the value 1 if a farmer adopts inorganic fertilizer technology and zero otherwise, Z is a vector of household characteristics and α is a vector of parameters.

The level of adoption (Y) decision has an equation:

$$Y_i = Y_i^* .. if \ldots Y_i^* > 0 \ldots and \ldots . D_i^* > 0$$
$$Y_i = 0 \ldots otherwise \quad (2)$$
$$Y_i^* = \beta' X_i + V_i$$

Where Y_i^* is the observed proportion of agricultural technologies, X_i is a vector of household socioeconomic characteristics and β is a vector of parameter.

The log-likelihood function for the double hurdle model is

$$\log L = \sum ln\left[1 - \Phi(\alpha Z'_i\left(\frac{\beta X_i}{\sigma}\right)\right] + \sum ln\left[\Phi(\alpha Z'_i)\frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X'_i}{\sigma}\right)\right] \quad (3)$$

Under the assumption of independency between the error terms V_i and U_i the double hurdle model is equivalent to a combination of univariate Probit model (1) and the truncated regression model (2). A hypothesis test for the double hurdle model against the Tobit model was used. The double hurdle log-likelihood is the sum of the truncated regression and the Probit models. The test can be done by estimating three regression models (Tobit model, the truncated regression and the Probit models) separately and use a log-likelihood ratio (LR) test. The LR statistic can be computed using the formula (Greene, 2003):

$$\Gamma = -2\left[\ln L_T - \left(\ln L_P + \ln L_{TR}\right)\right] \sim \chi^2_k \qquad (4)$$

Where L_T= likelihood for the Tobit model; L_P= likelihood for the Probit model; L_{TR}= likelihood for the truncated regression model and k is the number of independent variables in both equations.

The test hypothesis is written as:

H_0: $\lambda = \frac{\beta}{\sigma}$ and H_1: $\lambda \neq \frac{\beta}{\sigma}$

H_0 will be rejected on a pre-specified significance level if $\Gamma > \chi^2_k$

Measurement and definitions of variables for adoption

The Dependent variables of Probit and truncated regression models

The dependent variable of Probit model have a dichotomous value depending on the farmers' decision either to adopt or no to adopt the inorganic fertilizers. However, the truncated regression model would have a continuous value which should be the intensity, the use and application of the technology. In this case, it indicates the amount of inorganic fertilizer applied in kilogram. The inorganic fertilizers in question are DAP and Urea which were imported from abroad.

The Independent variables and their definitions used in double hurdle model

Adoption literatures provide a long list of factors that may influence the adoption of agricultural technologies. Generally, farmers' decision to use improved agricultural technologies and the intensity of the use in a given period of time are hypothesized to be influenced by a combined effect of various factors such as household characteristics, socio-economic and physical environments in which farmers operate.

The explanatory variables included in the empirical models were selected following the literature on farm level investment theory (Feder *et al.*, 1985; Feder *et al.*, 1992; Clay *et al.*, 1998; Berhanu and Swinton, 2003). Following these literature, farm investment can be modeled as a function of market access factors (as a proxy for return on investment factors); capacity to invest; physical incentive to invest; socio-institutional factors; and household demographic characteristics.

The market access factors affect the relative profitability of investment in improved technology. Ideally such factors would include crop prices, cost of labour and materials used for improved agricultural technologies and the yield effect of such practices. However, the survey results revealed that it was not possible to get accurate information on grain selling prices from the majority of the sample respondents. Instead, relative prices were proxied by distance from market place and input supply institutions. Labour input is a major cost component in crop and livestock production investment in the study area. Distance from an all-weather road was used to proxy for differences in the opportunity cost of labour.

Physical factors create opportunities for investing in crop and livestock production. These factors were expected to detract from investment due to increased transaction costs. The factors expected to affect the capacity to invest include livestock holding, off/non-farm income, farm size and family labour. Farm size is measured as the total acreage (in hectares) of cultivated land, and family labour is measured as number of household members in man equivalent. The effect of farm size is that more land indicates greater wealth and capacity and should encourage investment in improved technology. Own labour availability should encourage investment either due to availability of labour to do the work or due to the need to feed more people. Livestock holding is measured as the number of livestock in Tropical Livestock Unit (TLU). Livestock are important source of income, food and draft power, and represent an asset which indicates the wealth status of the household and as such are expected to facilitate the adoption of improved agricultural technologies. Off/non-farm income is captured as a dummy variable indicating whether or not the farmer had access to additional income from off/non-farm activities.

Several socio-institutional variables were hypothesized to encourage farmers to invest in crop and livestock production. These include access to credit service and contact with agricultural extension agents. Household demographic variables include age, sex, number of dependents in the household expressed in adult equivalent and literacy level of the household head. In the course of identifying factors influencing farmers' decision to use improved agricultural technologies, the main task is to analyze which factor influences the decision, how and by how much. In this study, it was hypothesized that probability of adoption and intensity of adoption of chemical fertilizers are influenced by the combined effect of various factors. The potential explanatory variables which are hypothesized to influence the probability of adoption and intensity of adoption of chemical fertilizers in the study area are given in Table 2.

Table 2. Summary of definitions and measurements of Probit and Truncated model variables

Definition of variables	Measurement of variables	Expected sign
Dependent variables		
Adoption of inorganic fertilizers	Dummy (Yes/no)	
Amount of inorganic fertilizers	Continuous (Kilogram)	
Independent variables		
Distance to nearest market	Walking minutes	-
Distance to nearest all weather road	Walking minutes	-
Age of the household head	Years	+/-
Education of the household head	Formal schooling in years	+
Adult equivalent in the family	Number	-
Labour available in the family	Number	+
Farm size	Cultivated area in ha	+
Fragmentation	Number of plots	-
Livestock owned	TLU	+
Distance to input supply institutions	Walking minutes	-
Distance to extension agent(s) office	Walking minutes	-
Distance to credit office	Walking minutes	-
Sex of the household head	Male/female	+
Access to off/non farm income	Yes/no	+/-
Access to extension service	Yes/no	+
Access to credit	Yes/no	+

Table 2. Descriptive statistics of explanatory variables on probability of adoption and intensity of adoption of inorganic fertilizer (means)

Variables	Non-adopters (207)	Adopters (45)	Total (252)	t-value
Distance from home to nearest market	81.17	94.22	83.50	-1.46
Distance from home to road	37.66	24.42	35.30	-2.84***
Respondent's age	54.12	49.27	53.25	2.96***
Highest Level of years of schooling	1.88	3.80	2.22	2.69***
Number of man equivalent	3.73	4.56	3.87	3.64***
Number of adult equivalent	4.61	5.71	4.80	2.88***
Total cultivated area in hectare	0.63	0.91	0.68	3.08***
Number of plots	3.61	4.78	3.82	8.76***
Total Tropical Livestock Unit	3.40	4.76	3.64	4.22***
Number of oxen	0.96	1.76	1.10	4.6***
Distance from distribution centre	107.19	47.04	96.45	-9.55***

***, ** and * implies significant at 1%, 5% and 10% probability level, respectively
Source: Own survey, 2009

RESULTS AND DISCUSSION

Improved technologies such as improved seed and breed, fertilizers and herbicides have played a significant role in enabling farmers to increase the production and hence improve the standard of living of smallholder farmers. The process of adoption of improved agricultural technologies is the interest of many agricultural economists. The majority of smallholder farmers in Ethiopia are producing both crops and livestock. Yield of

Table 3. Proportion of farm household involved in access to socio-institutions (%)

Variable		Non-adopters (207)	Adopters (45)	Total (252)	χ2-value
Sex	Female	18.4	1.6	20	4.132**
	Male	64	16	80	
Off-farm Income	%	57	16	73	7.293***
Extension service	%	39	15	54	20.993***
Credit Participation	%	6	13	18	5.4**

***, ** and * implies significant at 1%, 5% and 10% probability level, respectively
Source: Own survey, 2009

Table 4. Variance inflation factors (VIF) of the continuous explanatory variables

	Collinearity Statistics	
Variables	**Tolerance**	**VIF**
Distance from home to nearest market	0.756	1.323
Distance from home to nearest all weather road	0.790	1.266
Highest Level of education of the head	0.842	1.188
Number of man equivalent in the family	0.153	6.536
Number of adult equivalent in the family	0.149	6.728
Total cultivated area in hectare	0.744	1.344
Number of plots	0.796	1.256
Total Tropical Livestock Unit	0.764	1.310
Distance from distribution centre for improved wheat seed	0.384	2.603

these activities are very low due to low adoption and application of improved agricultural technologies mainly improved seed, fertilizer, improved forage and cow.

Description of variables of empirical adoption models

The rate of adoption of chemical fertilizer was 17.9% of the sample respondents. The mean level of use of chemical fertilizer was 43 kg and 8 kg for adopters and for full sample, respectively. The description of continuous variables indicated that adopters are slightly old, educated and resource endowed mainly labor, land and livestock (Table 2).

Moreover, description of dummy variables indicated that there was a significant difference between adopters and non-adopters with regard to sex, access to off/non-farm income, credit and extension service (Table 3).

Estimation Procedure of Empirical Adoption Models

There are farmers who have adopted and non-adopted improved agricultural technologies. These farmers can use the new technology in a different level. Therefore, the rate of adoption was estimated using Probit model whereas the intensity and level of use of the improved agricultural technologies was estimated using truncated regression model. Hence double hurdle model was used to estimate the Probability and intensity of adoption of improved agricultural technology. Accordingly explanatory variables were checked for problems of multicollinearity, endogeneity and heteroscedasticity. Following Gujarati (1995), the problem of multicollinearity for continuous explanatory variables was investigated using a technique of variance inflation factor (VIF) and tolerance level (TOL), where each continuous explanatory variable is regressed on all the other continuous explanatory variables. The larger is the value of VIF, the more worrying is the multicollinearity or collinear is the variable (X_j). As a rule of thumb, if the VIF of a variable exceeds 10 and R^2 exceeds 0.90 the variable is said to be highly collinear. The values of VIF were less than ten and hence no signals of multicollinearity problems (Table 4).

To observe the degree of association between dummy explanatory variables contingency coefficients were computed. Contingency coefficient is a chi-square based measure of association where a value 0.75 or above indicates a stronger relationship between explanatory variables (Healy, 1984). This was also checked and less than 0.7 (Table 5). For endogeneity an

Table 5. Contingency coefficients for dummy explanatory variables

Variables	Sex	Extension access	Credit access	Off/non-farm access
Sex	1	0.173	0.039	0.074
Extension access		1	0.106	0.141
Credit access			1	0.026
Off/non-farm access				1

Table 6. Test statistics of double-hurdle model

Type of statistics	Probit, D	Truncated, Y(Y>0)
$\chi^2(16)$	94	126
p-value	0.00***	0.00***
LOG-L	-46	-177
AIC((-LOG-L+k)/N)	0.25	4.29
χ^2-Test Double Hurdle versus Tobit	$\Gamma = 64 > \chi^2(16) = 32$	

attempt was made to exclude dependent variable as explanatory variable. To avoid heteroscedasticity problem, robust standard error was estimated.

At this stage farmers were classified into adopters and non-adopters. Adopters are farmers who use inorganic fertilizer (DAP and Urea). Non-adopters are farmers who use none of this technology during the survey year (2008/2009 production year). The study depicted low consumption of improved wheat seed which is 29.6% of total cultivated land in Ethiopia and was 19% in south Wollo (CSA, 2009b). The test statistics of double hurdle versus Tobit model indicate the rejection of Tobit model (Table 6). Overall, the likelihood (rate or probability) of adoption of chemical fertilizer was modest; an average farmer had 17.9% predicted probability of adopting the technology. An average farmer had used chemical fertilizer of 43kg with an average cultivated area of 0.29 hectare for adopters.

Econometric results of inorganic fertilizer technology adoption model

The parameter estimates of the Probit and truncated regression models employed to identify factors influencing farmers' adoption of inorganic fertilizer are presented in Table 7. In all the analyses the likelihood ratio test statistics suggested the statistical significance of the fitted regression. Results of the analyses also revealed that rate of adoption and intensity of adoption of inorganic fertilizer were influenced by different factors and at different levels of significance for different factors. The discussion of results about the significant factors is presented as follows.

Age had a significant positive effect on the level of use of inorganic fertilizer at less than 1% level of significance. This might be related the reason that older farmers might have gained knowledge. The result is consistent with the findings of Teklewold *et al.* (2006) and Hailu (2008). The model result indicates that as the age increases by one year, the intensity of inorganic fertilizer use of the farm households increases by 114%. However, this may diminish, as the household head gets older. As expected, being male was positively related to the intensity of use of inorganic fertilizer at less than 1% level of significance. This means that male farmers use more inorganic fertilizer, compared to their female counterparts, even though sex is excluded from the first hurdle since it had no significant effect on probability of adoption. The result is consistent with the findings of Abay and Assefa (2004) and Teklewold *et al.* (2006). The justification for this is that male farmers might have access to information through male extension agents. Education was hypothesized to affect technology adoption positively since it increases the capacity of farm households to acquire information and knowledge of improved technologies and promote the decision to use it on his/her farm. In this study, in conformity with the hypothesis, education positively and significantly affected the intensity of use of inorganic fertilizer at less than 5% level of significance. The result is consistent with the findings of Doss and Morris (2001) and Abay and Assefa (2004). The model result indicated that farm households who increase their formal education by one year will increase intensity of inorganic fertilizer by 189%.

As expected, labour force available had influenced the level of use of inorganic fertilizer positively at less than 1% level of significance. The probable reason for this finding was that improved practices are labour intensive and hence the household with relatively high labour force uses the technologies on their farm plots better than others. This finding is consistent with the results of Hailu (2008). Adult equivalent was found to be significantly and negatively influencing the intensity of

Table 7. Factors affecting probability of adoption and intensity of use of chemical fertilizer

	Probit			Truncated		
Variables	**Coefficient**	**Robust Std. Err.**	**Marginal effect**	**Coefficient**	**Robust Std. Err.**	**Marginal effect**
Distance to market	-0.006**	0.003	-0.0002	-0.123**	0.05	-0.12
Distance to road	-0.008	0.007	-0.0003	-0.41***	0.11	-0.40
Sex	-0.719	0.413	-0.0440	23.64*	14.1	23.04
Age	-0.009	0.012	-0.0003	1.17***	0.29	1.14
Education	0.051	0.046	0.0019	1.94**	0.80	1.89
Adult equivalent	-0.207	0.178	-0.0076	13.1***	3.22	12.78
Active labour force	0.285	0.180	0.0105	-17.1***	3.73	-16.7
Total cultivated land	0.265	0.292	0.0097	21.3***	5.38	20.72
Number of plots	0.080	0.062	0.0029	-6.02***	1.55	-5.87
Livestock owned	0.042	0.082	0.0016	6.48***	2.21	6.32
Off/non-farm income	0.622	0.439	0.0178	14.63**	5.73	14.26
Distance to input supply	-0.03***	0.008	-0.0011	-0.33**	0.16	-0.32
Extension service access	1.95***	0.668	0.1005	35.9***	11.4	35.04
DA distance	0.02***	0.008	0.0009	-0.36**	0.16	-0.35
Credit service	1.2***	0.371	0.0239	-20.52	13.6	-20.0
Credit distance	-0.01***	0.005	-0.0005	-0.28***	0.10	-0.27
Constant	-0.114	1.492		72.38***	22.7	
Test statistics	**No of observation=252**			**No of observation=45**		

***, ** and * implies significant at 1%, 5% and 10% probability level, respectively

use of inorganic fertilizer at less than 1% level of significance. This implies that increase in adult equivalent negatively influences, through increases in household food requirement, the decision to intensify inorganic fertilizers.

In this study, in conformity with the hypothesis, farm size had influenced the intensity of use of inorganic fertilizer positively at less than 1% level of significance. The result is consistent with the finding of Doss and Morris (2001). Farm size is an indicator of wealth and perhaps a proxy for social status and influence within a community. Number of plots had influenced the intensity of use of inorganic fertilizer negatively at less than 1% level of significance. The reason might be related to the poor transportation access in the study areas and the land fragmentation problems, as the number of plot increases the time required to reach the plots and labour required increases. The cost of intensifying inorganic fertilizer on fragmented plots is likely to be high. The result is consistent with the findings of Chilot (2007). Ownership of livestock had the expected positive and significant effect on intensity of inorganic fertilizer at less than 1% level of significance. Livestock ownership is considered as an asset that could be used either in the production process or it could be exchanged for cash (particularly small ruminants) for the purchase of inputs whenever the need arose. Moreover, livestock is considered as a sign of wealth and increases availability of cash for adopting technologies. The result is consistent with the findings of Abay and Assefa (2004).

Access to extension service had the expected positive and significant effect at less than 1% significant level on probability of adoption and intensity of its use due to access to information for these technologies. Agricultural extension services are the major sources of information for improved agricultural technologies. One means of which, farmers' access information about improved technologies is by contacting the extension agent. The result is consistent with the finding of Teklewold *et al.* (2006). Having access to credit had the expected positive and significant effect at less than 5% significant level on probability of adopting inorganic fertilizer due to access to finance for these technologies. Agricultural credit services are the major sources for improved agricultural technologies to solve financial constraints. If farmers can get access to credit, they can purchase improved technologies. The result is consistent with the finding of Abay and Assefa (2004) and Teklewold *et al.* (2006). According to the results of the double-hurdle model, relative to farmers who face credit constraint, farmers who get credit were about 2.4% more likely to adopt inorganic fertilizer technology. In many cases, farmers will need to use some of their own equity to finance at least part of their investments. In other case, assets such as land or the crop itself may be used as collateral for financing an improved technology. The result therefore suggests that the availability of credit is one of the most important determinants of smallholder farmers' probability of inorganic fertilizer technology adoption. Access to off/non-farm income had influenced the decision behavior of farm household to use inorganic fertilizer positively at less than 5% level of significance. The possible justification for this result is that off/non-farm income earned might solve the financial constraints to hire labour and purchase farm inputs like fertilizer. The result is consistent with the finding of Teklewold *et al*. (2006).

The coefficient of distance to market had the expected negative sign and significant effect on the probability and intensity of adoption of inorganic fertilizer. The negative sign indicated the importance of proximity to a regular markets leading to better access, lower transport cost, and timely delivery of inputs and disposal of output and better output price for farmers. The market is used to buy required input and sell surplus output. Thus the closer distances of a farmer's home to the market enables and facilitates marketing of inputs and outputs. The result is consistent with the finding of Berhanu and Swinton (2003). The coefficient of distance to all weather roads had the expected negative sign and significant effect on the intensity of adoption of inorganic fertilizer. It is not only the proximity to local and external markets that influences adoption of improved technologies but the distance to all weather roads is also significant. Proximity of farmers to all weather roads is essential for timely input delivery and output disposal. It also decreases the transport cost of inputs; hence, investment in improved road infrastructure is crucial for promoting adoption and welfare gains. The result is consistent with the finding of Berhanu and Swinton (2003).

The coefficient of distance to input supply institutions had the expected negative sign and significant effect on the probability and intensity of adoption of inorganic fertilizer. This variable had influenced adoption of improved agricultural technologies through proximity for farmers. Proximity of farmers to such places is essential for timely input delivery and less transport cost of inputs. This variable had influenced adoption of improved agricultural technologies through proximity for farmers. The coefficient of distance to DA office had not the expected negative sign but significant effect on the probability of adoption of inorganic fertilizer. However it had the expected significant and negative influence on the intensity of adoption of inorganic fertilizer. Distance between credit office and home of the household had influenced adoption of improved agricultural technologies through proximity for farmers. The coefficient of distance to credit office had the expected negative sign and significant effect on the probability and intensity of adoption of inorganic fertilizer.

SUMMARY AND CONCLUSION

The general objective of the study was to assess adoption and intensity of adoption of inorganic fertilizer in two districts of north eastern Ethiopia. As part of the agricultural development-led industrialization program, the Ethiopian government launched the new extension program. The program was expected to result in abrupt changes in the production and productivity of Ethiopian agriculture. In spite of intensive efforts to expand the use of improved agricultural technologies, such as improved varieties and fertilizers, the yield of major crops and livestock, remained low. There has been a growing concern by researchers, extension personnel and policy makers about the effectiveness of adoption of improved agricultural technologies particularly on the area allocated and amount of use of these technologies and farmers learning process from the program to alleviate the food shortage problem in the country. This study was initiated to identify factors that affect the probability and intensity of farmers' decision to use improved fertilizer technologies. There are several studies on farmers' adoption of improved agricultural technologies using static and dynamic models in developing countries including Ethiopia. However, there is no study on this research problem conducted in the study area.

Cross-section data were used to analyse the effect of farmers socioeconomic and institutional setting and physical attributes on the probability and intensity of improved agricultural technologies adoption and determinants of production efficiencies. The study used data obtained from a survey of farmers in north east Ethiopia of South Wollo zones of Dessie Zuria and Kutaber districts collected for the period July 2009 to November 2009. Dessie Zuria and Kutaber districts were selected to represent medium and highland agro-ecological environment in South Wollo. Then 252 farmers were selected using simple random sampling of farm households in six farmers associations where the sample size in each farmers associations was determined based on proportions and size and sample sizes were distributed proportionately over the six farmers associations. Double hurdle model was employed to study farmers' decision to adopt and intensity of use of improved technologies. The adopters of inorganic fertilizer were characterized by educated and slightly high resource endowment (labour, land and livestock) than non-adopters.

The results of the study provided empirical evidence of the positive impact of education in enhancing the intensity of adoption of inorganic fertilizer technologies to increase production. The study found access and availability of extension service to be more powerful than other factors in explaining adoption and intensity of inorganic fertilizer technology adoption. Family labour availability was also powerful in explainin intensity of inorganic fertilizer technologies suggesting that this input require additional labour for different crop operation.

The age of the farmer significantly and positively affected the intensity of use of inorganic fertilizer technologies. Older farmers adopted more improved agricultural technologies than younger farmers suggesting that accumulated knowledge gained through experience enables older farmers to adopt improved agricultural technologies. Sex of the farmer was significant on probability of inorganic fertilizers technologies adoption suggesting that attention should be provided for empowering female household. Farm land size was critical in the adoption of improved technologies. Farmers with large farm size could increase their production by using inorganic fertilizer. Although small farmers account for most of the cultivated land and production in the country, the fact that farm size had a positive impact on intensity of inorganic fertilizer adoption implies that policy makers should give attention to large farmers in designing technological intervention for increased production and food production.

Physical characteristics like distance from farmers' home to markets, road, and input supply and credit institutions played a critical role in the adoption of improved agricultural technologies as proximity to information, sources of input supply and credit and markets save time and reduce transportation costs. Given the critical role of proximity to such centers and better roads for promoting adoption and productivity gains, the effort of investment in improved roads infrastructure should be enhanced to achieve increased production, ensure food security and eradicate poverty.

The empirical results show that agricultural extension service was significantly influenced agricultural technology adoption for improving the production and productivity of smallholder farms. The development and dissemination of improved agricultural technologies should be given more emphasis to bring about a significant improvement in the productivity of smallholder mixed crop-livestock farming and eradicate the widespread poverty and food insecurity problem in the country in general and the study area in particular. The agricultural research and extension service should be given priority and emphasis ought to be placed upon fastening the production and dissemination of existing and newly developed improved technology.

Given the critical role of proximity of farmers to market centers and better roads for promoting adoption and productivity gains, the effort of investment in improved roads infrastructure should be expanded to achieve increased production. Moreover, improving technology delivery mechanism, mainly fertilizer production and distribution system, should be expanded. In this regard, encouraging the private sector in the input market could improve the efficiency of input availability and distribution. Therefore, the results of the study suggest that technology adoption of farmers should be improved by raising their education, farm household asset formation and providing extension and credit service. Such actions may, in turn, reduce food shortage problems and facilitate economic growth by enhancing productivity.

REFERENCES

Abay A, A Assefa (2004). The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agricultural Economics 30, 215–228.

Asfaw N, K Gunjal, W Mwangi, S Beyene (1997). Factors Affecting the Adoption of Maize Production Technologies in Bako Area, Ethiopia, Ethiopian J. of Agric. Econ. 1(2), 52-72.

Berhanu G, S M Swinton (2003). Investment in soil conservation in northern Ethiopia: The role of land tenure security and public programme. Agricultural Economics 29, 69-84.

Burton M, R Dorsett, T Young (1996). Changing preferences for meat: Evidence from UK household data. 1973-1993. European Review of Agricultural Economics 23(3), 357-370.

Clay D C, T Reardon, J Kangasniemi (1998). Sustainable intensification in the highland tropics: Rwandan farmers' investment in land conservation and soil fertility. Econ. Dev. Cult. Change 46, 351–378.

Cragg J (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica 39, 829-844.

CSA (Central Statistical Agency) (2008). The 2007 Population and housing census of Ethiopia, statistical report on population size and characteristics, 1(1), Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

CSA (Central Statistical Agency) (2009a). Agricultural sample survey, report on area and production, private peasant holding, Statistical Bulletin, Volume I, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

CSA (Central Statistical Agency) (2009b). Agricultural sample survey, report on farm management practices, private peasant holding, Statistical Bulletin, Volume III, Central Statistical Agency (CSA), Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization) (2007). Statistical database for Ethiopia, available at www.FOASTAT.FAO.ORG

Feder GL, RE Just, D Zilberman (1985). Adoption of agricultural innovation in developing countries; a survey. Economic Development and Cultural Change 32(2), 255 –298.

Feder G,LJ Lau, JY Lin, X Luo (1992). The determinants of farm investment and residential construction in post-reform China. Economic Development and Cultural Change 41, 1–26.

Greene WH (2003). Econometric analysis. 5th Edition. Macmillan, New York, USA.

Gujarati ND (1995). Basic econometrics, 3rd Edition. McGraw-Hill, Inc., New York, USA.

Hailu B (2008). Adoption of improved teff and wheat production technologies in crop and livestock mixed systems in Northern and Western Shewa zones of Ethiopia, PhD Dissertation, University of Pretoria.

Healy FJ (1984). Statistics: a tool for social research. Wadsworth Publishing Company, California, USA.

Johnston J, J Dinardo (1997). Econometrics methods. 4th Edition. The McGraw-Hill Companies, Inc, New York, USA.

Kiflu BK, Berhanu (2002). Farmer participatory research. An Overview .In Gemechu K., Yohannes G., Kiflu B., Chilot Y. and Asgelil D. (eds). Towards Farmers Participatory Research, Central High lands of Ethiopia. Proceedings of Client Oriented Research Evaluation Workshop, 16-18 October 2001, Holeta, Addis Ababa, Ethiopia.

MOFED (Ministry of Finance and Economic Development) (2006).

Ethiopia: building on Progress a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10).Volume I: Main text, Ministry of Finance and Economic Development (MoFED), September, 2006, Addis Ababa, Ethiopia.

MOFED (Ministry of Finance and Economic Development) (2010). National Income accounts, Ministry of Finance and Economic Development (MoFED), available at www.MOFED.database.com (Accessed on 4 February 2010).

Newman, C., M. HEnchion and A. Matthews (2001). Infrequency of purchase and double-hurdle models of Irish households' meat expenditure. European Review of Agricultural Economics 28(4), 393-419.

Teklewold H, D Legesse, Y Alemu, N Dana (2006). Determinants of adoption of poultry technology: a double-hurdle approach. Livestock Research for Rural Development. 18(40). Available on line from the web site at http://www.cipav.org.co/lrrd/lrrd18/3/tekl18040.htm (Accessed on 30 November 2008).

Tesfaye Z (2004). Adoption of inorganic fertilizer on maize in Amhara, Oromiya and Southern Regions. In Abebe Kirub (edt.), Agricultural technology evaluation, adoption and marketing Part 2. EARO, Addis Ababa, Ethiopia.

Tesfaye Z, H Alemu (2001). Adoption of improved maize technologies and inorganic fertilizer in northern Ethiopia: Research report no. 40. EARO, Addis Ababa, Ethiopia.

Tesfaye Z,T Bedassa, T Shiferaw (2001). Adoption of high yielding maize technologies in major maize growing regions of Ethiopia, research report no 41, Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.