Determinants of smallholder teff farmer's chemical fertilizer technology adoption in Southern Ethiopia, in case of Gena District in Dawro Zone (Heckman Two-Stage Model)

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Abstracts
Increasing technology adoption among smallholder farmers has a big potential to uplift living standards of poor through increasing production and consumption pattern. The objective of this study was analyzing determinant of smallholder teff farmer's chemical fertilizer technology adoption and its intensification in Southern Ethiopia, in case of Gena district in Dawro Zone. The study used data from 180 respondents from four selected teff dominant *kebele*s of Gena districts in Dawro Zone, through structured questioner. The descriptive statistics and Heckman two stage econometric methods were employed to analyze data collected from sampled household. The significance of coefficient of inverse Mill's ratio (λ) indicates the presence of selection bias and the effectiveness of applying Heckman two stage model. In the 1st stage of probit regression results of study show that the adoption decision of chemical fertilizer use were driven by factors such as farm size, size of family, family labor, education, access to credit; access to information, distance to near market place. In the second stage, the intensification of chemical fertilizer application was influenced by membership to cooperative, availability of extension service, access to credit, size of farm land, size of family member, family labor, educational status, sex of head. The policies which expand the accessibility of credit service, dissemination of productive agricultural technology information, and creating opportunity of education for farm house hold has potential to increase the chance of chemical fertilizer adoption decision and strengthen the level of adoption among smallholder farmers.

***Keywords**: Gena, Heckman two stage, Smallholder, Technology adoption*

JEL Classifications: D04, D12, D22, D90

INTRODUCTION

Agriculture plays an important role in economic growth, enhancing food security and poverty reduction in most of developing world. Smallholder agriculture is identified as a vibrant development tool for achieving Millennium Development Goals, one of which is to split the people suffering from extreme poverty and hunger by 2015 (World Bank, 2008).

The Smallholders considered more than 80 per cent of the world's estimated 500 million small farms and afford over 80 per cent of food items consumed in a large part of under developed world, contributing significantly to poverty reduction and food security

(UNEP, 2013). They harvest foodstuff and non-food products on a small scale with inadequate external inputs, cultivating field and tree crops as well as livestock, fish and other aquatic organisms. However majority of smallholder farmers relies on traditional methods of production and this has lowered the level of productivity. For instance, over 70% of the maize production in the majority of developing countries is from smallholders who use traditional methods of production (Muzari, Gatsi & Muvhunzi, 2012). These farmers generally obtain very low crop yields because the local varieties used by farmers have low potential yield, most of the maize is grown under rain-fed conditions and irrigation is used only in limited areas, little or no fertilizers are used and pest control is not adequate (Muzari, Gatsi & Muvhunzi, 2012; Shao, 1996).

Increasing agricultural productivity is critical to meet expected rising demand and, as such, it is instructive to examine recent performance in cases of modern agricultural technologies (Challa, 2013). Agricultural technologies include all kinds of improved techniques and practices which affect the growth of agricultural output (Jain, Arora & Raju, 2009). According to Lavison (2013) the most common areas of technology development and promotion for crops include new varieties and management regimes; soil as well as soil fertility management; weed and pest management; irrigation and water management. By virtue of improved input/output relationships, new technology tends to raise output and reduces average cost of production which in turn results in substantial gains in farm income (Challa, 2013). Adopters of improved technologies increase their productions, leading to constant socio-economic development. Adoption of improved agricultural technologies has been associated with: higher earnings and lower poverty; improved nutritional status; lower staple food prices; increased employment opportunities as well as earnings for landless laborers (Kasirye, 2010). On the other hand, non-adopters can hardly maintain their marginal livelihood with socio-economic stagnation leading to deprivation (Jain, Arora & Raju, 2009, 2009).

In low income countries, improving the livelihoods of rural farm households via agricultural productivity would remain a mere wish if agricultural technology adoption rate is low (Ajayi, Franzel, Kuntashula, & Kwesig, 2003). A new farm technology adoption has direct effect on the farmer's income resulting from higher yields and prices (Ibrahim, Mustapha & Nuhu, 2012). Therefore, it is necessary to adopt the recognized agricultural technologies so as to enhance production as well as productivity and thereby the living condition of the rural poor. The procurement and distribution of agricultural inputs more particularly high yield varieties and chemical fertilizer have been the central solution to enhance crop production and productivity so as to improve the living standards of farm households. This thought is crucial for countries like Ethiopia whose people heavily rely on subsistence farming. In line with this idea, different literatures were review regarding to the amount of agricultural inputs which have been applied to increase the production and productivity of teff in Ethiopia. For instance, the study by Engdawork (2009) identified that teff productivity depends on good weather condition and use of appropriate technologies (fertilizer, improved seed, and herbicide) with the recommended rate and time.

However, the adoption of productive technology very low with smallholder farmers and it is varying from farmer to farmer based on farmer's skill and external factors. This is similar with the report made by international finance corporation, to whom the adoption level of improved technology vary widely among smallholder farmers depending on their ability to invest in production. For example, the fertilizer adoption is near zero in some African countries, while it exceeds 500 kg per hectare in China and Egypt (IFC, 2013).

The adoption of more efficient farming practices and technologies that enhance agricultural productivity and improve environmental sustainability is also varying from place to place in Ethiopia. In central part of the country, there is relatively good practice but in peripheral part there is very low adoption resulting low productivity and stagnant life of farm family. This articulate the need for investigation to analyze demographic, socio-economic and institutional factors hindering the smallholder farmers technology adoption in crop potential area like Gena district of Dawro zone in south nation nationality and peoples regional state. Contrasting to its natural endowment, the crop commercialization in area was the lowest relative to other areas in South nation nationality and people's regional state (JICA, 2012). This show its low productivity resulted from low application or improper application of improved technology. In addition, there was no research has been done concerning the hindering factors of their low technology adoption. Hence, it needs empirical analysis to verify the factors responsible for low status of chemical fertilizer adoption in study area. Therefore, this study was designed to identify demographic, institutional and socio-economic factors that determine the smallholder teff farm house hold chemical fertilizer adoption decision and extent of adoption.

LITERATURE REVIEW

New technology adoption is a decision-making process in which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision (Ray, 2001). Agricultural technology adoption states to the decision to use a new technology, method, practice, etc. by a farmer (Feder, Just & Zilberman, 1985). On the other hand, extent of technology adoption is defined as the level of adoption of a given technological package among user (Nkonya, Schroeder & Norman, 1997). The expansion of new agricultural technology application has increased agricultural productivity, contributed to overall economic growth, and reduced food insecurity and poverty in developed and some developing countries (Bandeira & Rasul, 2005; Cornejo & McBridgje, 2002).

Different research on technology adoption across various region witness that demographic, institutional and socio-economic factor affects the farm house hold decision to adopt new technology and its intensification. Using panel probit and bivariate probit model in Malawi, Holden & Lunduka (2012), found that households with more livestock endowment and off/non-farm income were applying significantly more fertilizer on their plots, showing the importance of wealth for accessing fertilizer. According to Ermias (2013), the farmer's adoption decision and intensity of use of improved sorghum varieties were positively influenced by irrigated farm size, tropical livestock unit, farmers' perception of yielding capacity and taste preference for improved sorghum varieties while active labor ratio, distance from farmers training center to home, proportion of sorghum farm from the total cultivated land and farm size had negative and significant influence on both the probability and intensity of adopting improved sorghum varieties.

Moreover, Kapalasa (2014) examined the significant influence of demographic, socio-economic and Institutional factors such as age, access to extension services and distance to the nearest market of the household on farmers' decision to adopt and intensity use of improved soybean varieties. This study also found the negative influence of age of family head on the probability of adoption of new technologies. Bayissa (2014), applying double-hurdle model in East Wollega Zone examined that both adoption and intensity use of improved teff were positively and significantly influenced by sex of the household head, farming experience, participation on crop production training, educational level, yield superiority and maturity period of new varieties but the distance to the nearest market place had negative influence on the adoption and intensity use of improved technology.

METHODS

Description of the study area

This study was take place in South nation, Nationality and people's regional state Gena district of Dawro Zone, in South Nations, Nationalities, and Peoples' Regional state (SNNPR). Dawro zone lies in between 6^0 36' to $7^0$21' north latitudes and $36^0$68' to 37^0 52' east longitudes. The Gojeb and Omo Rivers circumscribe and demarcate Dawro from northwest to southwest in a clockwise direction. Dawro shares boundaries with Konta Special Wereda in west, Jimma in northwest, Hadiya and Kambata-Tambaro zones in northeast, Wolayita zone in east, and Gamo-Gofa zone in southeast. It has eleven administrative district and one town administration. The political center of the zone is Tarcha, which is located in 486 km from south western of Addis Ababa through Jimma road, and 282 km from Hawassa.

The climatic condition of the Gena district divided in to thee including Dega, Woina-dega and kola. Agriculture is the predominant economic activity in the Gena district. Crop and livestock production is the main household activities and the basis of subsistence in district. Rain fed mixed farming is practiced in all parts of the district i.e. livestock husbandry and crop production entirely practiced and irrigation (flood) farming practiced in very few area. Due to agricultural dependence on rain water, many crops are planted during rainy seasons (meher). The dominant cereal crops like maize, teff and wheat produced in meher season and collected from October to December. Major crops produced in the area include maize, teff, wheat, barley, sorghum, pulses, enset etc.

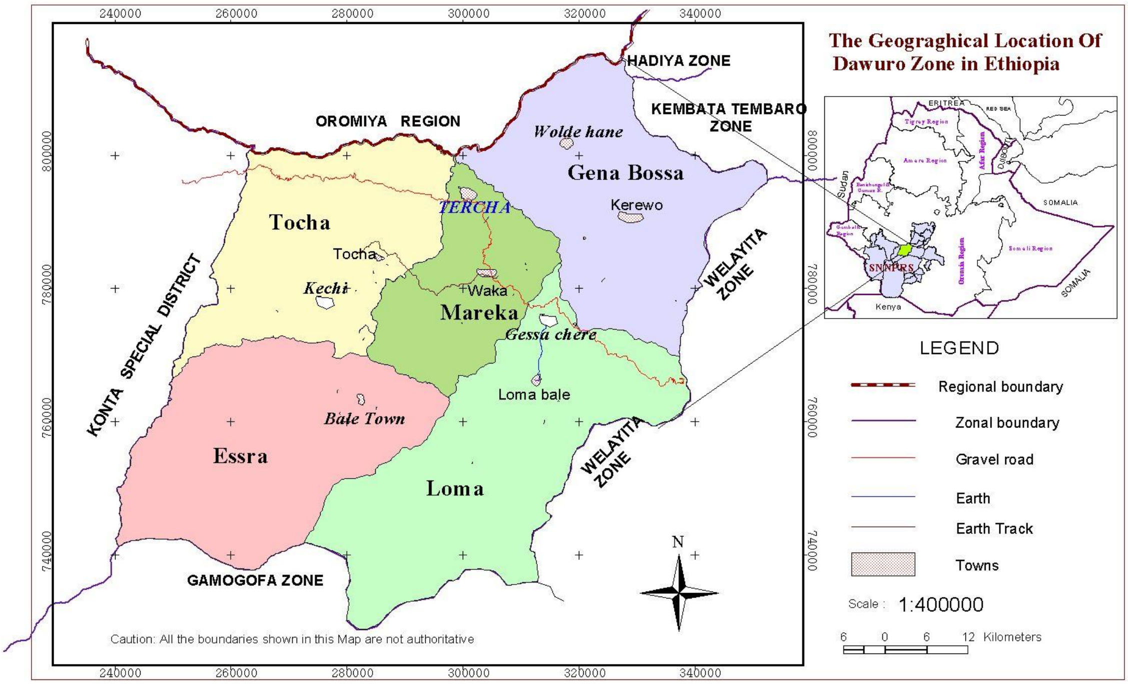

Figure1. The Location of Gena district in Ethiopia

Research strategy

In this inquiry, both quantitative and qualitative research strategies was employed. The quantitative strategy used to investigate the data that was collected using structured questionnaire from 180 sampled farm household heads. The qualitative research strategy used to analyze data that was collected using the unstructured interviews with local traders; rural experts; *kebele* administrative body; and consumers to capture supplementary information and to observe the validity of information's from household survey.

Research design

The cross-sectional (survey) research design was applied in this study. Accordingly, demographic, socio-economic and institutional data related to chemical fertilizer application status of smallholder farm family was collected for the harvest year of 2018/19 and analyzed through econometric and descriptive methods.

Sample size determination

The samples for this study distinguished according to the formula for sample size determination for finite population given by Kothari (2004) as shown below;

$$n = \frac{z^2.p.q.N}{e^2(N-1)+Z^2.p.q} \quad (1)$$

Where:
n = stands for estimated sample size,
E = the allowable error;
N = number of population under the study;
p = sample proportion of successes;
q = 1 – p;
z = standard variate for given confidence level (as per normal curve area). It is 1.96 for a 95% confidence level.

Assuming confidence level 95.5%; N=1262; e = 0.02; z =2.05; p = 0.02 and q = 1-0.02 we can have the following:-

$$n = \frac{(2.05)^2 \times 0.02 \times (1-0.02) \times 1262}{(0.02)^2 \times (1262-1) + (2.05)^2 0.02 \times (1-0.02)} = \frac{103.9496}{0.5867} \cong 177 \quad (2)$$

Hence, 177 respondents rounded off to 180 to enable the distribution of the sample in to four selected *kebele*.Based on the size of farm household in each *kebele* these 180 potential respondentswere designated.

Table 1. The list of selected *kebele*s and sample size in each study site

Selected site	No. of farm household in *kebele*			Sampled respondent
	M	F	Total	
Dilamo	308	22	330	45
Baza-Koysa	379	23	402	58
Wozo-Hylata	222	30	252	35
Denba-Gena	264	14	278	42
Total	1173	89	1262	180

Source: survey data (2018/19)

Methods of data analysis

In this study the descriptive statistics such as mean, standard deviation, percentages, frequency, t- test, Chi-square and graphs were used in analyzing the data. Furthermore, it was assumed that smallholder farmers who cultivate teff may or may not apply chemical fertilizer in teff cultivation. Therefore, the dependent variable in this model is discrete consisting of two outcomes, yes or no. In this case, the use of Ordinary Least Square/OLS technique for such variables poses inference problems, and thus not appropriate for investigating dichotomous or limited dependent variables. In such circumstances, maximum likelihood estimation procedures such as logit or probit models are generally more efficient (Gujarati, 1995).

Several investigators used different models for analyzing the determinants of technology adoption at farm level. Various adoption studies have used Tobit model to estimate adoption relationships with limited dependent variables while the others used double-hurdle model. However, it is conceivable to use Heckman's (1979) two step procedure in case of anticipated problem of selection bias in the sample. Selection bias was anticipated in this study because among the representative not all households are believed to participate in fertilizer adoption due to individual problems.

The Heckman two-step selection model allows for separation between the initial decision to adopt technology $(Y > 0 \; versus \; Y \leq 0)$and the level of their application. The model uses in the first step a probit regression to assess the probability of decision to adopt and in the second step uses ordinary least squares (OLS) to determine the intensity of adoption (Green, 2007) and the method correct sample selection bias. This technique used in order to control the selectivity bias and endogeneity problem and to obtain consistent and unbiased parameter estimates (Green, 2007). In selection model procedure, sample bias is determined by the relationship between the residuals of the two stages (stage 1 and stage 2). Estimates are biased if the residuals in the stage 1 and 2 are correlated. Similarly, Stage 1 does not affect stage 2 results if the residuals are unrelated. Positive and negative correlations between residuals are indicated respectively, by positive and negative mu (μ) values, which is the correlation between error terms of two regression model.

The first stage Heckman two step or the probit model that analyze the factors determining the probability of chemical fertilizer adoption decision specified as:

$$pr(Y_{1i} = 1/x_{1i}, \beta_{1i}) = \Phi\big(f(x_{1i}, \beta_{1i})\big) + \varepsilon_i \quad (3)$$

Where;Y_{1i} is an indicator variable that is equal to unity for chemical fertilizer user households;Φ is the standard normal cumulative distribution function; x_{1i} is variable that affect adoption decision and was described in table 3.2; β_{1i} is a coefficient to be estimated. The variable Y_{1i} takes the value 1 if the household use chemical fertilizer and zero otherwise. This can be shown mathematically:-

$$Y_{1i}^* = \beta_0 + \beta_{1i} X_{1i} + \varepsilon_i \quad (4)$$

Where; i = 1, 2, 3……………….n

$$Y_{1i} = \begin{cases} 1 \; if \; Y_{1i}^* > 0 \\ 0 \; if \; Y_{1i}^* \leq 0 \end{cases} \quad (5)$$

Y_{1i}^* is a latent variable of marginal utility the farmer's get from adoption of chemical fertilizer input,

β_0 is Constant term,

ε_i is error terms in the first stage model assumed to be normally distributed with zero mean and constant variance (σ^2).

In the second stage parameters can consistently be estimated by OLS by incorporating an estimate of the inverse Mills ratios denoted as λ_i from probit regression model as additional explanatory variable as specified bellow:-

$$Y_{2i} = \alpha_0 + \alpha_i X_{2i} + \mu_i \lambda_i + v_i \quad (6)$$

Where:
Y_{2i}= is the quantity fertilizer applied per hector,
X_{2i}= implies the explanatory variables influencing the level of chemical fertilizer applied shown in table 3.2,
α_0 = is the Constant term in OLS regression model,
α_i = is the Parameters to be estimated in the second stage,
λ_i = is the inverse mills ratio computed from first stage estimation,
μ_i = implies the Correlation between first and second stage error terms or corr (ε_i,v_i),
v_i = is the error terms in the second stage.

According to Heckman (1979), the IMR (λ_i) is a variable for controlling bias due to sample selection. This term is constructed using the model in the probit regression (first stage) and then incorporate into the model of the second stage (OLS) as an independent variable. It can obtained:-

$$\lambda_i = \frac{\phi(\beta_0+\beta_{1i}X_{1i})}{\Phi(\beta_0+\beta_{1i}X_{1i})} \qquad (7)$$

Where, $\phi(.)$denotes the standard normal probability density function and $\Phi(.)$ denotes the cumulative distribution function for a standard normal random variable.
But the value of λ_i is not known, the parameters β_0 and β_{1i} can be estimated using a probit model, based on the observed binary result. Then the estimated IMR calculated as:-

$$\widehat{\lambda_i} = \frac{\phi(\widehat{\beta_0}+\widehat{\beta_{1i}}X_{1i})}{\Phi(\widehat{\beta_0}+\widehat{\beta_{1i}}X_{1i})} \qquad (8)$$

Hypotheses and justification of explanatory variables

One of the important parts in this section is to specify and hypothesize the dependent and explanatory variables that were used in the model. Regarding to its definition, measurement and hypotheses of variables, which was used in our model, summarized in the Table 2.

Table 2. Explanation of hypothesized effect of explanatory variables on chemical fertilizer adoption and its intensity

Variable	Nature of variable	Variable definition and measurement	Expected effect
Fertilizer adoption decision	Binary	1 if household use chemical fertilizer, 0 otherwise.	
Quantity of fertilizer applied	Continuous	Fertilizer in kg per hector	
Age of the farm household head	Continuous	Age of the household head in year	-/+
Farm size	Continuous	Farm land size in hectare	+
Household labor	Continuous	household labor force or number of family in working age	+
Size of family	Continuous	number of family members	-
Distance to the market	Continuous	Distance from selected farm household to the market place in Km	-
Sex of farm head	Dummy	sex of farm household head (if female=1, 0, otherwise)	-
Educational status of the household head	Dummy	Educational status of the household head(1 literate, 0, otherwise)	+
Participation in nonfarm activity	Dummy	participation in nonfarm activity(if have =1,0, otherwise)	-/+

Variable	Nature of variable	Variable definition and measurement	Expected effect
Road condition	Dummy	Road condition to nearby town (if Good=1, 0, Otherwise)	+
Membership of cooperative	Dummy	Households membership to coope-rative (if member Yes=1,0 Otherwise)	+
Access to extension	Dummy	Access to extension agent support (if have access Yes=1, 0 Otherwise)	+
Use of credit	Dummy	use of credit (having access=1, 0, otherwise	+
Access to information	Dummy	access to new technology adoption skill (having inf. =1, 0, otherwise)	+

Source: Authors hypothesis (2018/19)

RESULT AND DISCUSSION

Descriptive analysis

Out of total sample of 180 smallholder teff farm household, 135(75%) participated in adoption of chemical fertilizer in their cultivation, while the remaining 45(25%) were no practicing fertilizer technology. Table 3 illustrate the mean, minimum and maximum age of head, size of land ownership, distance to market center, number of family and family labor for total survey, fertilizer adopter and non-adopter in comparison.

The descriptive statistics result for continuous variable (Table 3, t-value) show that there was no statistically significant difference between fertilizer adopter and non-adopter concerning age of head, family size and distance to local town or market place while there was significant difference in land holding and handiness of family labor. This demonstrates the importance of family labor force and arable land whether the household to adopt or not to adopt productive technology.

Table 3. Description of continuous variables

Variables	Participant(N=135)			Non- participant (N=45)			Total (N=180)			t-value
	Mean	Min.	Max.	Mean	Min	Max.	Mean	Min.	Max.	
Age of HH	47.22	26	82	47.02	28	75	47.17	26	82	0.0955
Size of land holding	3.03	1	5	2.29	0.5	5	2.84	0.5	5	3.5251***
Size of family	7.4	3	13	7.68	4	13	7.47	3	13	0.7219
Size of active family	3.54	1	8	3.07	2	10	3.42	1	10	1.8941**
Distance to local town	8.47	6	13	9.29	6	13	8.68	6	13	2.8332

****, ** and * imply statistically significant at 1, 5 and 10% respectively.*
Source: Own survey data (2018/19)

Table 4.summarizes frequency, percentage and level of influence of dummy variable. Accordingly, there was statistically significant difference between fertilizer adopter and non-adopter in education level of head, membership to cooperative, affordability of credit and access to information. On the other hand, the difference between chemical fertilizer adopter and non-adopter is not significant in gender, obtaining extension service and participation of off-farm activity.

Table 4. Description of dummy variables

Variables		Participant		non- participant		
		Frequency	Percent	Frequency	Percent	t-value
Had female headed family	Yes	16	11.85	17	37.78	(4.0448)
	No	119	88.15	28	62.22	
The family headed was literate	Yes	70	51.85	3	6.67	5.7966***
	No	65	48.15	42	93.33	
Participate in non-farm activity	Yes	28	20.74	8	17.78	0.4282
	No	107	79.26	37	82.22	
Have member to cooperative	Yes	47	34.81	6	13.33	2.7813***
	No	88	65.19	39	86.67	
Have access to extension	Yes	123	91.11	39	86.67	0.8576
	No	12	8.89	6	13.33	
Have access to credit	Yes	49	36.30	5	11.11	3.2689***
	No	86	63.70	40	88.89	
Have access to information	Yes	45	33.33	1	2.22	4.3325***
	No	90	66.67	44	97.78	

****, ** and * imply statistically significant at 1%, 5% and 10% respectively.*
Source: Own survey data (2018/19)

An econometric estimation results

In this sub-section, Heckman two stage selection analyses is executed to identify the household-level demographic, socio-economic and institutional factors that determine the decision of smallholder farmers to adopt or not to adopt chemical fertilizers in the first stage by applying probit regression. In the second stage the conditional estimation/OLS method was used to investigate factors that influence the level of their adoption.

However, before running the regression analysis, the diagnostic tests, such that, the existence of multicollinearity and the problem of heteroscedasticity of variables included in the model are needed to be checked both for the continuous and discrete explanatory variables. According to Gujarat (2004), when the values of VIF approach to infinitive there is serious problem of multicollinearity, while if VIF is below 10 there is no much problem. In this study all the computed value of VIF for explanatory including IMR variable was blow five. Therefore, there is no evidence of multicollinearity problem in our model. The data were tested for heteroscedasticity using the Breusch-Pagan test (Wooldridge, 2012). The Breusch-Pagan test evaluates the null hypothesis of a constant variance in the data. The Chi-square value results of STATA output were presented in appendix--. Accordingly, the null hypothesis of a constant variance was not rejected implying absence of heteroscedasticity in survey data.

Factors determining smallholder teff farmers' chemical fertilizer technology adoption decision

Table 5. shows the probit regression and marginal effect of probit outcomes of factors that influence the likelihood of small teff farmers' technology adoption decision. The models constructed with 13 independent variables and out of these 8 variables are significantly determining the adoption decision with hypothesized sign. These variables include size of farm land, size of family, availability of family labor force, education status of household head, accessibility of credit service ; access to modern technology information, distance to near town and nearby road condition significantly affect the teff farmers' technology adoption decision. Whereas, age of household head; participation in off-farm activity; sex of household head; membership to farm cooperative and access to

agricultural extension service insignificantly but all variables with expected sign influence the technology adoption decision.

Table 5. Factors that determine teff farmers' chemical fertilizer technology adoption decision – Probit model result

Variables	Parametric estimation			Marginal effect		
	Coefficient	Std. Err.	*z*	Coefficient/dF /dx	Std. Err.	P>|z|
Age of HH	-.000669	.0114707	-0.06	-.0001013	.0017342	0.953
Size of farm land	.2833829	.1361792	2.08	.0429217**	.0222735	0.037
Size of family	-.20539	.0697466	-2.94	-.0311087***	.0125296	0.003
Size of family labor	.314829	.1209661	2.60	.0476846***	.0194406	0.009
Distance to nearby town	-.2330726	.0856155	-2.72	-.0353016***	.0151054	0.006
Sex of HH	-.3871656	.3162718	-1.22	-.0692904	.068749	0.221
Education status of HH	1.030386	.376136	2.74	.1425391***	.0579773	0.006
Off-farm activity	.0719233	.3476857	0.21	.0105712	.0498617	0.836
Road condition	-.6056992	.3149832	-1.92	-.0938703*	.0544667	0.054
Membership to coop.	.1774871	.3801732	0.47	.0255694	.0523672	0.641
Access to extension	.4178456	.4081969	1.02	.0790363	.0929736	0.306
Access to credit	1.035122	.4084254	2.53	.122643**	.047505	0.011
Access to input technology info.	1.753076	.6617307	2.65	.1691507***	.0460535	0.008
Constant	1.845224	1.087742	1.70	-	-	-

Number of observation = 180; LR chi2 (13) = 81.33; Probability > chi2 = 0.0000
Log likelihood = -60.56; Pseudo R2 = 0.4017
****, ** and * imply statistically significant at 1, 5 and 10% respectively.*
Source: Survey data (2018/19)

As specified in Table 5., the marginal effect report of the probit regression provides the probability that a farm household able to adopt technical input particularly chemical fertilizers in their teff production.

The farm size of respondent was positive and had statistically significant influence at 5% level on the adoption of chemical fertilizer input. The marginal effect result indicates that a farmer, who has one additional hector of arable land, would increase the likelihood of teff farmers' chemical fertilizer adoption by 4.29 %. This result is in line with the argument of Nowak (1987), which claimed that larger arable land ownership enable farmers to have more flexible in their decision making, greater access to discretionary resource, and give more opportunity to adopt new farm practice. This is due to the fact that availability of more arable land enable farmers' to allocate more land to produce teff crop leading increment in output and the rise in output widen the chance of farmers' more income and the increment in family income enable farmers to widen the understanding and use of new technology.

As hypothesized, distance to the nearest town was found to be negatively and significantly influenced the probability of adoption of chemical fertilizer adoption decision at 1% significance level. Holding other variables constant, a kilometer increase from farmers' residence to near town leads 3.5% reduction on the likelihood of adoption of chemical fertilizer on teff cultivation. This implied that the longer the distance between farm basis and the market place, the lower will be the probability of adoption of fertilizer input. Farmers who dwell around town or local market center might have more chance to access information about new agricultural technology and input. Moreover, nearness to market place reduce the transportation and other transaction costs out lied in search for fertilizer input and then reduce cost of production than those farmers who are in distant location. This finding is similar with Susie (2017), Bessir (2014) and Debelo (2015). According to their finding an increase in distance from market center increases transaction costs related to the sale of farm output and purchases of critical input that would reduce farmers' motivations to engage in agricultural production activities using improve technologies.

In the same genre, the nearby road condition found the expected negative influence and is significant at 10% level, on the probability of adoption of chemical fertilizer in teff production. Keeping other variables constant, compared with farmers who have good roads on the spot, those farmers who have no accessible road infrastructure reduce the probability of chemical fertilizer adoption by 9.5 %.

As expected, the availability of family labor force have positive impact on likelihood of teff farmers' chemical fertilizer adoption at significance level of below 1%. The marginal effect verify that the availability of one more active person in family increase the probability of chemical fertilizer input adoption on teff cultivation by 4.67 %, holding all other factors constant. This finding is consistent with the results of Beshir, Emana, Kassa, & Haji (2012), which reason out that improved farm practices are labour intensive and hence the household with relatively high labour force uses the technologies on their farm plots better than those with little labour force in family. In contrary, the size of family is negatively related with the probability of fertilizer adoption at 1% level of significance. A one additional person in family member results, 3.11% decline in likelihood of farm household fertilizer adoption. The large family is expected to consume the higher quantity of crop compared to small family, causing smaller amount of marketable surplus with low level of family income.

As hypothesized, education level of household head was found to be positively and significantly influenced the probability of adoption of chemical fertilizer input in teff cultivation. Holding other variables constant, as compared to illiterate farmers the probability of adoption of fertilizer input in teff production for literate farmers would increase by 14.25 %. This indicates that the educated farmers are more confident to adopt fertilizer input in their cultivation than those who are illiterate. Farmer with formal education have better ability to obtain information's about productive input and new technology of production relative to uneducated one. Education also increase decision making ability of farmers based on identified information of cost and benefit. This result is consistent with work of Bayissa (2014) and Leake & Adam (2015), they forwarded that having education increases the probability of adoption of new agricultural technology by farmers.

As expected, access to input market information has shown positive influence on likelihood of teff farmers' fertilizer technology adoption decision at 1% level of significance. Keeping other variables constant, farmers with accessibility to input market information have 16.91% better opportunity to adopt chemical fertilizer than those with insufficiency of information. Accessible information increase farmers chance to adopt technology because it enables farmers to make right decision how to apply and increase productivity with minimum probability of risk.

Access to credit service also positively determines the probability of teff farmers' fertilizer technology adoption at 5% level of significance. Keeping other variables fixed, availability of credit service encourage the likelihood of household fertilizer technology adoption decision by 12.26 %. This result was consistent with finding of Ogada (2013), which reason out that accessible credit solve the smallholders problem created due to their low saving ability to purchase relatively more expensive technologies like inorganic fertilizer. Hence, the accessibility of credit enables farmers to purchase inputs like improved seed, fertilizer, which increase output through productivity increment. On the other hand, accessibility of credit solve farmers cash problem that hinders farmers to purchase chemical fertilizer at early period of crop collection in which there was no sufficient market or low price for agricultural output. Therefore, farmers who have availability of credit service are more likely to adopt chemical fertilizer than without credit.

Factors determining the intensity of teff farm household technology adoption

The Heckman model in the second stage estimation identifies the factors that determine the intensity of chemical fertilizer adopted using the OLS model. The coefficient of inverse Mill’s ratio /Lambda is significant at 5% level. The significance of Mill’s ratio discloses the presence of selection bias and the effectiveness of applying Heckman two stage models due to its ability to handle the selection problem. The positive sign of lambda reflects that the error terms in the adoption decision model and selection equations are positively correlated.

Table 6. reveals that the regression results of variables that affect the level of technology adoption among smallholder farmers. Out of 14 explanatory variables size of farm land, size of family member, the number of family labor force, educational status of house hold head, membership to cooperative, availability of extension service, access to credit, sex of head and lambda significantly influence the intensity of technology adoption, while age of house hold head, the existing road condition, participation in off-farm activity, availability of input information and distance to the nearest town place insignificant to influence the level of adoption.

Table 6. Results of the second-stage selection estimation (intensification of technology adoption)

Variables	Coefficient	Std. Err.	***t***	P>| ***t*** |
Age of HH	.0078799	.0069553	1.13	0.260
Farm land size	.2404788***	.0683283	3.52	0.001
Size of family	-.1033396***	.0395494	-2.61	0.010
Family labor	.1871805***	.0652871	2.87	0.005
Distance to near town	-.0596027	.0492811	-1.21	0.229
Sex of HH	-.4295681*	.2439408	-1.76	0.081
Education of HH	.4842824**	.1938138	2.50	0.014
Participation in off-farm activity	-.1551343	.1817373	-0.85	0.395
Road condition	-.0074408	.1632477	-0.05	0.964
Membership to coop.	.468811***	.1653608	2.84	0.005
Access to extension	.5587541**	.2618734	2.13	0.035
Access to credit	.575232***	.1705756	3.37	0.001
Access to information	.2800549	.1785002	1.57	0.119
Mills lambda	.7250642*	.369385	1.96	0.052
Constant	1.314168*	.6838175	1.92	0.057

Number of observation = 180; Censored observation = 45; Uncensored Observation = 135; R-squared = 0.4124; Adj R-squared = 0.3439; F (14, 120) = 6.02; Prob> F = 0.0000
****, ** and * imply statistically significant at 1, 5 and 10% respectively.*
Source: Survey data (2018/19)

Analogous to the first stage result, size of land holding, family size, size of house hold labour, educational status of family head and availability of credit service determine both adoption decision and intensity of adoption significantly with expected sing. Moreover, level of household head education and availability of credit service have the expected positive effect on level of fertilizer adoption at significance level of 5% and 1% respectively. The size of family and household labor force determine the intensity of fertilizer adoption by 1% significance level and have expected negative and positive influence on intensity of adoption respectively. One additional person in family deteriorate the use of fertilizer by 0.10kg, while one more active labor to family enhance the use of fertilizer by 0.19kg, holding all other variables constant. Size of land holding also found positive and significant influence on the level of fertilizer adoption at 5% level. A one hector increase in land holding increase fertilizer applied by 0.24kg, keeping other variables constant.

As expected, being member to producer group has positively and significantly influences the intensity of fertilizer adoption at 1% level. Membership to group empowers farmers to obtain on time productive technology information and minimize transaction costs both on production process and output marketing through creating group sharing of cost and benefits. This finding is similar with Sebatta, Mugisha, Katungi, Kashaaru & Kyomugisha (2014), they reason out that working in group creates collaboration among the farmers and enable them to access market information and sharing of best experiences together. Access to extension services is also shown expected sign and statistically significant at 1% level. This suggests that households, who had access to extension programs support, are more likely to intensify chemical fertilizer adoption on their teff cultivation than without contact.

Regarding the effect of the remaining variables, access to information, off-farm income availability, distance to town and age of head were statistically insignificant to influence the intensity of fertilizer with expected influence but nearby road condition shown unexpected negative sign.

CONCLUSION AND POLICY IMPLICATION

Conclusion

A remarkable improvement in agricultural Productivity in majority of developing countries in late 1960s resulted from agricultural Transformation agenda including of agricultural research, extension services and rural infrastructural development that basically underline the role technology adoption among smallholder's farmer in increasing production was vital. Technological change in agriculture comprises of introduction of high yielding variety of seeds, fertilizers, plant protection measures and irrigation. These changes in agricultural sector augment the productivity per unit of land and bring about rapid increase in production to tackle the severe problem of poverty. In Ethiopia, even though some progress has been recorded over time, the use of agricultural technologies special chemical fertilizer is found at its low level. To this end, this study was conducted with the aim of investigating the institutional, demographic and socio-economic factors that influence the adoption decision and extent of chemical fertilizer among smallholder teff farmers. Accordingly, the descriptive statistics and Heckman two stage econometric methods were employed to analyze data collected from sampled household. The significance of coefficient of inverse Mill's ratio (λ) indicates the presence of selection bias and the effectiveness of applying Heckman two stage model.

The adoption decision of chemical fertilizer use was driven by factors such as size of farm land, size of family, availability of family labor force, education status of household head, accessibility of credit service; access to modern technology information, distance to near town and nearby road condition. While the intensity of chemical fertilizer application was influenced by membership to cooperative, availability of extension service, access to credit, size of farm land, size of family member, the number of family labor force, educational status of house hold head, sex of head.

Policy implication

In light of these findings, Membership to a farmer group or cooperative being a crucial factor in enhancing the farmer technology adoption, it is suggested that policy makers should promote collective action among smallholders because it eases access to production, technology diffusion and marketing information as well as cheaper inputs.
Moreover, the policies which expand the accessibility of credit service, dissemination of productive agricultural technology information, and creating opportunity of education for farm house hold has potential to increase the chance of chemical fertilizer adoption decision and strengthen the level of adoption among smallholder farmers.

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