
Determinants of Adoption of Improved Teff Varieties by Smallholder Farmers: The Case of Kobo District, North Wollo Zone, Amhara Region, Ethiopia

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Abstract: Adoption and wider diffusion of improved *teff* varieties is playing vital role in reversing the present situation of food insecurity in many parts of Ethiopia. However, the uses of improved *teff* varieties are constrained by various factors. Hence, in this study, an attempt was made to examine factors affecting adoption and intensity of use of improved *teff* varieties. A multi-stage random sampling technique was employed to select 150 sample households from Kobo district. Double-hurdle model was used to identify factors influencing households' adoption decision and intensity of use of improved *teff* varieties. The result of double-hurdle model shows that educational level of household head, participation on crop production demonstration, distance from the nearest market, frequency of extension contact, off/non-farm income, proportion of cultivated land allocated for *teff*, livestock holding, improved *teff* seed availability, and perception on better yielding capacity of the new varieties over local varieties were found to be significantly influencing households adoption decision, whereas, sex, age, family labor, membership to an organization, off/non-farm income, frequency of extension contact and land allocated for *teff* were found to be significantly influencing the intensity of use of improved *teff* varieties. Therefore, the result implies that strengthening the existing extension services, providing good transport facilities for farmers through infrastructural development, improving access to improved seeds, improving farmers' level of education, strengthening farmer's organization, encouraging the use of labour saving technologies, improving crop-livestock production system and provision of demonstrations of new technologies are areas that need policy attentions to enhance adoption and intensity of use of improved *teff* varieties. Further, high yielding *teff* varieties need to be given special priority in *teff* variety scaling out programs.

Keywords: Adoption, Improved *teff* Varieties, Double-hurdle Model, Intensity, Kobo

1. Introduction

Ethiopia is fundamentally an agrarian country and agriculture is Ethiopia's most important sector, crucial for the country's food security and the livelihoods of its people. The sector is the largest contributor to the overall economy and is fundamental to Ethiopia's overall development. Despite the dominance of traditional smallholder farmers in the sector, increased engagement with mid and large-scale private sector partners has brought new technologies and improved market linkages [2]. Although the transformation towards a more

manufacturing and industrially oriented economy is well underway, the agriculture sector continues to be the most dominant aspect of the Ethiopian economy, accounting for nearly 42% of GDP, 85% of employment, and 90% of foreign export earnings [11].

Despite of its contribution to the national GDP by large, agriculture in Ethiopia is subsistence. Smallholder farmers are cultivating 95% of their farmland using mostly traditional farming practices and inadequate improved technology be found in the low productivity Ethiopian agriculture. Furthermore, the majority of the agriculture sector is made up

of smallholder farmers who live on less than 1.17 hectares of land (38). This is particularly true to the major food crops grown in the country.

Teff is one of the cereals grown in most agro-ecological zones of Ethiopia and mainly used for food consumption. It ranks first in area coverage and second after maize in total production. The crop accounted for about 24.17% of the total grain cultivated land [11]. It is a multipurpose crop, being utilized in different forms where the grain is used to make the Ethiopian staple food, *Injera*. It is also valued for its fine straw, which is used for animal feed as well as for reinforcing mud for plastering wooden walls of buildings [6].

The popularity of *teff* can be also explained with its high price. It is the highest priced cereal grown in Ethiopia and is an attractive cash crop for farmers. Combined with the high share of the final price obtained by the farmers, income from *teff* is much higher than income from other cereals and even 34% higher than income from coffee, the major export crop in Ethiopia [25, 37]. About 25-30 million people are directly depend on *teff* production. The higher *teff* price followed by an increasing commercialization of smallholder farmers represents an opportunity to directly increase the living standard of rural communities in Ethiopia [20]. Despite its economic importance in Ethiopia, the productivity of *teff* remains low. For instance, in 2018/19 production year, *teff* yield was 17.56 qt/ha, significantly lower than other cereals, such as maize (39.92 qt/ha), sorghum (27.36 qt/ha) and wheat (27.64 qt/ha) [11]. The low *teff* yield is apparently explained by the limited knowledge about the possible avenues for improving *teff* productivity, together with the problems inherent to its botany. Moreover, *teff* yield is low because of lodging, low modern input use, traditional way of sowing, socio-economic factors such as lack of access to market information, post-harvest losses and lack of high yielding cultivars [6, 33].

Consequently, in Ethiopia, to increase the productivity of *teff* several improved varieties were developed and disseminated to farmers along with their optimum management practices [29]. However, different area-specific evidences indicate that intensity and adoption rate of improved *teff* varieties in the country is low. This low rate of adoption decisions of farmers is usually determined by various factors which can be specific to socio-economic, institutional, demographic and psychological. In addition, factors such as expensiveness and unavailability of seeds and desired varieties, lack of awareness and the serious sequence of agronomic practices have commonly been mentioned as the constraints contributing to the low level of improved *teff* varieties adoption [35, 17, 3].

The study area is mainly characterized by erratic rainfall condition, dependence on traditional technology and risk prone farming systems. As a result, crop production has become highly unpredictable and subsistence throwing the major proportion of the rural population in to food insecurity situation [28]. Apparently, food security of the majority of farmers can be enhanced through improving the performance agricultural production in the area. As part of this goal, in the

study area improved *teff* varieties are often introduced in a package program although adopters use part of the package.

In spite of such intervention, information with regard to adoption of improved *teff* varieties on location specific factors influencing adoption and intensity of adoption of improved *teff* varieties being promoted in the districts was not empirically studied and documented. Hence, this study was aimed at analyzing factors affecting the adoption and intensity of use of improved *teff* varieties in order to draw important conclusions and policy implications for future intervention.

2. Methodology

2.1. Description of the Study Area

The study was conducted at Kobo district, Northeastern escarpment of Amhara Region. The district town, Kobo is located on the Addis Ababa-Adigrat highway, found around 575 kilometers away from Addis Ababa. The landscape of this district is characterized by a broad fertile plain which is separated from the lowlands of the Afar Region by the Zobil Mountains, which are over 2000 m. a. s. l. [26]. The mean annual rainfall ranges between 500-800 mm while the temperature varies from a minimum of 19°C to a maximum of 33°C annually [28]. The agro-climatic feature of the area is tropical as 7.9%, 37.2% and 54.9% are *Dega*, *Weyina dega* and *Kola* respectively. In the district, there are 34 rural and 6 urban *Kebele* administrations. The total population in the district was estimated to be 239,504, of whom 120,383 were males and 119,121 were females [10].

The agricultural practice in Kobo is mainly characterized by mixed farming system where nearly 66.5% of the population is engaged in mixed farming whereas 27% and 2% of the population depend only on crop and livestock production respectively [26]. Crop production sub system in the district is both rain fed and irrigated. The rain fed crop production is dominated by cereals such as sorghum and *teff* whereas the irrigation crop farming is dominated by vegetables and cereals again. Improved *teff* varieties cultivated in the district are *Quncho*, *Boset* and *Zobel*. Currently, *Quncho* and *Boset* are widely cultivated varieties by farmers.

2.2. Data Type, Sources and Methods of Data Collection

The study used data generated from both primary and secondary sources. Cross sectional data of 2015/16 production season was used. This contains both quantitative and qualitative data collected from selected households with semi-structured questionnaire. Interview schedule was mainly used as a data collection tool. The interview schedules were first pre-tested using non-sample respondents before actual data collection and amendments were made. Accordingly, primary data were collected by interviewing smallholder farmers growing *teff* during the 2015/16 production season. This contains data on key demographic, institutional and socio-economic factors affecting adoption decision and intensity of adoption of improved *teff* varieties

and the perceptions towards improved *teff* attributes were collected. While, secondary data were collected from books, journals and other published and unpublished documents, from district agricultural offices, websites and other related sources to supplement primary data.

2.3. Sampling Procedure and Sample Size

Multi-stage sampling procedure was employed to select representative sample households. In the first stage, Kobo District from North Wollo Zone was selected purposively based on maximum cultivated land under *teff*. In the second stage, 4 *Kebeles* were selected randomly from 20 *teff* producing *Kebeles* of the district. Then, the farmers in each randomly selected *Kebeles* were stratified into adopter and non-adopter categories giving the relative homogeneity of sample respondents' adoption status. Finally, from each stratum of the randomly selected *Kebeles*, 150 representative sample respondents were selected randomly through taking probability proportional to size of *teff* growing households in each *kebeles* for both groups.

2.4. Methods of Data Analysis

The study used both descriptive statistics and econometric model for analyzing the data. Descriptive statistics such as mean, standard deviation, frequencies distribution and percentage were employed in order to have clear picture about the socio-economic, institutional and demographic characteristics of sample households. Chi-square test and independent sample t-test were used to see the presence of systematic association between those who adopt and those who do not in terms of hypothesized variables.

Econometric Analysis: Various researchers used different models for analyzing the determinants of technology adoption. In principle, the decisions on whether to adopt and how much to adopt can be made jointly or separately [7]. Several adoption studies have used Tobit model to estimate adoption relationships with limited dependent variables. Tobit model is, however, statistically restrictive because it assumes that the same set of variables determine both the probability of adoption and intensity level. In this case, the appropriate approach is to use double-hurdle model. This model assumes farmers faced with two hurdles in any agricultural decision making processes [12]. In this study, double-hurdle model was used since it allows for the distinction between the determinants of improved *teff* variety adoption and the intensity of use of improved *teff* varieties through two separate stages. The model estimation involves running a probit regression to identify factors affecting the decision to adopt using all sample households in the first stage and a truncated regression model on the participating households to analyze the intensity of adoption in the second stage.

As already noted, the general form of Cragg's double-hurdle model (probit and truncated models in particular) that was used for this study is specified as follows.

$$D_i^* = W_i' \alpha + U_i \quad (\text{Adoption Decision Equation}) \quad (1)$$

$$D_i = 1, \text{ if } D_i^* > 0, D_i = 0, \text{ otherwise}$$

Where, D^* is the latent variable describing the household's decision of whether or not to adopt improved *teff* varieties that takes the value 1 if the household adopted and 0 otherwise, D_i is the observed variable which represents the household's adoption decision, W_i is a vector of explanatory variables, α is a vector of parameters to be estimated and U_i is the error term.

$$Y_i^* = X_i' \beta + V_i \quad (\text{Intensity Equation}) \quad (2)$$

$$Y_i = Y_i^* = X_i' \beta + V_i \text{ if } Y_i^* > 0 \text{ and } D_i^* > 0, Y_i = 0, \text{ otherwise}$$

Where, Y_i^* is the latent variable describing the intensity of adoption of improved *teff* varieties. Y_i is the area of improved *teff* varieties cultivated in hectare signifying the intensity of adoption. X_i is vector of explanatory variables influencing how much the household use improved *teff* varieties, β is a vector of parameters to be estimated and V_i is the error term. If both decisions are made by the individual farmers independently, the error term are assumed to be independently and normal distributed as: $U_i \sim N(0, 1)$ and $V_i \sim N(0, \delta^2)$

The log-likelihood from the Cragg type double-hurdle model is the sum of the log-likelihood from a probit and a truncated regression. Hence, double-hurdle model is given by:

$$\text{Log } l = \sum_i \ln \left(1 - \Phi \left(W_i' \alpha \left(\frac{X_i \beta}{\sigma} \right) \right) \right) + \sum_i \ln \left(\Phi(W_i' \alpha) \frac{1}{\sigma} \phi \left(\frac{Y_i - X_i \beta}{\sigma} \right) \right) \quad (3)$$

Where, Φ and ϕ are standard normal cumulative distribution function and density function respectively.

To determine the appropriateness of models, a hypothesis test for the double-hurdle model against the Tobit model was made. The test can be done by separately estimating Tobit, truncated and probit regression models and then conducting a likelihood ratio test that compares the Tobit with the sum of the log-likelihood functions of the probit and truncated regression models. The LR statistic can be computed using the formula developed by [16] as:

$$\Gamma = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \sim \chi_k^2 \quad (4)$$

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 the equations.

The test hypothesis is written as: $H_0 : \lambda = \frac{\beta}{\sigma}$ and $H_1 : \lambda \neq \frac{\beta}{\sigma}$

The null hypothesis (H_0) that Tobit model is the best fit model will be rejected on a pre-specified significance level if $\Gamma > \chi_k^2$.

3. Result and Discussions

3.1. Rate and Intensity of Improved *Teff* Varieties Adoption by Sample Households

In the study area, farmers are commonly cultivating three improved varieties namely, *Quncho*, *Boset* and *Zobel*. Table 1

summarizes adoption status and area covered by improved *teff* varieties of adopter sample households. The results indicated that, out of the total adopters, 27 (37.5%) of them were practice *Quncho*, 33 (45.8%) were used *Boset* and it was most widely adopted variety, and only 12 (16.7%) of the adopters were users of *Zobel teff* variety. In this study, the adoption intensity measures the extent of adoption expressed in terms of area of land allocated to improved *teff* varieties. An average of 0.35 ha of land was found to be allocated for improved *teff* varieties by adopter sample households. Out of which, on average 0.11, 0.17 and 0.07 ha of land was allocated to *Quncho*, *Boset* and *Zobel* respectively.

Table 1. Adoption status and area covered by improved *teff* varieties.

Variety	Growers		Average area (ha)
	N	%	
Quncho	27	37.5	0.11
Boset	33	45.8	0.17
Zobel	12	16.7	0.07
All improved varieties	72	100	0.35

Source: own survey results, 2016

3.2. Result of Descriptive Statistics for Dummy and Continuous Explanatory Variables

The descriptive statistics of socio-economic, demographic and institutional characteristics of sample respondents

examined in this study are presented in Tables 2 and 3. Table 2 presents for dummy variables whereas Table 3 presents for continuous variables. Out of the total sample respondents 72 (48%) were adopters and 78 (52%) were non-adopters.

Table 2 shows the result of descriptive statistics for dummy explanatory variables. Totally, 150 household heads were considered in this study. Out of these, 134 (89.3%) were male headed and the remaining 16 (10.7%) were female headed households. The chi-square test was computed for dummy variables and it was found to be statistically significant for credit access at 5% significance level, for perception of farmers towards yield, participation on demonstration, improved *teff* seed availability and education level at 1% significance level and for membership to an organization it was found to be statistically significant at 10% significance level.

Table 3 shows the result of descriptive statistics for continuous variables. As indicated from the table, t-value was computed for all continuous variables and it was found to be statistically significant for family labor in adult equivalent, livestock holding in TLU, distance from the nearest market, cultivated land size and proportion of cultivated land allocated for *teff* at 1% level of significance and for age of the household head at 10% level of significance. This implies that there was significant difference in all these variables between the two adoption categories.

Table 2. Descriptive statistics for dummy explanatory variables.

Variables		Adopters		Non-adopters		Total		χ^2 -value
		N	%	N	%	N	%	
Sex of household head	Male	67	93.1	67	85.9	134	89.3	2.01
	Female	5	6.9	11	14.1	16	10.7	
Education level	Illiterate	12	16.7	45	57.7	57	38	42.25***
	Read & write	23	31.9	27	34.6	50	33.3	
	Grade (1-8)	30	41.7	6	7.7	36	24	
	Grade 9 & above	7	9.7	0	0	7	4.7	
Participation on demonstration	Yes	61	84.7	31	39.7	92	61.3	31.94***
	No	11	15.3	47	60.3	58	38.7	
Improved <i>teff</i> seed availability	Yes	71	98.6	57	73.1	128	85.3	19.50***
	No	1	1.4	21	26.9	22	14.7	
Access to credit	Yes	39	54.2	27	34.6	66	44	5.81**
	No	33	45.8	51	65.4	84	56	
Membership to an organization	Yes	61	84.7	57	73.1	118	78.7	3.03*
	No	11	15.3	21	26.9	32	21.3	
Perception on yield capacity	Yes	62	86.1	38	48.7	100	66.7	23.56***
	No	10	13.9	40	51.3	50	33.3	

Table 3. Descriptive statistics for continuous explanatory variables.

Variables	Adopters		Non-adopters		Combined		t-value
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Age of household head	41.93	8.90	44.78	9.80	43.41	9.43	-1.86*
Farming experience	20.00	8.40	18.18	9.46	19.05	8.98	1.24
Family labor	2.75	0.96	2.07	0.84	2.39	0.95	4.61***
Off/non-farm income	5574.2	9895.2	3592.2	9016.1	4543.6	9468.6	1.28
Cultivated land size	0.99	0.36	0.81	0.29	0.89	0.34	3.59***
Livestock holding	3.43	1.61	2.11	1.40	2.74	1.64	5.34***
Extension contact	7.67	4.88	7.03	4.33	7.33	4.59	0.85
Distance from the nearest market	9.39	1.80	11.05	1.62	10.26	1.89	-5.89***
Proportion of cultivated land allocated for <i>teff</i>	0.42	0.19	0.34	0.13	0.38	0.16	3.05***

***and *represents the level of significance at 1% and 10% respectively.

Source: own survey results, 2016

3.3. Econometric Model Results

Prior to the estimation of the Double-hurdle model the variables included in the models were tested for multi-collinearity using correlation coefficient. The test result shows that the problem of multi-collinearity among all the explanatory variables did not find. A hypothesis test of Double-hurdle model against Tobit model was made. Accordingly Double-hurdle model was chosen over Tobit model and used to analyze the influence of various demographic, socio-economic and institutional variables on adoption and intensity of use of improved *teff* varieties. This is done based on log-likelihood ratio test. The test statistics of the double-hurdle versus the Tobit model indicated the rejection of Tobit model and acceptance of the double-hurdle model. The test result in Table A1 revealed that the calculated statistical value of likelihood ratio was 90.64 which was greater than the tabulated or critical value of $\chi^2(16) = 32$ at 1% level of significance. This result provides an empirical result of farmers' independent decisions making regarding the adoption and intensity of use of improved *teff* varieties in the study area.

3.3.1. Factors Determining the Probability of Adopting Improved *Teff* Varieties

The results of the probit (first hurdle) model of the double-hurdle revealed that out of sixteen variables included in the model nine were found to be significantly influencing farmers' decision to adopt improved *teff* varieties. Detail of significant variables from the probit model are discussed as follows.

Education level of household head had a significant positive influence on the probability of adoption of improved *teff* varieties at 1% level of significance. This might be due to relatively literate farmers having more access to information, capable to interpret and analyze the information and become aware to new technology than illiterate farmers and this awareness enhances the adoption of new technologies. The model result indicates that, as compared to illiterate farmers the probability of adoption of improved *teff* varieties for literate farmers would increase by 35.3%. Similarly [23, 5, 24] reported that having education increases the probability of adoption of new agricultural technology by farmers.

As the model result indicates, the variable off/non-farm income was positively and significantly influenced the likelihood of adoption of improved *teff* varieties at 5% significance level. Keeping all other variables constant, for each additional 1% increase in off/non-farm income the probability of adopting improved *teff* varieties increases by 4%. Hence, the result of this study revealed that farmers with relatively higher off/non-farm income are more likely to use improved *teff* varieties as compared to farmers with lower income. The reason might be off/non-farm income increases the income of the household and might increase the capacity to invest in technology adoption. The result is consistent with other findings by [18, 9].

Proportion of cultivated land allocated for *teff* had a

positive and significant effect on the probability of adoption of improved *teff* varieties at 5% level of significance. Other variables held constant, the marginal effect showed that an increase in proportion of cultivated land allocated for *teff* by 1% would result in 148.8% increase on the probability of adoption of improved *teff* varieties. This result implied that farmers who allocate relatively higher proportion of land for *teff* are more likely to adopt improved *teff* varieties than farmers who allocate relatively smaller proportion of land for *teff* production. The reason might be an increased risk taking behavior of farmers' with an increase proportion of *teff* area. Consistent with this, [40, 30] found that the higher the share of crop area the more likely to increase the use of improved technologies.

The number of tropical livestock unit had affected positively and significantly the probability of adoption of improved *teff* varieties at 5% probability level. Other variables held constant, as the number of livestock increase by one TLU, the probability of adoption of improved *teff* varieties increases by 13.4%. The result could be explained as, better risk bearing behavior of those wealthy farmers with better livestock would enable them to try those newly adopted *teff* varieties. Previous empirical findings by [27, 13] confirms this result.

As hypothesized, frequency of farmers extension contact with agricultural extension agents had a positive and significant effect on the probability of adoption of improved *teff* varieties at 5% level of significance. Other variables held constant, for each additional contact with extension agents the probability of adoption of improved *teff* varieties increases by 2.8%. The result indicated higher probability of farmers with more contact with extension agents in adopting than farmers with less contact. The possible justification for this is that frequent contacts create awareness and build the necessary knowledge for using the innovation and enhancing the exposure of farmers on the adoption practice of improved technologies. The result is similar with the finding of [39, 21].

Households' participation on crop production demonstration positively and significantly influenced the probability of adoption of improved *teff* varieties at 5% significant level. Other variables held constant, participation on demonstration would result in 36.7% increase on the probability of adoption of improved *teff* varieties. The result in relation to this variable showed that farmers who have opportunity to attend demonstration of improved *teff* technology are more likely to use improved *teff* varieties than those farmers who have no similar opportunity. The reason might be participation on demonstration help farmers to create awareness and promote the understanding about merits of the available information by showing the practical applicability of the technology selected to be adopted. This result goes along with previous studies by [1, 22].

Availability of improved *teff* seed was found to be positively and significantly influenced the probability of adoption of improved *teff* varieties at 5% probability level.

Other variables held constant, timely availability of improved *teff* seed brings about 52.5% increase in the probability of adoption of improved *teff* varieties. The result implied that those farmers who get improved seed are more likely to adopt improved *teff* variety than those who do not have access. The possible explanation for this finding could be timely availability of seeds either in the local stores or in the market eases the households to purchase and cultivate new improved varieties in their fields. The result is consistent with studies by [15, 36] who found that availability improved seeds affect probability of adopting improved varieties.

Distance from the nearest market had a negative and significant influence on the probability of adoption of improved *teff* varieties at 1% level of significance. Keeping other variables constant, an increase in distance from farmers' residence to market place by a kilometer would result in 14.6% reduction on the likelihood of adoption of improved *teff* varieties. The result implied that the longer the distance between farmers' residence and the market place, the lower will be the probability of adoption of improved *teff* varieties. The plausible explanation for this result might be farmers nearby the market centers had more access to production inputs, have higher probability of obtaining up-to-date market information and hence access more information about improved technology that could enable them to try new technologies than those farmers who are in distant location. The finding of this research is in line with [19, 13].

Farmers' perception of better yielding character of improved *teff* varieties was significantly and positively affected the adoption decision of the farm households at 5% level of significance. Other variables held constant, a change in the perception of the farmer on the yield of improved variety to be higher than that of local variety (that is, a change from 0 to 1) brings 33.8% increase in the probability of adoption. The result of this study showed that if farmers perceive that new varieties are superior in terms of yield as compared to the local varieties, they will more likely adopt and widely use them. The possible reason is that farmers' interest of maintaining and enhancing *teff* yield in the production year. The result is similar with the finding of [14, 5].

3.3.2. Factors Determining the Intensity of Adopting Improved *Teff* Varieties

The factors affecting the intensity of use of improved *teff* varieties were estimated using truncated regression model. The model result from Table 4 indicated that from sixteen variables included in the model seven were found to be significantly affecting the intensity of use of improved *teff* varieties at different probability levels. Detail of significant variables from this model are discussed as follows.

Sex of household heads had positive and significant effect on the intensity of use of improved *teff* varieties at 5% level of probability. As compared to female headed households, the intensity of use of improved *teff* varieties for male headed household increased by 14.7%. The result suggests that those male headed households are more likely to allocate larger amount of land to improved *teff* varieties than their counter

parts, *ceteris paribus*. This could be attributed to various reasons, which could be the problem of economic position of female headed households, including shortage of labor, limited access to information on improved varieties and required production inputs due to social position. The result is consistent with the findings of [23, 19, 5].

Age had negative and significant influence on the intensity of use of improved *teff* varieties at 5% probability level. Other variables held constant, as age of the household increases by a year, the intensity of use of improved *teff* varieties decreases by 0.5%. The result implied that older household heads are resistant and less likely to adopt improved varieties than young household heads. The possible justification is that as the household heads get old they might reduce trust towards new technologies adoption as new technologies need financial investments and intensive field managements. The result in accordance with the findings of [34, 4].

Family labor in adult equivalent was positively and significantly influenced the intensity of using improved *teff* varieties at 10% probability level. Keeping all other variables constant, a unit increase in family labor, increases the intensity of use of improved *teff* varieties by 2.6%. This result indicated that farmers with high labor force are more likely to allocate more hectares of land to improved *teff* varieties than those with low labor force. The possible reason is that *teff* production is a labor-intensive activity and hence a household with high working labor force would be in a position to manage the labor-intensive *teff* production activity. Previous studies by [31, 19, 24] also reported that the more family labour available the better intensity of adoption of agricultural technologies.

Off/non-farm income positively and significantly influenced the intensity of using improved *teff* varieties at 1% level of significance. Other variables held constant, 1% increase in off/non-farm income increases the intensity of use of improved *teff* varieties by 0.9%. This result showed that households with relatively higher off/non-farm income are expected to allocate more hectares of land to improved *teff* varieties than their counterparts. The probable reason for this finding is that additional income earned through participation in off/non-farm activities improves farmers' financial capacity and might increase the ability to acquire improved seeds and associated inputs. This result goes along with the previous studies by [8, 27, 9].

The proportion of cultivated land allocated for *teff* was found to have positive and significant influence on the intensity of using improved *teff* varieties at 5% level of significance. Other variables held constant, each 1% increase in proportion of cultivated land allocated for *teff* production would result in 23.4% increase in the intensity of use of the improved *teff* varieties. As stated by [39, 30], farmers who allocate higher proportion of cultivated land for their crops are more likely to use improved technologies extensively than those farmers with smaller proportion of cultivated land.

As expected, frequency of extension contact was found to be positively and significantly influenced the intensity of adoption of improved *teff* varieties at 10% probability level.

The intensity of adopting improved *teff* varieties increases by 0.45% as for each additional contact with extension agents. The result implied that frequent contact with extension agents increases the availability of information about improved technologies and make farmers being aware of new technologies on how they can apply and hence increase the intensity of use of technologies. The result is consistent with the findings of [18, 21, 24].

Intensity of use of improved *teff* varieties was positively and significantly influenced by membership of organizations at 1% level of significance. The model result indicates that as

compared to non-membership to organizations, being membership in organizations would increase in the intensity of use of improved *teff* varieties by 10.6%. Farmers' organization could served as a platform for accessing and dissemination of new information and improved technologies. Hence, the result of the study implied that farmers belonging to organizations have easy access to information, credit, labor and inputs such as, fertilizer, improved seeds and chemicals and are expected to allocate more hectares of land to improved varieties. The result is consistent with other previous studies by [4].

Table 4. Parameter estimates of Cragg's double-hurdle model for adoption and intensity of adoption of improved *teff* varieties.

Variables	Adoption decision (probit model)			Intensity of adoption (truncated model)	
	Coef.	Std. Err	Marginal effect	Coef.	Std. Err
Sex of the household head	-0.1249	0.6666	-0.0498	0.1468***	0.0543
Age of the household head	0.0072	0.0281	0.0029	-0.0049**	0.0021
Educational level	0.8851***	0.2481	0.3527	-0.0100	0.0145
Family labor	0.1336	0.2247	0.0532	0.0263*	0.0139
Off/non-farm income	0.1005**	0.0422	0.0400	0.0090***	0.0028
Farming experience	0.0082	0.0278	0.0032	-0.0028	0.0020
Cultivated land size	-0.6307	0.7371	-0.2513	-0.0683	0.0566
Proportion of <i>teff</i> cultivated land	3.7331**	1.8491	1.4875	0.2335**	0.1026
Livestock holding	0.3352**	0.1606	0.1335	0.0041	0.0087
Frequency of extension contact	0.0705**	0.0349	0.0280	0.0045*	0.0025
Participation on demonstration	0.9678**	0.4505	0.3673	0.0389	0.0411
Improved <i>teff</i> seed availability	1.7774**	0.8102	0.5254	-0.0576	0.1060
Distance from the nearest market	-0.3674***	0.1103	-0.1464	0.0023	0.0070
Access to credit	0.4732	0.3697	0.1869	0.0278	0.0248
Membership to an organization	0.3758	0.5125	0.1472	0.1057***	0.0339
Perception on yield capacity	0.8915**	0.4441	0.3380	0.0057	0.0380
_CONS	-4.6099***	1.7801	-	0.1932	0.1534
LR/Wald chi ² (16)	131.22		-	78.24	
Prob> chi ²	0.000			0.000	
Log likelihood	-38.24			70.39	
Pseudo R ²	0.63			-	
Number of observations	150			72	

***, ** and * represents the level of significance at 1%, 5% and 10% respectively.

Source: Model output

4. Conclusions

The study was initiated to identify factors affecting the probability of adoption and intensity of use of improved *teff* varieties in kobo district. A double-hurdle econometric model was employed. The study empirically provides that farmers' decision to adopt and the decision concerning intensity of use of improved *teff* varieties were made separately. The model result shows that level of education, off/non-farm income, and proportion of cultivated land allocated for *teff* production, frequency of extension contact, livestock holding, participation on demonstration, improved *teff* seed availability, and perception on yield were found positive and significant in the first hurdle while distance from the nearest market had negative and significant effect. Whereas, in the second hurdle, sex of household head, age of household head, off/non-farm income, family labor, proportion of cultivated land allocated for *teff*, frequency of extension contact and membership to an organization were found to be significantly influenced households' intensity of use of improved *teff* varieties. Clearly, the use of improved agricultural technologies particularly

improved varieties is considered to be the most important input for the achievement of increased agricultural production and productivity of smallholder farmers in Ethiopia. However, in the study area the performance of farmers in terms of use of improved *teff* varieties has not been to the expected levels and the rate of adoption remains low. Hence, concerted efforts should be made to promote the use of improved agricultural technologies in *teff* farming. Moreover, understanding the factors that hinder adoption of improved *teff* varieties is vital in planning and executing technology related programmes for addressing the challenges of production enhancing technology adopted by farmers in Ethiopia particularly in the study area.

5. Recommendations

Based on the empirical findings of the study, the following recommendations are suggested. Since the level of education affected adoption of improved *teff* varieties, the diffusion of technology needed to be facilitated through educated farmers to be used as contact farmers so that they can use the available inputs more efficiently under the existing

technology. In the study area, emphasis need to be given to increase adoption of improved *teff* varieties by making better access to improved seeds timely. Strengthening extension service is needed to increase farmers' awareness about the benefits of using improved *teff* technologies including improved *teff* varieties as it enhances their ability to acquire and use information required for production.

Improving the existing market center in the study area through construction of whether roads and providing good transport facilities for farmers need to be given more attention to enhance the adoption of improved *teff* varieties. In the study area farmers' organization also need to be strengthened to reinforce farmer-to-farmer knowledge sharing should go through workshops, trainings and pertinent demonstration activities to capacitate their human and financial resources by providing incentives so that they can be the center for agricultural technology transformation. Sex of the household head was positive and significant on the intensity of use of improved *teff* varieties suggesting that due attention should be provided for promoting and empowering females by addressing the resource and information constraints. Policies should consider availability of labour force before introducing labour intensive technologies.

Appendix

Table A1. Test statistics for comparison of double-hurdle with Tobit Model.

	Tobit	Double hurdle	
		Probit	Truncated
Wald/LR χ^2	143.61	131.22	78.24
Prob > χ^2	0.000	0.000	0.000
LOG-L	-13.17	-38.24	70.39
Number of observations (N)	150	150	72
Log likelihood ratio statistics	$\Gamma = 90.64 > \chi^2(16) = 32$ at 1% level of significance		

Source: Data result, 2016

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