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Determinants of Multiple Agricultural Technology Adoption: Evidence from Rural Amhara Region, Ethiopia

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Abstract

The adoption of agricultural technology is an important path for raising agricultural productivity, and thereby for reducing food insecurity and poverty. Despite the efforts to promote adoption in most of the rural areas of Ethiopian farmers, the adoption rate has always been very low. So, it is essential to understand the barriers to adoption. As a result, this study examined the determinants of adoption of multiple agricultural technologies in rural Amhara region of Ethiopia. The study is based on Ethiopian socio-economic survey of 2015/16. A sample of 656 farm households was considered. The paper used multinomial logit model to assess the factors affecting adoption. The result shows that farmers with more educational level, family size, off-farm participation, livestock, extension contact, credit access, advisory service, and farmers closer to plot, all-weather road, zonal town, and farmers with lower remittance income are more likely to adopt new or improved agricultural technology. Therefore, the study recommends the need of policies and interventions on adoption of agricultural technology should pay attention and move along with those variables significantly influencing adoption of agricultural technology.

Keywords: *Agricultural technology, Adoption, Multinomial Logit, Poverty, Rural Amhara*

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PUBLIC INTEREST STATEMENT

In our country Ethiopia, where agriculture is at the heart of the economy. This study tried to examine the determinants of multiple agricultural technology adoption so as to raise the productivity of the agricultural sector. The result reveals that educational level, family size, off-farm participation, livestock, extension contact, credit access, advisory service, and farmers closer to plot, all-weather road, zonal town, and farmers with lower remittance income are the determinants of multiple agricultural technology adoption in Amhara Region.

1. INTRODUCTION

Agricultural or rural developments are a central issue to improve the welfare of rural households such as poverty, food insecurity and environmental sustainability. The various manifestations of poverty are found disproportionately in rural areas: low income, vulnerability to shocks, a poor infrastructure facility, political marginalization, and exposure to the degradation of natural resources, and make their livings from smallholder agriculture. This implicates the need for improving agricultural productivity at farm level, and thereby improving farmer's welfare (McCalla, 2001; and Admassie & Ayele, 2010). Furthermore, agriculture, with its high contribution to country's GDP, exports, and employment, it is an essential motor of growth in most developing countries.

According to Wik et al. (2008), growth originating in agriculture is about four times more effective in reducing poverty than other sectors. For this reason, policies that increase agricultural productivity can have a significant impact on poverty reduction. This is possible if and only if modern agricultural technologies are properly transferred and diffused so as to increase productivity. The green revolution introduced high yield varieties, fertilizers, pests, and others in developing countries, but the take up of these technologies in many developing countries has been uneven and have a low rate. In many areas traditional farming practices still dominate and the take up of the new technologies remains limited (De Janvry et al, 2017). This is true for SSA countries where the agricultural sector dominates and is characterized by low productivity due to the low rate of technology adoption (Asfaw et al, 2012).

In eastern African countries specifically, Ethiopia's agricultural and rural development policy has been aiming at enabling efficient use of modern agricultural inputs and practices (land management, fertilizer, chemicals, soil and water conservation, improved seed, advisory and credit service) among smallholder farmers for increased productivity by research and extension system (Tefera et al., 2016). Since, land is scarce; the feasible way to improve agricultural productivity in the country is through agricultural intensification (investing in new technologies) (Mohammed, 2014). However, the uptake of new technologies is low despite the fact that adoption has a direct impact on increasing yield and income generation as well as nutrition level (Woldegiorgis, 2015). Hence, their production and productivity are remaining very low; but the rapid population growth together with limited farm size and low productivity threatens the lives of the population for the future.

There are different scholars have been conducted on determinants of agricultural technology adoption in rural parts of Ethiopia. To mention some of them are CIMMYT (1993); Admassie and Ayele (2010); Adekambi et al., (2009); Challa and Tilahun (2014); Asfaw et al.(2012) stated that many factors can be associated with a lower rate of agricultural technology adoption: manly influenced by factors of socioeconomic, institutional, access and distance related factors, and plot characteristic. Specifically: credit constraint, lack of insurance, high transaction cost, behavioral inadequacies and information about new technologies (extension services, agro-dealers, farmers' cooperatives, and social networks), farm size, number of family size, age and sex of farmers, perception of farmers, off-farm income, distance to urban centers and development agents, plot distance, soil quality and cost of inputs. The study conducted by Sebsibie et al (2015) conducted on agricultural technology adoption and rural poverty in Amhara Region, Ethiopia (only on fertilizer use); (Amare, 2018): determinants of adoption of wheat row planting in Wogera district of Amhara region; Wudu (2017): determinants of adoption of improved wheat technology in Gozzamen district of Amhara region; Gebru (2016), the determinants of modern agricultural inputs adoption and their productivity in Amhara and Tigray regions on single adoption. The previous study focused on the determinants of single agricultural technology adoption in Amhara Region, Ethiopia. Hence, none of them examined farmers' decision to adopt multiple agricultural technologies Amhara Region, Ethiopia. Furthermore, some of the studies have also a small area coverage and small sample which might not be helpful to reach on a general conclusion at regional level. However, given the major research and knowledge gap, this study intends to examine the determinants of multiple agricultural technology adoption in Amhara Region, Ethiopia. Furthermore, this study includes remittance income as an additional factor of adoption.

2. METHODOLOGY

2.1. Data Description

The study is conducted in the rural part of Amhara region of Ethiopia. The data for this study were obtained from the Ethiopian Socio-economic Survey (ESS) during 2015/16. The survey covers all the regions of Ethiopia; however, the data is argued to be representative for regional estimation in the most populous regions of Tigray, Amhara, Oromia, and Southern Nation and Nationality people's regional state. The survey covered a wide range of topic such that, covers a range of topics including demography, education, health, labor, welfare, agriculture, food security, and shocks. The survey meets Ethiopia 's data demand gaps and is believed to be of high quality, and accessible to the public. The survey covers rural areas, small towns, medium and large towns in all regions except some exceptional zones of Afar and Somali region. Accordingly, the study considered 656 farm households drawn from rural Amhara regional state as a sample of the study.

2.2.Model Specification

2.2.1. Multinomial Adoption Selection Model

The choice of agricultural technologies is made according to the expected benefits from the adoptions of specific choices given their limitations. The common starting point is a random utility framework, in which the utility of each alternative is a linear function of observed characteristics plus an additive error term. Economic theory dictates that farmers adopt a single or a combination of technologies that can maximize their utility. This implies adoption occurs if the utility of the chosen package is higher than the utility of the other alternatives. However, the utility that gained from adopting agricultural technology is not observed but only its choice of technology, one can assume a random utility model which states conditional probability choice given farmers choice. To formalize this, consider the following latent variable:

$$A_{ij}* = z_i\alpha_j + \eta_{ij} \quad \text{..........} (1)$$

Where: A_{ij}* is a latent variable which describes the ith farmer's behavior in adopting the alternative package of technology J (j = 1, 2, …….m) with respect to another alternatives K. Z's are a vector of observed independent variables (household characteristics, farm-level factors, institutional factors, biophysical factors and technology aspects) and η_{ij} are unobserved characteristics which are relevant to the farm household's decision maker but are unknown to the researcher.

$$A_i = \begin{cases} 1 & iff\ A_{i1}^* > \max_{k\neq 1}(A_{ik}^*) \quad or\ \varepsilon_{i1} < 0 \\ \vdots & \vdots \\ M & iff\ A_{im}^* > \max_{k\neq 1}(A_{ik}^*) \quad or\ \varepsilon_{im} < 0 \end{cases} \quad \text{..........} (2)$$

The farm household i will choose a package of j- technologies with respect to adopting any other technologies of k if it provides greater expected utility than any other alternative k, k ≠ j, i.e., if $\varepsilon_{ij} = max_{k\neq j}\ (A_{ik}* - A_{ij}*) < 0$.

It is assumed that the covariate vector of Z_i is uncorrelated with the unobserved error termη_{ij}, i.e., E $(\eta_{ij}|z_i) = 0$. Assuming that η_{ij} are independent and Gumbel (identically) distributed (independence across utility functions and identical variance), that is under the independence of irrelevant alternatives (IIA) hypothesis; this model leads to the selection of a multinomial logit model.

2.2.2. Multinomial Logit Model

Under adoption of multiple agricultural technologies, the number of alternatives that can be chosen is more than two; we can apply the multinomial discrete choice model to estimate simultaneously the effects of the explanatory variable on the adoption of different agricultural technologies. The variable A_{ij} is a multiple choice variable and can be consistently estimated using a limited dependent variable (Maddala, 1983). In this regard, this study applied the multinomial logit model over other since the model is simple to calculate the choice probability and computers can maximize the resulting likelihood function even for a large number of choices. And also the result obtained from the model is more stable than others when independence of irrelevant alternatives(IIA) assumption fulfilled. (Kropko, 2008) also shows the multinomial logit model nearly always provides more accurate and realistic results than others even if the independence of irrelevant alternatives (IIA) assumption is severely violated. The probability of choosing alternative packages of J using multinomial logit model (P_{ij}) can be computed as:

$$P_{it} = P(\mathcal{E}_{ij} < 0|x_i) = \frac{\exp(x_i\alpha_j)}{\sum_{k=1}^{m}\exp(x_i\alpha_k)}, \text{ Where j =1,2… J} \qquad (3)$$

Where, Pit is adoption of multiple agricultural technologies, αi is the vector of parameters and Xi is a vector of all explanatory variables those are age of the household head, sex of household head, number of family size, education of the household head, total land size, distance to market, distance from zonal town, distance from the all-weather road, total livestock, credit access, extension services, getting advice, amount of farm remittance income, off-farm activities, far from homestead, plot potential wetness index, soil fertility quality and ownership of plots of land. The interpretation of the multinomial logit model is relative to the reference or base category group is difficult, even if this study used non-adopters as a base category. The coefficients need to be adjusted to be marginal effects in the case of the logit model.

2.2.3. Modeling Multiple Technology Adoption

The adoption of multiple agricultural technologies can be modeled in the setting of a framework. The adoption variable for this study is generated from the combinations of the organic fertilizer, inorganic fertilizer and herbicide technologies. The estimations of the adoption of alternative agricultural technology packages are estimated using multinomial logit model.

Table 2: Alternative Adoption of Agricultural Technology

Choice	Binary package	Fertilizer		Manure		Herbicide	
		F_0	F_1	M_0	M_1	H_0	H_1
1	$F_0M_0H_0$	√		√		√	
2	$F_1M_0H_0$		√	√		√	
3	$F_0M_1H_0$	√			√	√	
4	$F_0M_0H_1$	√		√			√
5	$F_1M_1H_0$		√		√	√	
6	$F_1M_0H_1$		√	√			√
7	$F_0M_1H_1$	√			√		√
8	$F_1M_1H_1$		√		√		√

Note: *Each element in the combination is a binary variable and for chemical fertilizer (F), organic manure (M) and herbicide adoption (H), and the subscripts represent 1 = adoption and 0 = non-adoption.*

2.3.Measurement and description of variables

Table 1: Measurement and description of variables used in the study

No	Variable	Variable description	Variable value	Description	Expected sign
Dependent variable					
1	***Adoption***[1]	Chemical Fertilizer Manure Fertilizer Herbicide	dummy	CF (1 = if Yes, 0= if No) MF (1 = if Yes, 0= if No) H (1 = if Yes, 0= if No)	
Independent variables					
2	Age	Age of the household head	Continuous	Measured in years	Negative
3	Sex	sex of household head	Dummy	1 = Male 0=Female	Positive
4	Family size	Number of Family size	Continuous	In number	Positive
5	Education level	Education of the household head	Continuous	Measured in years of schooling	Positive
6	Land size	Total Land size	Continuous	In hectare	Positive
7	Access to market	Distance to market	Continuous	In Kilometer	Negative
8	Zonal distance	Distance from zonal town	Continuous	In Kilometer	Negative
9	All weather road distance	Distance from the all-weather road	Continuous	In Kilometer	Negative
10	Livestock	Total livestock herd	Continuous	In TLU	Positive
11	Access to credit	Credit access	Dummy	1= if they have access	Positive
12	Extension visits	Extension services	Dummy	1 = if they have contact	Positive
13	Advisory service	Getting Advice	Dummy	1 = If they had advised	Positive
14	Remittance	Amount of Farm remittance income	Continuous	In Birr	Positive
15	Off-farm Employment	Off-farm activities	Dummy	1 = if they had participated	Positive
16	Plot distance	Far from homestead	Continuous	In Kilometer	Negative

[1]Adoption refers a farm household who used at least one technology in one of crop fields.

17	Plot wetness index	Plot Potential wetness index	Continuous	Index	Positive
18	Soil quality	Soil fertility quality	Categorical	1 = if it is good	Positive
20	Land ownership right	Ownership of plots of land	Dummy	1= if farmers have the right for own plot	Positive

3. Results and Discussion

3.1. Descriptive Statistics

The eight possible agricultural technology packages are summarized in Table 3. Of the total 685 sampled farm households, about 21.04% are non-adopters ($F_0M_0H_0$), whereas 7.77%, 17.84% and 2.74% of them adopted only one technology ($F_1M_0H_0$, $F_0M_1H_0$, $F_0M_0H_1$) respectively, and 19.82%, 8.84% and 3.35% of them are adopted a combination of two technology packages ($F_1M_1H_0$, $F_1M_0H_1$, $F_0M_1H_1$) respectively, and lastly 18.6% of the farm households simultaneously adopted all of the three packages ($F_1M_1H_1$). The result shows that package of $F_1M_1H_0$ and $F_1M_1H_1$, followed by $F_0M_1H_0$ have the higher frequencies which may indicate that farmers expected utility derived from those could be higher than the rest of the technology packages.

Table 3: Description of Alternative Technology Packages

Choice	Binary package	Chemical Fertilizer (F)		Manure fertilizer (M)		Herbicide (H)		Frequency	Percentage
		F_o	F_1	M_o	M_1	H_o	H_1		
1	$F_0M_0H_0$	√		√		√		138	21.04
2	$F_1M_0H_0$		√	√		√		51	7.77
3	$F_0M_1H_0$	√			√	√		117	17.84
4	$F_0M_0H_1$	√		√			√	18	2.74
5	$F_1M_1H_0$		√		√	√		130	19.82
6	$F_1M_0H_1$		√	√			√	58	8.84
7	$F_0M_1H_1$	√			√		√	22	3.35
8	$F_1M_1H_1$		√		√		√	122	18.60
							Total	**656**	**100**

Source: Own computation (2019/20)

The descriptive statistics of explanatory variables for the eight combined alternative packages considered in this study are presented in Table 4. The explanatory variables' mean value of non-adopters ($F_0M_0H_0$) is used as a base category to compare with mean values of alternative adopters ($F_1M_0H_0$, $F_0M_1H_0$, $F_0M_0H_1$, $F_1M_1H_0$, $F_1M_0H_1$, $F_0M_1H_1$ and $F_1M_1H_1$). The result shows that the mean comparison test between adopters and non-adopters are significantly larger for adopters and the values are different across the different alternatives. For instance, a set of household characteristics like sex (adopters are more of male headed), regarding education, adopters have high education level. Moreover, on average adopters have large family size than the non-adopters. On the other way, the mean age of the household head for adopters is lower than the non-adopters.

Total farm size, remittance income, livestock wealth measured in TLU, and off-farm employment are used as a means to describe the economic status of the household. Average farm size for non-adopter is lower than adopters (except for herbicide adopters). The mean livestock wealth and the proportion of households with off-farm activity participation for adopters are higher than non-adopters. On average, remittance income of the household is larger for non-adopters ($F_0M_0H_0$).

The mean distance from road, market and zonal town are larger for non-adopters. But adopters of manure, herbicide and a combination of the two packages, are higher than non-adopters indicating that as the distance increases farmers adopt the kind of technology that are easy to carry and nearby available technologies so as to reduce transportation costs.

Institutional factors such as extension contact, advisory service, credit access, and tenure security are other factors which affect the adoption decision. The first two are related with farmers' access to information on different packages and its profitability while access to credit indicates farmers' ability to finance their purchase of modern technology under cash constraints. The result shows these supports are higher for adopters. This may indicate that the institutional support system has long been a major factor for modern agricultural technology adoption even if its support has remained low (Kassie et al, (2010). Furthermore, adopters have significantly higher mean values in terms of microclimate indicators like plot potential wetness index, and lower mean values in terms of plot distance from homestead. Similarly, the proportion of non-fertile soil plot is significantly higher for non-adopters than adopters.

Table 4: Summary of Descriptive Statistics

Explanatory Variables	*Non-adopter*	*Adoption of.*						
	$F_0M_0H_0$	*$F_1M_0H_0$*	*$F_0M_1H_0$*	*$F_0M_0H_1$*	*$F_1M_1H_0$*	*$F_1M_0H_1$*	*$F_0M_1H_1$*	*$F_1M_1H_1$*
	Mean (SE)	*Mean (SE)*	*Mean (SE)*	*Mean (SE)*	*Mean (SE)*	*Mean (SE)*	*Mean (SE)*	*Mean (SE)*
Sex	.543 (.499)	.823 (.385)	.743 (.438)	.777 (.427)	.815 (.389)	.844 (.365)	.681 (.476)	.893 (.309)
Age	54.18 (18.1)	48.88 (16.75)	50.82 (14.59)	49.55 (14.2)	49.83 (14.2)	45.20 (13.2)	48.36 (12.21)	46.00 (13.1)
Education	.913 (2.54)	1.84 (3.15)	1.128 (2.43)	1.333 (.766)	2.053 (3.65)	1.655 (2.57)	1.681 (3.68)	1.245 (1.94)
Family size	3.23 (2.02)	4.25 (1.70)	4.820 (2.09)	4.11 (2.90)	4.83 (1.72)	4.534 (1.88)	4.590 (2.44)	4.909 (1.56)
Off-farm employment	.050 (.220)	.137 (.347)	.076 (.267)	.111 (.323)	.053 (.226)	.068 (.255)	.045 (.213)	.081 (.275)

TLU	1.54 (2.38)	3.18 (2.68)	3.818 (3.38)	2.869 (2.93)	4.183 (2.63)	3.743 (3.04)	4.064 (5.00)	5.620 (5.36)
Remittance income	2338.6 (13005.9)	729.4 (2241.1)	1099.4 (2946.7)	1218.05 (2297.0)	1325.8 (4303.6)	520.5 (1149.9)	1236.36 (2411.3)	509.13 (1826.3)
Distance to market	54.15 (31.62)	50.41 (29.7)	58.68 (37.6)	65.27 (34.2)	42.52 (29.53)	59.43 (28.99)	76 .00 (45.52)	48.78 (30.04)
Distance to Zonal town	196.7 (72.41)	170.8 (82.1)	208.3 (65.8)	239.77 (44.8)	148.2 (84.7)	173.7 (95.2)	195.0 (66.2)	123.28 (86.9)
Distance to all weather road	17.92 (20.08)	14.86 (18.2)	25.90 (22.6)	22.22 (23.68)	12.007 (13.1)	15.84 (17.7)	31.36 (23.88)	10.27 (11.5)
Extension visit	.028 (.168)	.784 (.415)	.119 (.325)	.277 (.460)	.884 (.320)	.724 (.450)	.045 (.213)	.934 (.248)
Credit access	.057 (.234)	.313 (.468)	.102 (.304)	.333 (.485)	.346 (.477)	.362 (.484)	.181 (.394)	.368 (.484)
Advisory service	.384 (.488)	.901 (.300)	.641 (.481)	.555 (.511)	.915 (.279)	.862 (.347)	.500 (.511)	.918 (.275)
Tenure security	.681 (.467)	.686 (.468)	.760 (.428)	.666 (.485)	.861 (.346)	.672 (.473)	.545 (.509)	.713 (.454)
Plot distance	.954 (1.44)	.926 (.959)	.644 (.784)	.606 (.831)	.600 (.562)	1.149 (.999)	.960 (1.13)	.640 (.718)
Plot potential wetness index	12.15 (1.26)	12.59 (.951)	12.32 (1.75)	11.86 (.981)	12.71 (1.08)	12.77 (1.097)	12.33 (1.96)	13.19 (1.02)
Land size per hectare	.581 (.537)	.632 (.649)	.663 (.816)	.490 (.671)	.806 (.756)	.701 (.575)	.764 (1.33)	.881 (.842)
Good Soil quality	.391 (.489)	.450 (.502)	.393 (.490)	.333 (.485)	.561 (.498)	.534 (.503)	.409 (.503)	.598 (.492)
Fair Soil quality	.514 (.501)	.490 (.504)	.529 (.501)	.444 (.511)	.384 (.488)	.431 (.499)	.500 (.511)	.368 (.484)
Poor Soil quality	.094 (.293)	.058 (.237)	.076 (.267)	.222 (.427)	.053 (.226)	.034 (.184)	.090 (.294)	.032 (.178)

Source: Own computation (2019/20)

Econometric analysis

In econometric analysis, the study applies a method of analysis of maximum likelihood estimation technique for the purpose of estimating the multinomial logit functions. The model fits the data reasonably well. Various post estimation tests were made to check the validity of the model. These are Wald test is used to ensure that all regression coefficients are jointly equal to zero is rejected with [χ^2(133)=(478.82); *P*>0.000], The Hausman test result for test of independence of irrelevant alternatives assumption, Variance inflation factor for continuous and correlation matrix for categorical variable also have been seriously conducted for multinomial logit model. The results confirm that there is no serious multicollinearity problem across the explanatory variables. And finally, robust regression has used to control the problem of hetrosckedasticity and non-normality.

Multinomial logit estimation results

Table 5: Maximum Likelihood Estimates for the multinomial Logit model

	Alternative technology Adoption Packages						
	F1MoHo	*FoM1Ho*	*FoMoH1*	*F1M1Ho*	*F1MoH1*	*FoM1H1*	*F1M1H1*
Explanatory Variables	*Coffe. (SE)*	*Coffe. (SE)*	*Coffe. (SE)*	*Coffe. (SE)*	*Coffe. (SE)*	*Coffe. (SE)*	*Coffe. (SE)*
Sex	0.320	-0.027	0.768	-0.119	0.071	-0.531	0.275
	(0.600)	(0.379)	(0.709)	(0.535)	(0.549)	(0.662)	(0.616)
Age	-0.008	-0.007	-0.009	-0.024*	-0.030**	-0.004	-0.038**
	(0.015)	(0.010)	(0.024)	(0.014)	(0.015)	(0.016)	(0.016)
Education	0.121	0.051	-0.349	0.132*	0.101	0.115	0.047
	(0.080)	(0.064)	(0.261)	(0.074)	(0.071)	(0.074)	(0.078)
Household	-0.110	0.199**	0.045	0.048	-0.059	0.285**	-0.083
size	(0.123)	(0.095)	(0.188)	(0.122)	(0.126)	(0.141)	(0.128)
Off-farm	1.813**	0.327	1.859**	0.495	0.889	0.016	1.115
employment	(0.739)	(0.602)	(0.965)	(0.696)	(0.804)	(0.937)	(0.753)
TLU	0.050	0.211***	0.138	0.162**	0.135*	0.179***	0.326***
	(0.095)	(0.066)	(0.108)	(0.076)	(0.082)	(0.070)	(0.069)
Remittance	-0.149*	-0.036	-0.019*	-0.052**	-0.170**	-0.008	-0.169***
income	(0.084)	(0.025)	(0.012)	(0.025)	(0.069)	(0.016)	(0.057)
Distance to	0.005	-0.008	0.007	-0.002	0.011	0.007	0.010
market	(0.008)	(0.007)	(0.014)	(0.007)	(0.007)	(0.008)	(0.008)
Distance to	-0.007**	0.001	0.008*	-0.009***	-0.006**	-0.000	-0.012***
zonal town	(0.003)	(0.002)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)
Distance to	-0.014	0.037***	0.006	-0.012	-0.019	0.023	-0.033**
all road	(0.015)	(0.011)	(0.027)	(0.014)	(0.015)	(0.015)	(0.015)
Extension	4.808***	1.078	1.942**	5.266***	4.388***	0.153	6.237***
visit	(0.707)	(0.680)	(0.825)	(0.698)	(0.702)	(1.159)	(0.804)
Credit	0.680	-0.055	1.717**	0.742	0.930*	0.684	0.780
access	(0.574)	(0.529)	(0.747)	(0.563)	(0.580)	(0.712)	(0.566)
Advisory	1.575***	0.695**	0.072	1.164**	1.192**	0.287	0.778
service	(0.558)	(0.323)	(0.721)	(0.501)	(0.536)	(0.535)	(0.554)
Tenure	-0.032	0.277	0.053	0.892*	0.253	-0.446	0.302
security	(0.503)	(0.360)	(0.743)	(0.500)	(0.488)	(0.537)	(0.540)
Plot distance	0.085	-0.572***	-0.509	-0.442**	0.209	-0.250	-0.333
	(0.174)	(0.170)	(0.365)	(0.207)	(0.164)	(0.213)	(0.319)
Plot	0.062	0.131	-0.324	0.080	0.243*	-0.009	0.462***
potential wetness index	(0.163)	(0.109)	(0.217)	(0.151)	(0.151)	(0.251)	(0.132)
soil quality	0.364	-0.001	0.142	0.164	0.116	-0.092	0.607
(fair)	(0.463)	(0.315)	(0.655)	(0.435)	(0.473)	(0.681)	(0.468)
soil quality	0.223	-0.123	1.156	0.287	-0.559	-0.203	0.376
(poor)	(0.915)	(0.516)	(0.869)	(0.687)	(0.855)	(0.918)	(1.029)
Land size	0.031	-0.170	-0.473	0.287	0.074	-0.115	0.143
per hectare	(0.284)	(0.289)	(0.711)	(0.230)	(0.220)	(0.317)	(0.236)
Constant	-3.069	-3.461**	-1.043	-2.170	-4.386**	-3.424	-6.879
	(2.417)	(1.514)	(3.684)	(2.009)	(2.177)	(3.776)	(2.076)

Model VCE= Robust; Pseudo R^2 = 0.328; Number of observations =656; SE is standard error in parenthesis; the asterisks *, **, *** denotes significance level at 10%, 5%, and 1% respectively.

Source: Own estimation (2019/20)

The result from the multinomial logit model is presented in Table 5. The base category is non-adoption ($F_0M_0H_0$), where results of alternative packages are compared.

The estimated coefficients of the multinomial logit model are presented in table 5. Based on this estimation, the result indicates that the sign of age of household head is negative and significant, indicating that young farmers are more likely to adopt farm technology since young farmers may have formal education than the non-adopter, less risk averse, more willing, and have greater flexibility in accepting new ideas, other things being constant. This is consistent with Simtowe et al. (2012) and Admassie & Ayele (2010). Similarly, education level of the head has positive sign and significant for $F_1M_1H_0$, which is similar with the finding of Asfaw et al., (2012) and Kassie et al. (2010). This is because farmers with more educational years are more likely to adopt as they able to acquire, analyze and evaluate information on modern technology, market opportunity and its implied benefit.

The family size of farmers has a positive and significant effect on the adoption decision of manure and a combination of manure with herbicide packages. This implies the more family member the more the adoption will be, because adoption of multiple farm technologies requires and attracts more labor force for agricultural activities Kassie et al, (2010).

Livestock wealth measured by TLU significantly and positively affects the adoption decision of multiple technologies. This is because of farmers who possess a flock of livestock are more likely to adopt than the have-not as it helps to get improved technology (as income means and source of manure input), consistent with Mulugeta & Hundie (2012). Farm households who participate in off-farm activity are also more likely to adopt chemical fertilizer and herbicide packages. This is because of participating in off-farm activities can generate income and solve the problem that the farm household's face while intending to purchase farm technologies, consistent with Kassie et al. (2010); and Mulugeta & Hundie (2012).

The other important factor is farm remittance income, and the result shows that the impact of remittance income on the adoption decision is negative and significant. The descriptive analysis also supports this finding. From the descriptive analysis it was found that the remittance income is higher for non-adopter. One plausible reason for this is the household's way of spending the money from remittance. Most often income from remittance will be used for daily consumption purpose than investing in agricultural development. This is supplemented by (Tuladhar et al., 2014*)*. The higher remittance inflows to households, and subsequently, the higher income buffer, might have increased the opportunity cost of engaging in agriculture, resulting in reliance on remittance income more than the income from the agriculture sector.

Distance to market, road and zonal town are significant proxy variables which capture the relationship between access to market information, access to input and farm households' technology adoption. Distance to zonal town has a strong and negative effect on the adoption of package $F_1M_0H_0$, $F_1M_1H_0$, $F_1M_0H_1$, and $F_1M_1H_1$. Distance to all weather roads has also negative effect on the adoption of package $F_1M_1H_1$. This result may verify that those framers who live away from service centers such as urban centers, development agent, and market place are less likely to adopt farm technologies because of farmers could have less access to information on improved technologies and high production cost, and hence are unlikely to adopt new or improved technology; similar with Admassie & Ayele (2010); and Hailu et al. (2014). However, distance to road and zonal town affects positively the adoption of package $F_0M_1H_0$ and $F_0M_0H_1$ respectively. This is because of as the distance to road increases; farmers choose nearby available and easy to carry type of technology packages so as to reduce production costs.

Institutional support factors such extension contact, advisory service, credit access and tenure security are considered equally important to understand farm household's technology adoption decision. That is, access to extension visit and advisory service has a positive and significant relation on the adoption of alternative technologies. This is because the extension contact helps the farmers to raise their awareness about the characterization and attributes of the technology, use and their impact. Extension gives detailed information, training and advisory services about the source, use and importance of the technologies to the farmers and engaging in input distribution. Advisory service on the other hand indicates that having access to regular and frequent advisory services by development agents, farm cooperatives and meetings plays a fundamental role in the dissemination and adoption of farm technology. Access to credit has a positive impact on the adoption decision of different packages. This is because of credit access solves income problems that household could face while they want to purchase agricultural technologies; and hence paves the way for timely application of modern farm inputs.

The positive and significant effect of tenure security for a combination of chemical and manure fertilizer shows that when farmers are secured for their own land, the more likely in the adoption practice since they can make long-term investment, similar with Admassie & Ayele (2010); Tefera et al. (2016); Sebsibie et al. (2015); (Mohammed, 2014); and Hailu et al. (2014). Plot characteristics and microclimate variables are another set of factors considered in explaining household's likelihood of technology adoption, such as soil quality, plot wetness and plot distance. Plot distance from the homestead is negatively affects the adoption of package $F_0M_1H_0$, and $F_1M_1H_0$. This is because of as plot is far away from the homestead, the less likely will be on time plot preparation, weed, harvest and input utilization and hence farm households are less likely to adopt, confirmed with Kassie et al. (2010); and Hailu et al. (2014). On the other way also, plot potential wetness index has a positive impact on the probability of the adoption of full packages ($F_1M_1H_1$). This is because of as the wetness of the plot increases (maintains vascular plant species richness, soil pH, groundwater level and soil moisture) the more likely the adoption of the agricultural technology. This is in line with the finding of Sebsibie et al (2015). Most of the explanatory variables like sex of the family head distance to market, farm size and soli quality, even if they are not statistically significant, they have the expected signs with the adoption decision.

4. Conclusion and Policy Recommendation

Agriculture is the mainstay of Ethiopian economy, and where severe poverty is the main challenge, reducing poverty is the preliminary concern, by boosting production and productivity of agriculture through the use of improved agricultural technology is considered as a major solution. Thus, the main objective of this study was to explain factors affecting the adoption of multiple farm technologies in rural Amhara region. Multinomial logistic regression model was employed to identify the determinants of adoption of multiple farm technologies in rural Amhara Region, Ethiopia. The result of the study revealed that farm household's decision to adopt improved or new farm technologies is manly influenced by factors of socioeconomic, institutional, access to information and distance factors, and plot characteristic. More specifically, the adoption of multiple agricultural technologies is positively and significantly affected by education level of the head, household size, off-farm activity, livestock wealth, farmers contact with extension and advisory service, farmers having credit access, farmers secured for their own land, and plot potential wetness index. On the other hand, the adoption of farm technologies is negatively and significantly affected by age of the family head, distance from zonal town, road and plot distance from the homestead, and farmers getting remittance income. However, the effect of distance from road and zonal town for the adoption of herbicide and manure technologies is positive, indicating as the farm lives far away from urban centers and development agents, farmers adopt nearby available technologies and easy to carry type technologies so as to reduce their cost of production.

Thus, in terms of policy implication, polices for strengthening the access to information about the farm technologies by increasing the availability and quality of extension service, encouraging the participation of farmers in training centers and providing advisory service to increase the adoption by farm households. The influence of extension service, trainings and advisory services can counter balance the negative effect of lack of years of formal education on the overall decision to adopt farm technologies.

Distance from zonal town and road matters the adoption decision of multiple farm technologies. Thus, the government and other stakeholders should support the access of these infrastructural services.

Access to credit is also found a significant factor that positively affects technology adoption. This may call for the need and expansion of credit institutions in rural areas where financial constraint is a major challenge for farmers while in adopting farm technologies.

Lastly, the effect of remittance income on technology adoption is negative. So, Policy measures aimed at channeling remittances to investments in productivity-enhancing agricultural capital and inputs might help increase agriculture yield.

Overall, better targeting of agricultural technology adoption and appropriate rural institutions on rural farmers might be the main vehicle for increasing farm technology adoption by the rural poor.

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