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Drivers of Farm-level Adoption of Crop Extension Packages in Ethiopia

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Abstract: Smallholder farmers' adoption of agricultural technologies varies to a great degree with respect to spatial diversity, household related characteristics, access to infrastructure and institutional design. This cross-sectional study was conducted in order to understand the factors affecting the uptake agricultural technologies in the highlands of Ethiopia. Analysis was conducted on data collected in 2014 from a survey of 2,880 households in four major regions of the country covering 30 districts. Econometric method (two-limit Tobit model) was used to analyse determinants of farm-level adoption of crop technology packages promoted by the national agricultural extension service. Findings reveal that 71%, 66%, 60%, 52%, 46% and 29% of the sample households adopted recommended technology packages for potato, wheat, maize, tef, barley, and sorghum respectively. Results demonstrate that agro-ecology and spatial variability, distance from homestead to farm plots, slope index of the farm, access to extension services, access to credit, lagged gross annual income and membership to a cooperatives were all significant factors influencing technology adoption. The study shows there is significant variation in technology adoption between model farmers and non-model farmers. However, the productivity difference is limited to few crops. The findings suggest that investment in infrastructure, promoting access to institutional services and access to credit are instrumental to technology adoption by smallholders. The extension strategy should therefore promote inclusive strategy in which both model and non-model farmers have equal access to technology supply and extension services.

Keywords: adoption intensity, agricultural technology, extension package, two-limit Tobit model, Ethiopia.

Introduction

Agriculture receives increased attention by policy makers and donors in the past decades based on the evidence that the use of modern agricultural technologies gives good results in term of food security and economic growth (Barret *et al*., 2010). For example, recent studies in Malawi show that by combining sustainable intensification practices, rather than adopting a single practice, higher net maize income has been achieved while reducing or keeping constant the input use (Kassie *et al*., 2015). This is also the case in Ethiopia, where the government has launched a green-revolution strategy to drive agricultural growth and break the cycle of low agricultural productivity, malnutrition and poverty. This strategy has three key and interrelated components: 1) linear technology generation and transfer; 2) serious commitments to make modern inputs of seeds of improved varieties and mineral fertilizer available to smallholder farmers; and, 3) massive investments in agricultural extension services. Accordingly, the Ethiopian Government has made significant investments in its agricultural sector (Over 17% of the GDP), building the largest extension system in sub-Saharan Africa (SSA) in terms of manpower and institutional reach (MoA, 2017; Gebremedhin *et al*., 2006; Yu *et al*., 2011). The number of extension agents grew from less than 15,000 around the year 2000, to more than 60,000 in 2019 (Roo *et al*., 2019). Its disciplinary focus has also widened to cover crop and livestock development, natural resource conservation, watershed management and cooperative development. When it comes to crop development, a package of agricultural technologies are promoted including seeds for improved crop varieties, fertilizer, pesticides, and improved agronomic practices such as row planting, along with technical support such as on-site training for farmers are promoted. Until recently, the agricultural extension programme used a technology dissemination design based on the so-called 'model farmers' approach, which other farmers look to peers as examples for agricultural related advices (Lefort, 2012).

Despite major emphasis in agricultural research for technology development and extension services, uptake of modern technologies by smallholder farmers in Ethiopia fail to keep pace with the investment (Tilahun, 2018; Jaleta *et al*., 2015). Recent studies however shown some sign of improvement in the adoption of major cereal crops and mineral fertilizer is about 40-47% (Yu *et al*., 2011), it is not much higher in other countries in Central and Eastern Africa (Ogade *et al*., 2014; Odame *et al*., 2013; Beyene and Kassie, 2015). It is notable, however, that Ethiopia has seen a 50% and 30% improvement in uptake of seed and fertilizer technologies respectively over the past 15 years (Spielman *et al*., 2010; Gebremedhin *et al*., 2009). Even then, given the huge diversity in biophysical and socioeconomic settings in Ethiopia, the pathway to technology adoption and the extent to which the full package promotion by the extension system and. the model-farmer approaches are successful, has not been adequately examined. A deeper understanding of the factors affecting the uptake of modern agricultural technologies in Ethiopia is essential to inform policy makers and the donor community in Ethiopia. This study was designed to generate insights around the effective promotion of agricultural technologies to smallholder farmers by identifying the major drivers and inhibitors of technology adoption. By so doing, the study will provide data to support a more targeted approach in scaling up agricultural technologies in the Ethiopian highlands.

The paper is structured as follows, the next section presents the model farmer approach, while section three deals with the methodology applied in the study. Sections 4 through 6 present the results and discussion organised by household and farm characteristics, technology uptake, and econometric analysis respectively. The last two chapters discuss the findings followed by the concluding remarks and policy implications drawn from the study.

Model farmer approach

According to Ragasa (2019) many countries have long histories of using contact farmers, such as model farmers in Ethiopia or master or progressive farmers (*achikumbi*) in Malawi (Jimu, 2008), to support government extension workers in technology transfer and information dissemination. Kaleb (2016) identifies four factors in differentiating model and non-model farmers in Ethiopia: social (number of relatives the households rely on living both outside and inside the community), economic factors (telephone ownership, land holding size), institutional (contact with extension worker and market access) and household related characteristics (technical efficiency and years of experience in farming). According to Ministry of Agriculture (MoA, 2017) model farmers who in general have relatively better resources and are early adopters, are defined as those that have adopted at least 70% of the technology package delivered by the agricultural extension system and are recognized by Development Agents (grass root extension workers) for their influence in the agricultural community. Non-model farmers are defined as late or none adopters of agricultural technologies (Tewodros *et al*., 2016). However, the lead farmers approaches have been criticized for the selection of richer and progressive farmers, also at times linked to clientelism and elite capture, and for limited productivity and development impacts (Lefort, 2012). It over emphasized on the hardcore technical philosophy in disregard of other aspects necessary for effective dissemination of technologies, such as communication processes, leadership and institutional organization (Nagel, 1997).

Methodology

Study area and sample size

This research applies the cross-sectional study design used to establish a baseline for CASCAPE (Capacity development for Scaling up of Evidence based best Practices for increased Agricultural Production in Ethiopia), a Dutch-funded action research project that supports the Agricultural Growth Programme (AGP) in Ethiopia. The data presented in this study was collected in 2014 through structured questionnaires administered to 2,800 households in the states of: Tigray, Amhara, Oromia and Southern Nations, Nationalities and Peoples' Regional State (SNNP) which accounts about 60% of the total area of Ethiopia. The sampling frame covered 16 zones, 30 districts (*woredas*) and 60 villages (*kebeles*) in the high-potential highland areas of Ethiopia. CASCAPE project staff members that are experts in agricultural extension and agronomy conducted data collection. Sample households were selected from the strata of model and non-model farmers, with 2/3 of those surveyed being model farmers. The interviews were carried out with degree holder enumerators and field assistants who were from the area to help in locate the sample respondents' home. In order to ensure consistency and reliability of administering the questionnaires by the enumerators they were trained before the start of the interviews and pretested in few non target kebeles. The whole data collection took two months.

Technology use and adoption intensity

This study focused on major cereal crops: maize (*Zea mais*), tef (*Eragrostis tef*), wheat (*Triticum aestivium*), barley (*Hordium vulgarae*) and sorghum (*Sorghum bicolor*), which together account for 80% of cereal production in Ethiopia. In addition, because of its food security contribution a tuber crop, potato (*Solanum tuberosum*) is included in this study. For each of the following components of the extension packages – seed of improved variety, mineral fertilizer, pesticides, and row planting – use and adoption intensity were assessed. *Use* refers to a dichotomy decision of application or rejection of the agricultural technology package, whereas *use intensity* refers to the degree of technology use in relation to the recommended rate.

Improved varieties

The use intensity of improved varieties was measured in area sowed, with values ranging between 0 and 100%. If the farmer sowed all plots with improved seed varieties, intensity was recorded as 100%, while exclusive use of local seed results in an intensity of 0%, as shown in the formula below.

$$\text{Improved variety use intensity} = \frac{\text{Land covered by improved variety (ha)}}{\text{Land covered by both improved and local variety (ha)}} \qquad (1)$$

Fertilizer

The use intensity for fertilizers – Diammonium Phosphate (DAP) and urea – was measured considering the actual application rate of the fertilizer against the recommended fertilizer rate for the respective crops.

$$\text{DAP use intensity} = \frac{\text{Actual DAP rate (kg)}}{\text{Recommended DAP rate (kg)}} \qquad (2)$$

$$\text{Urea use intensity} = \frac{\text{Actual urea rate (kg)}}{\text{Recommended urea rate (kg)}} \qquad (3)$$

Actual DAP and urea application rates were calculated by considering DAP/urea applied to local and/or improved varieties over the total area allocated for the specific crop considered.

Use of row planting

Row planting is a dummy variable that takes the value 1 if the household head cultivated the crop using exact or near exact[1] the recommended row spacing; otherwise, this value is equal to 0. The near extract row making is usually made using oxen plough and may not be exactly fit the recommended spacing.

[1] Some farmers make rows using oxen pulled plough, resulting in some deviation from the recommended intra and inter row spacing.

Use of pesticides

Pesticide use is a dummy variable that takes the value 1 if the household head used any pesticide (insecticides, fungicides or herbicides), or 0 otherwise.

Adoption indices

The construction of the adoption index for the abovementioned six crops was calculated by incorporating the package components:

$$ADP_i = \frac{\dfrac{AUIV_i + UA_i + DA_i + RPU_i + PU_i}{TA_i + UR_i + DR_i}}{5} \quad ....(4)$$

Where:

ADP_i = Adoption index for i^{th} crop (i.e. tef, maize, wheat, barley, sorghum and potato);
$AUIV_i$ = Area under improved variety for i^{th} crop measured in proportion of the total land allocated for i^{th} crop;
TA_i = Total area allocated for i^{th} crop measured in ha;
UA_i = Actual urea applied for i^{th} crop measured in kg;
UR_i = Urea recommended rate for i^{th} crops measured in kg/ha;
DA_i = Actual DAP applied for i^{th} crop measured in kg;
DR_i = DAP recommended rate for i^{th} crops measured in kg/ha;
RPU_i = Row planting practice for the i^{th} crops (1 if yes, 0 if otherwise);
PU_i = Pesticide use for the i^{th} crops (1 if yes; 0 otherwise).

Econometric estimation model

The dependent variable for this study was the proportion of the technology package recommended for the respective crops that was adopted by the sample households. Hence, the dependent variable exhibits relatively large numbers of observations at both extremes of the possible range of values (0% and 100%), implying double truncation. Thus, the two-limit Tobit model, which is well suited for such data (Al-Karablieh *et al*., 2009; Maddala, 1986; McDonald and Moffitt, 1980), was estimated by maximum-likelihood. To facilitate the use of the Tobit model, the dependent variable was reduced to a single value, representing the proportion of technology package being implemented by the respondent households.

For each of the five dependent variables (i.e., proportion of technology package implemented) the underlying model is specified as follows:

$$y^* = X\beta + \mu \qquad (5)$$

where y* is a continuous latent variable, X is a matrix of explanatory variables, ß is a vector of coefficients to be estimated, and μ is a vector of normally distributed error terms with variance μ^2. If we denote the observed dependent as y, then:

$$y = 0 \;\; if \;\; y^* < 0 \qquad (6)$$

$$y = Y^* if \;\; 0 < y^* < 100 \qquad (7)$$

The likelihood function for the nth observation 9n=1, 2, … N) of the two-limit tobit model is given by:

$$L_n = \Phi\left[\frac{L_1 - \beta' X_n}{\sigma}\right]^{dn0}\left[\frac{1}{\sigma}\phi\left(\frac{y_n - \beta' X_n}{\sigma}\right)\right]^{dn1}\left[1-\phi\left(\frac{L_2 - \beta' X_n}{\sigma}\right)\right]^{DN2} \quad (8)$$

Where Φ (.) is the standard normal cumulative distribution function, ϕ (.) is the standard normal probability density function, β is the vector of regression coefficients, σ is the standard deviation, x_n is the matrix of independent variables, and y_n is the observed value of the normally distributed dependent variable. For each observation, one of the exponents d_{nj} (j=0, 1, 2) will take a value of one, depending upon whether the value of the observed y_n is equal to the lower limit, is the interval between limits or equal to the upper limit, respectively, and all other exponents will take a value of zero. The lower and the upper limits of the censored distribution L_1 and L_2 have been set equal to zero and one, as the data have been defined to take values between those two limits, inclusive.

Data and description of variables

A comprehensive pre-tested questionnaire was used to collect household characteristics and resource endowments, crop production, technology use intensity and adoption data. In the majority of cases, the interview was conducted jointly with the head of the household as well as with other members of the household to increase the accuracy of the data. The variables and description statistics are given in Table 1.

Results

Household characteristics

The overwhelming majority of households (85%) included in the study were male-headed households. The inclusion of female-headed households ranges from 6.7% in SNNP to 26.3% in Tigray.

The level of education of household heads was measured based on the education structure in Ethiopia by categorizing respondents as illiterate, reading and writing or religious education, elementary first cycle (1-4 grade), elementary second cycle (5-8), secondary (9-10) or preparatory and above. Out of the total households included in the survey, about 28% household heads were illiterate, while 72% of household heads had some level of education.

Housing type can be considered to be an indicator of the socio-economic status of households, with many studies associating houses having corrugated iron roofs with better economic status (Evans, 2003; Evans *et al.*, 2003). In this study, 73% of respondents lived in a house with a corrugated iron roof, which can be viewed as an indicator of recent improvements in the wellbeing of the farming community. Compared to other regions, Tigray had the lowest percentage (42%) of respondent households who had corrugated iron roofs and cement houses. Owing to the hot and dry climate in Tigray, people prefer houses made of earth with a stone roof.

The majority of respondents confirmed having access to credit in all regions, except in Oromia. Access to irrigation structure was generally found poor in all regions, except in

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Table 1 - Description of the explanatory variables considered in the econometrics models.

EXPLANATORY VARIABLES	TYPE OF VARIABLES	DESCRIPTION
Regions	Categorical	List of regions included in the study
Agro-ecology of the area	Categorical	Agro-ecological features (Lowland, Midland and Highland)
Farmers type	Dummy	1= Model 0=non-model farmers
Sex of household head	Dummy	1=Male 0=Female
Education level of household head	Dummy	1=Literate 0=Illiterate
Age of household head	Continuous	Age of household head in years
Family size	Continuous	Number of individuals in the household
Dependency ratio	Continuous	Ratio of number of dependents (aged below 15 and above 64 years) to family size
Number of oxen	Continuous	Number of oxen owned
Total livestock	Continuous	Total livestock owned (in TLU)
Total livestock excluding oxen	Continuous	Livestock owned excluding oxen (measured in TLU)
Access to credit	Dummy	Access to credit service (1=Yes, 0=No)
Irrigation access	Dummy	Access to irrigation service (1=Yes, 0=No)
Membership to coops	Dummy	Membership to cooperatives (1=Yes, 0=No)
Average distance to farm	Continuous	Average distance to farm plots in km
Distance to all weather road	Continuous	Average distance to all weather road in km
Distance to Farmers Training Centre	Continuous	Average distance to the Farmers Training Centre in km
Percentage of output sold	Continuous	Proportion of produce sold out of total produced (%)
Total land size	Continuous	Total landholding size in ha
Slope index	Continuous	Weighted average for all plots (slope code *area of plot over total area; slope code 1 for flat; 2 middle; 3 steeps
Number of plots	Continuous	Number of parcels owned
Low extension contacts	Dummy	Low extension contacts (1=< 12 contacts per year, 0=other value)
Medium extension contacts	Dummy	Medium extension contacts (1=12 -24 contacts per year, 0=other value)
High extension contacts	Dummy	High extension contacts (1=once per week or per two weeks, 0=other value)
Lagged annual income (square root in ETB)	Continuous	Annual income (crop, livestock, off and on farm income)

Tigray. Membership in cooperative organizations was robust in all regions but particularly high in the Amhara region (90%). Regarding extension service provision, around 39%, 45% and 16% of the respondents reported high, medium and low access to services, respectively. This implies that the majority of households had on average, contact with extension agents assigned at *kebele* levels one or more times per month (Tewodros *et al.*, 2016). This is in line with other findings that argue the extension system of Ethiopia is highly organized and adequately staffed (Davis *et al.*, 2009).

Table 2 - Summary of categorical variables by region.

VARIABLES	TIGRAY (%)	OROMIA (%)	AMHARA (%)	SNNP (%)	AVERAGE (%)
Gender of household head					
• Female	26.3	15.7	9.4	6.7	14.9
• Male	73.8	84.3	90.6	93.3	85.1
Literacy status of household head					
• Illiterate	36.7	25.8	28.6	25.8	27.9
• Reading and writing	15.5	22.0	29.2	12.5	20.6
• Elementary 1st cycle (1-4)	16.9	20.0	17.8	21.5	19.4
• Elementary 2nd cycle (5-8)	23.1	22.2	20.5	31.7	23.6
• High school (9-10)	7.3	8.0	3.3	5.8	6.7
• Preparatory and above	0.5	2.2	0.6	2.7	1.7
Housing type					
• Corrugated iron roof	30.0	71.4	98.8	9.4	58.7
• Thatched roof	28.3	22.9	1.3	62.8	26.9
• Cement/concrete roof	0.0	1.2	0.0	0.8	0.7
• Corrugated iron and thatched roof	0.0	4.6	0.0	26.2	6.7
• Corrugated iron and cement	41.7	0.0	0.0	0.8	7.0
Access to credit					
• No access	15.4	72.1	14.2	43.1	48.2
• Access	84.6	27.9	85.8	56.9	51.9
Access to Irrigation					
• No access	44.0	65.9	42.1	85.4	61.4
• Access	56.0	34.1	57.9	14.6	38.6
Membership to Cooperative					
• Non-member	46.5	32.3	9.8	43.4	32.8
• Member	53.5	67.7	90.2	56.6	67.3
Frequency of Extension contact					
• Low	20.1	9.8	4.8	8.4	16.1
• Medium	33.1	52.7	29.6	50.1	45.1
• High	46.8	37.5	65.6	41.5	38.8

The average age of sample household head was 43 years, ranging from 41.5 in Oromia to 46.9 in SNNP. The average family size of respondents was 6.6 persons, higher than the national average family size (4.8 persons) for Ethiopia in 2011 (EPA, 2012; Tewodros *et al.*, 2016). The largest family size (7.0 persons) was reported in SNNP, while the smallest (6.0 persons) was in Tigray region. In order to examine the effect of family size on labour composition and endowment, age disaggregation was done following a standard economically active and dependent labour categorization. On average, around four members of the household were aged between 15 and 64, three below 15 and none over 64 years. The dependency ratio – measured taking age categories into account – indicated that household members in the productive age category in Oromia support more dependent household members as compared to other regions (10 productive labours support 11 dependents). The sample respondent household heads had an average of 22.6 years of experience in farming. This means on average the household heads spent half of their lives in farming (Tewodros *et al*., 2016).

Livestock provide draft power for land preparation and threshing of cereals. Average livestock ownership per household was 1.4 oxen and 5.4 Tropical Livestock Units (TLU), which is in agreement with previous studies (Storck *et al*., 1991). Oxen ownership was higher in Amhara and Tigray regions while the overall TLU ownership was found to be higher in the Tigray and Oromia regions. The national average of land holding was 1.4 ha with the largest landholding (5.4 ha) in Amhara and the smallest (1.1 ha) in Tigray. Similarly, the average number of plots owned was highest in Amhara (6 parcels per household) and the lowest number (2.4 parcels) was in SNNP. Oromia (3.7 parcels) and Tigray (3.6 parcels) had almost similar mean values of parcels per household. Ownership of a large number of plots implies land fragmentation and therefore poses difficulties in land management such as timely sowing, weeding and harvesting. However, having different plots in different places is a strategy for exploiting different agro-ecological niches and soil fertility variation in different landscapes (Giller *et al*., 2011). The average distance of the farm from the homestead, measured in km, affects crop choice and decisions on input use. The data showed that respondents in Tigray have to travel the longest distance (2.8 km) to their farmland, while those in SNNP travel the shortest distance (0.8 km). Data on access to infrastructure such as roads and markets was measured using the household's distance from an all-weather road, nearest market, farmer training centres and cooperatives.

The average lagged annual gross income[2] of respondent households was highest in Oromia (23,500 ETB) and lowest (9750 ETB) in SNNP. Crop sales are the dominant sources of income, while the sale of livestock provided some compliments and showed significant variation across regions (Tewodros *et al*., 2016). However, the large standard deviation on family income indicates it a large variability among the respondent households.

Farm characteristics

Crop production

Respondent households produced a wide range of crops. Maize was the most widely grown crop across regions as reported by 70% of the respondents. Next to maize, 57% of respondents produced tef, the majority of whom (79%) were in Amhara region, followed by Oromia (61%) and Tigray (51%). Wheat was grown by 42% of the respondents while only 29% grew food barley. The importance of sorghum varied widely from region to region with the highest prevalence in Tigray (45%), followed by Oromia (29%).

Use of seeds of improved varieties

The majority of maize growers (65%) used seeds of improved maize varieties, while the lowest usage of improved seeds variety was reported for sorghum (Table 4). The driving factor for using fresh seed is the hybrid nature of maize crops and the significant yield

[2] For this study reported annual income of 2013 were used as it influences the 2014 investment decisions in agricultural inputs. ETB refers Ethiopian currency called Birr.

reduction that results from loss of hybrid vigour when using farm saved seed. The majority of respondents in Amhara, SNNP and Oromia regions used an improved maize variety while respondents in Tigray predominantly used local varieties. The aggregated use of seeds of improved wheat variety was 60%, with the majority represented in Amhara (99%) region followed by SNNP (81%), Oromia (56%) and Tigray (45%) regions respectively.

Table 3 - Summary of continuous variables by region.

	VARIABLES	TIGRAY		OROMIA		AMHARA		SNNP		OVERALL	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Demography of HH	Age of household head	43.8	10.9	41.5	11	43.8	10.7	46.9	12.3	43.2	11.5
	Family size	5.9	2.0	6.8	2.5	6.2	1.9	7.3	2.6	6.6	2.4
	Male family members	2.9	1.4	3.5	1.7	3.2	1.4	3.6	1.7	3.4	1.6
	Female family members	3.0	1.4	3.3	1.6	3.0	1.2	3.6	1.8	3.2	1.6
	Member aged < 15	2.5	1.5	3.0	1.9	2.7	1.4	2.6	1.7	2.8	1.7
	Members aged 15-64	3.4	1.6	3.6	1.9	3.4	1.6	4.4	2.2	3.7	1.9
	Members aged >64	0.0	0.2	0.1	0.5	0.0	0.3	0.2	0.5	0.1	0.5
	Dependency ratio	1.0	0.8	1.1	0.9	1.0	0.7	0.8	0.8	1.0	0.9
Resource endowment	Farming experience (years)	22.5	10.8	21.9	11.	21.7	10.5	25.9	12.7	22.6	11.3
	Number of oxen	1.6	1.4	1.5	1.8	1.8	1.1	0.4	0.8	1.4	1.5
	TLU	6.0	5.5	5.5	4.7	5.4	3.4	4.6	4.7	5.4	4.7
	Landholding in ha	1.1	0.8	1.5	1.6	1.8	0.8	1.3	1.1	1.4	1.3
	Number of parcels	3.6	1.9	3.7	1.7	5.9	2.4	2.4	1.2	3.8	2.1
	Average distance from farm home to farm (km)	2.8	2.2	1.2	1.3	1.6	1.3	0.8	1.5	1.5	1.7
Market	Distance to all weather roads (km)	2.5	3.3	1.5	1.9	2.2	2.4	1.5	1.8	1.8	2.3
	Distance to nearest market (km)	7.6	6.4	4.1	3.6	4.0	3.2	3.8	3.2	4.6	4.3
	Distance to Farmer Training Centre (km)	3.4	3.2	2.3	3.2	2.8	2.4	2.6	2.5	2.6	3.0
	Distance to coops (km)	3.3	3.1	3.1	4.2	4.3	3.3	3.5	3.6	3.4	3.8
Lagged income (ETB)	Crop income (000)	10.4	11.5	10.1	14.5	9.4	10.5	6.1	8.1	9.3	12.6
	Livestock income (000)	4.5	7.3	8.5	16.	2.6	4.9	1.4	3.7	5.7	12.4
	On and off farm income (000)	2.2	7.1	2.0	6.9	1.4	5.5	2.2	7.8	2.0	6.9
	Annual gross income (000)	17.1	17.5	23.5	35.	13.7	14.3	9.8	15.0	18.6	27.8

Conversely, the percentages for use of seeds of improved variety of barley and sorghum was low in all regions except in SNNP where 62% of barely was cultivated using improved seed.

Table 4 - Percentage of farmers using improved and local varieties (%) by region in the 2013 production season.

Crop	Improved Seed Use*	Tigray (%)	Oromia (%)	Amhara (%)	SNNP (%)	Average (%)
Tef	No	63	69	55	29	65
	Yes	37	31	45	71	35
Maize	No	55	44	1	19	35
	Yes	45	56	99	81	65
Wheat	No	31	56	11	17	40
	Yes	69	44	89	83	60
Barley	No	88	85	96	38	76
	Yes	12	15	4	62	24
Sorghum	No	93	98	-	-	96
	Yes	7	2	-	-	4
Potato	No	47	86	72	30	58
	Yes	53	14	28	70	42

Mineral fertilizer use

The use of fertilizers in Ethiopia has increased in recent years, despite having one of the lowest rates of application (43 kg urea and 65 kg DAP/ha) when compared to sub Sub-Saharan standards (Girmay, 2015; Elias, 2017). The data from this study revealed that the majority of farmers (80%) used fertilizers in cereal production (Table 5). However, there was large variation among the regions; fertilizer use was highest in Amhara (96%) followed by SNNP and Tigray.

The average rate of DAP application in kg/ha was: 72 (tef), 102 (maize), 100 (wheat), 72 (barley), 46 (sorghum) and 134 (potato) (Table 5). The application level of urea in kg/ha was: 39 (tef), 94 (maize), 79 (wheat), 34 (barley), 50 (sorghum) and 89 (potato). The findings reveal maize and wheat were the only crops that received the recommended amount of DAP and no crop received recommended rate of urea. The ten year average (1994/95-2005/06) of fertilizer use (DAP and Urea combined) for major cereals indicate that farmers applied 57 kg/ha for wheat, 40 kg/ha for tef, 29/ha for maize, 22 kg/ha for barley and 3kg/ha for sorghum (Endale, 2010). The average intensity of fertilizer uses in the country (which is less than 40 kg/ha) remains much lower than elsewhere – e.g., 54 kg/ha in Latin America, 80 kg/ha in South Asia and 87 kg/ha in Southeast Asia (IFDC, 2015).

Table 5 - Average DAP and urea fertilizers application for major cereals in four Ethiopian Regions in the 2013 production season (kg/ha).

FERTILIZER	CROP	RFR*	TIGRAY		OROMIA		AMHARA		SNNP		TOTAL	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
DAP	Tef	100	49	49	57	65	117	52	85	28	72	64
	Maize	100	76	45	71	89	202	101	70	31	102	98
	Wheat	100	95	46	87	70	171	75	85	26	100	67
	Barley	100	71	48	39	53	101	59	75	32	72	53
	Sorghum	100	21	41	59	99					46	86
	Potato	165	92	56	141	108	147	107	126	60	134	91
Urea	Tef	100	40	45	39	57	29	42	69	31	39	51
	Maize	200	75	44	73	91	173	94	60	35	94	92
	Wheat	125	90	38	70	65	93	77	77	32	79	59
	Barley	50	65	49	4	18	23	38	139	21	34	41
	Sorghum	100	23	42	63	115					50	100
	Potato	**195**	**97**	**65**	**150**	**111**	**47**	**73**	**78**	**59**	**89**	**90**

*Recommended Fertilizer Rate- indicated through the extension system.

Row planting

In recent years, row planting of cereals has been promoted by the extension system as a yield enhancing agronomic practice. However, there have been challenges associated with row making implements for small cereals such as tef and barley. The results of this study reveal that farmers adapted their own innovations for making rows using oxen pulled ploughs or by making rows manually. Among cereals, row planting was poorly adopted for both tef and barley while it was better for maize, wheat, sorghum and potato (Table 6). This could be because the lack of proper row making technologies impedes farmers from fully practicing row seeding. Irrespective of different crops, farmers practiced row planting with improved seeds more often than with local seeds.

Pesticide application

The use of pesticides was generally low and farmers focused on high value crops such as tef and wheat that were meant for cash generation. According to the results of the study, the majority of both model and non-model farmers applied pesticides on tef and wheat. Less pesticides ware applied on maize, barley, sorghum and potato in comparison.

Table 6 - The practice of row planting for different crops and regions, Ethiopian highlands.

Crop	Tigray		Oromia		Amhara		SNNP		Overall	
	N	%	N	%	N	%	N	%	N	%
Tef	244	31	875	28	379	51	131	15	1629	33
Maize	276	62	997	87	463	99	273	94	2000	88
Wheat	299	58	598	41	157	90	150	81	1204	57
Barley	224	11	200	10	211	42	209	67	844	32
Sorghum	214	10	424	46	NA*	NA	NA	NA	639	34
Potato	35	89	276	95	238	34	282	98	831	78

*NA= not available or not applicable

Intensity of crop technology package use

The intensity of crop technology package adoption was ranked highest for potato (71%) and lowest for sorghum (29%) across the four regions (Table 7). Among the cereals, the highest average adoption of technologies was seen in wheat (66%), followed by maize (60%), tef (52%) and barley (46%). Region wise, crop technology package adoption was highest in Amhara (66%), followed by SNNP (62%), Oromia (56%) while the lowest was in Tigray (40%). This large regional difference in technology adoption may be associated with the biophysical conditions (soil fertility status, rainfall and length of growing period) that dictate the agricultural potential of an area (Tewodros *et al*., 2016). In all accounts, biophysical factors are poorest in Tigray, affecting package adoption in spite of aggressive promotion.

Table 7 - Crop technology package adoption intensity (%) for six crops in four regions of Ethiopia

Crop	Tigray	Oromia	Amhara	SNNP	Average
Tef	31	53	65	60	52
Maize	48	58	74	57	60
Wheat	62	62	85	70	66
Barley	31	36	45	64	46
Sorghum	15	34	NA	NA	29
Potato	53	90	63	58	71
Aggregated average	40	56	66	62	

Technology uptake by model and non-model farmers

The Ethiopian extension system anticipates productivity differences between model and non-model farmers. With the aim of bridging productivity gaps and in order to enhance peer learning among farmers, development groups are established with the model farmers playing a leading role in brokering knowledge and skill transfer to the non-model farmers. In this study, significant ($p<0.05$) difference in technology adoption and crop yields for selected crops was observed between model and non-model farmers (Table 8 and Table 9). The assessment on fertilizer inputs use revealed that model farmers applied 97% of the recommend rate of 150 kg DAP and 100 kg urea per ha application, while non-model farmers applied 89% of the recommended rate of DAP for wheat crops. Despite the fact that the intensity of urea application was lower than DAP for all crops, model farmers still applied relatively higher amounts of urea as compared to their non-model counterparts. Model and non-model farmers were statistically different in practicing row planting for crops, whereby model farmers practiced row planting more than non-model farmers. A higher percentage (significant difference at 10% level) of model farmers applied pesticides for wheat and sorghum compared to non-model farmers. The findings show that in most cases yield attained by model farmers was higher than those of non-model farmers Moreover, the use of improved seed along with fertilizers lead to higher productivity. However, the observed productivity difference was only significant for wheat, barley and potato crops.

The findings show, in most cases, that yield levels attained by model farmers was higher than those of non-model farmers except in the case of tef. However, the productivity difference was only significant for wheat, barley and potato crops.

Econometric estimation

The dependent variables in econometric models are called ‘adoption indices’ and are calculated from a range of parameters including improved seed use intensity, fertilizer use intensity, row planting and pesticide use. This dependent variable is based on the reported uptake of technology packages by households for the respective crops. The econometric estimates of the coefficients show expected signs and prior premise (Table 10).

Variables included in the models were tested for multi-collinearity using the Variance Inflation Factors (VIF) prior to the estimation of the Tobit models. No multi-collinearity problem was noted among all the explanatory variables (Gujarati and Porter, 2004). The factors that influence the intensity of adoption of recommended technology packages were assessed using the two-limit Tobit model. Six separate regressions were run for tef, maize, wheat, barley, sorghum and potato. The choice of the independent variables included in the model was based on economic theory and review of empirical findings. All the models are well fitted and the results show that over 50% of the variation in crop extension package adoption for the respective crops is explained by the independent variables.

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Table 8 - Proportion of model farmer (MF) and non-model farmers (NMF) use of improved technology use in percentage.

CROP	IMPROVED VARIETY		DAP		UREA	
	MF	NMF	MF	NMF	MF	NMF
Tef	33	31	72	72	49	51
Maize	47	37	73	68	52	50
Wheat	76	61	97	89	72	65
Barley	13	6	71	68	65	62
Sorghum	8	3	32	33	35	37
Potato	52	66	93	86	76	71
	ROW PLANTING		PESTICIDE USE			
	MF	NMF	MF	NMF		
Tef	36	26	71	69		
Maize	89	85	20	21		
Wheat	61	46	51	46		
Barley	36	23	24	20		
Sorghum	34	34	33	25		
Potato	79	76	27	28		

MF=Model Farmers, NMF=Non-Model Farmers

Table 9 - Yield difference (kg/ha) for local and improved varieties of cereal crops for model and non-model farmers.

CROP	LOCAL VARIETY			IMPROVED VARIETY		
	MF	NMF	MD	MF	NMF	MD
Tef	11	10	11	13.8	14.3	-4
Maize	33	32	3	39	38	1
Wheat	25	20	24	27	26	5
Barley	21	19	14	30	24	29
Sorghum	39	27	46	32	29	12
Potato	95	92	3	120	96	25

MF=Model Farmers, NMF=Non-Model Farmers, MD= Mean difference percentage

Table 10 - Drivers of adoption for major cereal crops and potato in CASCAPE woredas, as explained by estimated coefficient and standard error.[1]

VARIABLES	TEF	MAIZE	WHEAT	BARLEY	SORGHUM	POTATO
Study region (Base)	Tigray	Tigray	Tigray	Tigray		Tigray
Oromia	0.172 (0.039) ***	0.146 (0.026) ***	-0.057 (0.031) *	0.057 (0.05)	0.391(0.082) ***	0.231(0.064) ***
SNNP	-0.290 (0.047) ***	0.139 (0.028) ***	0.084 (0.036) **	0.328 (0.052) ***		0.174 (0.06) ***
Amhara	0.280(0.47) ***	0.286 (0.028) ***	0.202 (0.032) ***	0.176 (0.043) ***		0.282(0/067) ***
Lowland agro-ecology	Base	Base	Base	Base	Base	
Midland agro-ecology	0.016(0.036)	-0.112 (0.023) ***	-0.043 (0.083)	0.428 (0.11) ***	0.116 (0.07) *	
Highland agro-ecology	0.045(0.040)	-0.212 (0.025) ***	0.014(0.085)	0.494 (0.11) ***	0.090 (0.067)	0.089 (0.025) ***
Farmers type	-0.017 (0.024)	0.035 (0.014) **	0.022 (0.02)	0.060 (0.03) *	0.013 (0.04)	0.01 (0.023)
Sex of HH	-0.021 (0.031)	-0.048 (0.02) **	-0.040 (0.024) *	0.029 (0.04)	0.027 (0.053)	0.013 (0.03)
Education level of HH	0.026(0.023)	0.020(0.013)	0.017(0.022)	-0.011 (0.037)	0.027 (0.04)	-0.002 (0.001)
Age of HH	0.001(0.001)	0.001(0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.002 (0.001)	0.001 (0.001)
Family size	0.004 (0.005)	-0.002 (0.002)	0.001 (0.004)	-0.004 (0.006)	0.17 (0.007) **	0.009 (0.004) **
Dependency ratio	-0.002 (0.012)	-0.003 (0.007)	0.012(0.01)	-0.018 (0.014)	-0.021 (0.018)	-0.003 (0.012)
Number of oxen	-0.003 (0.011)	0.002(0.004)	-0.001 (0.008)	0.017 (0.014)	0.038 (0.02) *	-0.033 (0.01) ***
TLU excluding oxen	0.002(0.003)	0.004 (0.001) **	0.001 (0.002)	-0.003 (0.003)	-0.001 (0.01)	0.001 (0.002)
Access to credit	0.039(0.039) **	-0.039 (0.014) ***	0.065 (0.02) ***	0.039(0.03)	0.017 (0.05)	-0.004 (0.02)
Irrigation access	-0.032 (0.025)	0.020 (0.012) *	-0.018 (0.02)	0.024(0.03)	-0.027 (0.04)	0.143 (0.03) ***
Membership to coops	0.041(0023) *	0.042(0.014) ***	0.064 (0.02) ***	0.113 (0.03) ***	0.033 (0.04)	0.039 (0.02) *

Dis. of homestead to farm plots	0.006 (0.008)	-0.002 (0.003)	-0.012 (0.006) **	0.003 (0.007)	0.015 (0.01)	0.001 (0.006)
Dis. of homestead to all weather road	0.003 (0.005)	0.001 (0.002)	-0.006 (0.006)	-0.011 (0.009)	-0.014 (0.01)	-0.006 (0.006)
Dis. of the homestead to the nearest market	-0.006(0.003) **	-0.005 (0.002) ***	0.006 (0.002) ***	-0.002 (0.004)	-0.001 (0.007)	0.003 (0.003)
Distance of the homestead to FTC	0.001 (0.004)	0.001(0.002)	-0.008 (0.005) *	-0.003 (0.006)	-0.007 (0.01)	-0.002 (0.004)
Total land size in ha	0.021 (0.01) **	-0.031 (0.007) ***	0.020 (0.007) ***	0.013 (0.01)	-0.118 (0,04) ***	0.004 (0.004)
Plots slope index	0.044(0.02) **	0.021 (0.012) ***	-0.0013 (0.02)	-0.011 (0.02)	-0.125 (0.051) **	0.085 (0.02) ***
Number of plots	0.009 (0.006)	-0.005 (0.003)	-0.003 (0.005)	-0.016 (0.08) *	0.009 (0.02)	-0.004 (0.009)
Medium extension contacts	-0.048 (0.04)	0.041 (0.026)	0.052 (0.03) *	-0.024 (0.04)	0.043 (0.08)	-0.053 (0.04)
High extension contacts	-0.019 (0.04)	0.046 (0.026) *	0.039 (0.03)	-0.041 (0.04)	0.080 (0.08)	-0.026 (0.04)
Lagged annual gross income (square root)	0.001 (0.001) ***	0.001 (0.001) ***	0.001 (0.001) ***	0.001 (0.001) **	0.0001 (0.002)	0.001 (0.001)
Percentage of output sold	0.001(0.001) ***	0.001 (0.001)	0.001 (0.003) ***	0.001 (0.001)	-0.001 (0.0015)	0.001 (0.003) ***
-cons	0.306 (0.09) ***	0.52 4(0.055)	0.663 (0.108)	-0.051 (0.14)	0.597(0.13)	0.499 (0.09)
/sigma	0.235(0.07)	0.186(0.005)	0.45(0107)	0.25(0.012)	0.281 (0.02)	0.21 (0.007)
No of observation	660	1192	695	430	285	495
F	10.05	18.47	13.15	12.51	11.91	6.54
Prob> F	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.68	430.7	1.33	0.56	0.53	1.08

[1] Figures in in parenthesis are standard error. *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%

Discussion

Drivers of technology adoption

Tef

Table 8 shows that intensity of tef technology adoption was significantly influenced by location variable, access to credit, and membership to cooperative organizations. To a lesser extent, it was influenced by distance to the nearest market, total land size, farm plot slope index, lagged annual gross income and percentage of output sold. The strongest predictive value, however, is the location variable, which shows that that adoption intensity of tef technology was significantly (p<0.01) higher among sample respondents in Oromia, and Amhara but lower in SNNP compared to the base region (Tigray).

There was significant (p<0.01) increase in tef technology adoption when households become members of a cooperative, had access to credit and when the farm size is bigger with a gentle slope position (0-5%). These factors also correlate with higher annual gross income and higher proportion of tef grain marketed. To the contrary, the significant (p<0.01) negative effect of distance to market indicates that farmers far away from market centres are less likely to adopt the tef technology package than those who are located in the vicinity of market centres.

Maize

The findings showed that maize technology package adoption intensity increased as the respondent household's status changed from non-model to model farmer status, from non-member to cooperative organization membership and from rain fed to irrigation access. Furthermore, farm plot slope index positively and significantly influenced maize technology package adoption (Bekele *et al*., 20090. A limited but significant positive effect was also found for household's livestock endowment, lagged annual gross income and proportion of percentage of maize produce sold. On the contrary, adoption intensity prospects deteriorated for Female Headed Households and households with access to credit. Furthermore, households further away from market centres were also less inclined to adopt the maize technology package, although this effect was rather limited.

Again, results indicate that location variation was significantly different in maize technology adoption intensity. Compared to the base Tigray regions, adoption of maize technology intensity was significantly higher in Oromia, SNNP and Amhara regions by 1% significance. Out of the three traditional agro-ecological zones[3] (highland, midland and low land), maize technology adoption intensity was significantly increased in lowland agro-ecological zone and the finding was statistically significant (p<0.01).

Wheat

Adoption decisions were found to vary with location. Region dummies included in the models were found to be highly statistically significant for wheat technology adoption intensity. Farmers in Tigray region had a significantly higher likelihood of adoption of improved wheat technology compared to farmers in Oromia (East and Western Oromia)

[3] The traditional agroecological zonation more precisely as being 'Kolla' at altitudes below 1800 m a.s.l. 'Weyna Dega' for altitudes between 1800 – 2400 m, and 'Dega' for areas above 2400 m was used in this study following Dove (1890) as cited in Huri, 1998.

region, while they were less likely to adopt the same technology compared to SNNP and Amhara regions.

Unlike for tef and maize, the findings indicate that having frequent contact with extension agents and living near to the farmer training centres has a positive effect on the likelihood of adoption of the wheat technology package. Furthermore, access to credit, membership in cooperatives, distance of respondent homestead from the nearest market, landholding size, proportion of annual gross income and proportion of wheat produce sold, positively influenced wheat technology package adoption intensity. Conversely, distance of the homestead from the farm plots and all-weather roads negatively influenced the same. The findings revealed that wheat technology package adoption intensity augmented as the respondent household's access to credit has improved and when they become members of a cooperative organization. In addition, proximity to primary market place was found to be a positive driver of wheat technology adoption while increased distance of farm plots from homestead and all weathered roads were major inhibitors of wheat technology adoption.

Barley

Intensity of barley technology package adoption was influenced by a number of explanatory variables, namely spatial variation, agro-ecology, farmer type, membership in cooperatives, number of plots and annual gross income. Study results indicate that region dummies were found to significantly influence barley technology adoption intensity. Compared to the Tigray region, adoption of barley technology intensity was significantly higher ($p<0.01$) in the SNNP and Amhara regions. Compared to the lowland agro-ecological zone, barley technology adoption intensity was highest in the midlands and highlands where tepid to cold climatic zones are most prevalent.

Furthermore, membership in cooperatives showed a significantly positive effect, indicating that members of a cooperative have a higher likelihood of adopting the barley technology package. Other variables, which showed little a significant positive effect, included being a model farmer and increased annual gross income. However, number of farm plots or parcels operated by a household negatively influenced the likelihood of adoption of barley technology. This suggests that farmers growing barley tend to be specialising in barley production, rather than diversifying their crop base. Put differently, farmers with fragmented landholdings face challenges in adopting the barley technology package.

Sorghum

Intensity of sorghum technology package adoption showed a rather different pattern than the other major cereals, being positively influenced by dependency ratio (when there were more mouths to feed) and the number of oxen. Annual gross income showed a very small but significant positive effect. Total landholding size, farm plots slope index and proportion of sorghum produce sold negatively influenced the intensity of sorghum technology package adoption. Sorghum was only grown in two regions, Oromia and Tigray, and the finding of this study show that farmers in eastern Oromia were more likely to adopt sorghum technology than farmers in the Tigray region.

This indicates that larger families with relatively small landholdings that mainly produce for home consumption have a higher likelihood of adopting the sorghum technology package. This shows clearly that sorghum is more of a food security crop than a cash crop.

Potato

Findings show that region dummy, agro-ecology, family size, access to irrigation, membership in cooperatives, farm plot slope index and percentage of potato produce sold influence adoption intensity positively and significantly, while oxen ownership influences it negatively as potato is dominantly a hoe farming crop. Potato technology adoption intensity varies across locations. Farmers in the Tigray region are less likely to adopt potato technology as compared to farmers dwelling in Oromia, SNNP and Amhara regions. Of the different agro-ecology dummies, potato was found to grow in midland and highland agro-ecological zones.

Potato adoption intensity was positively and significantly higher in midlands as compared to highlands. Family size (which captures labour availability and number of mouths to feed), access to irrigation, membership to cooperatives, well-drained soil with steep slope and production of potato for sale, positively and significantly influenced potato technology adoption. On the contrary, oxen ownership negatively influenced potato technology adoption. This might be due to the hoe farming practice associated with potato production in the study areas. Farmers who participated more in community-based organizations such as cooperatives and other informal groups were likely to engage in learning about the technology, thus raising the likelihood of adopting the technologies. This correlates with findings, which show that membership to cooperatives positively influences potato technology adoption intensity. Analysis shows that household size influenced the adoption process of agricultural technologies positively – in that a larger household had the capacity to relax the labour constraints required during introduction of new technology.

Major factors influencing technology adoption

The study shows that for most of the agricultural technologies promoted through the extension system, adoption levels of the full technology packages are below expectation. There is a reasonable level of use for some of the components of technology packages but not for all components. This supports the argument that further study on the adoption of agricultural technology needs to look beyond the technologies alone, and rather consider a mix of conditions conducive to technology uptake. The agency and sovereignty of farmers in adapting, modifying and rejecting technology supplied and promoted is crucial. It should also be acknowledged that adoption is a dynamic process whereby farmers can, over time, decide to test or to implement a certain element in one year and not in the next, a conclusion also supported by Kiptot *et al.*, 2007 in a study on improved tree-fallow in Kenya.

This study explored whether farmers apply the full-package as promoted by the extension system or adaptation to local specific context prevails. Based on the findings, it was observed that the latter was happening among smallholder farmers. For instance, row planting is done in a modified way manually or by making rows using oxen pulled by plough. The use of improved seed, seed rate fertilizer, pesticide use and other agronomic practices have been adjusted to suit the local context and households' circumstances (Gebremedhin and Swinton, 2003). Farmers will always pick and choose what is best for their realities and what is feasible within their economic means. However, the national extension system promotes a "take-all or none" approach with some level of coercion and a quota system that tends to be counterproductive. An example of this is the mandatory purchase of the recommended amount of fertilizer based on the crops the farmer grows in relation to the farm land(s) they possess. The supporting system should be reoriented to offer smallholders a basket of options applicable to the integrated system characteristic of many mixed smallholder farms in Ethiopia.

Spatial factors

Under this category, variables from the adoption equation were clustered, such as location, agro-ecology and slope index. Location and the agro-ecology (highland versus mid- or lowland) variables were the strongest predictors of adoption behaviour for the major cereals and potato technology package. A similar result was documented by Asfaw *et al*., 2012 and the study by Benin *et al*., 2003 also confirmed this finding as the probability of adoption of agricultural technologies was higher in highlands and midlands.

Institutional factors

Another other category is institutional variables, which can be manipulated by policies and development programmes to enhance technology adoption. Under this group, variables such as farmer type, access to credit, irrigation access, membership in cooperatives, and extension contact, significantly influenced technology adoption.

Access to credit positively and significantly influenced adoption of technology for tef and wheat (both considered cash crops). Findings indicate that households who had more access to formal and/or informal sources of credit were significantly more likely to adopt these cereal technology packages. This is in line with previous findings by Zeller *et al*., 1998; Oluoch-Kosura *et al*., 2001; Feleke and Zegeye, (2006); Akinola *et al*., 2010, and Ogada *et al*., 2014, as they showed that access to financial resources was necessary to finance the uptake of new technologies. The positive and significant influence of credit on fertilizer adoption was reported by Endale (2010).

Cooperative membership positively and significantly influenced adoption of all technology packages except for sorghum. This indicates the importance of cooperative membership for accessing inputs for the production of marketable crops (Uwagboe *et al*., 2012; Tewodaj *et al*., 2009). The positive influence of cooperative membership on the technology application on cereal crops was reflected in findings of this study. Studies by Olwande *et al*., 2009; Odoemenem and Obinne (2010) were consistent with this result. Various studies also reported cooperative membership had a positive influence on technology adoption through enhancing access to information on improved technologies, material inputs of the technologies such as fertilizers and pesticides, and credit for the purchase of inputs and payment of hired labour (Odoemenem, 2007; Odoemenem and Obinne, 2010).

Contrary to the hypothesis for this study, farmers' frequency of contact with extension agents was of much less relevance to the adoption of technology package for major cereals except the case of wheat, where there was a moderate (positive) effect. Despite the findings that the effect of extension was less visible in the contact moments, this does not mean that extension services are not important for the adoption of technologies (Odoemenem and Obinne, 2010). Many researchers have reported a positive relationship between extension services and technology adoption. Good examples include adoption of improved maize and land management in Uganda by Sserunkuuma (2005) and adoption of modern agricultural technologies in Ghana by Akudugu *et al*., 2012. Extension services play a major role in knowledge transfer, as well as availing inputs to farmers (through cooperatives and unions), which were captured in the other variables of this study.

There is a wide consensus in agricultural extension literature that innovators farmers are the first to adopt new technologies (Diederen *et al*., 2003). This give autonomy for extension workers in many countries to focus on this group of farmers to speed up technology diffusion. For example, the lead farmers approach implemented in Malawi revealed that lead farmers were not only adopting agricultural technologies in their own plots, but they also played a pivotal role in knowledge sharing and information transfer between farmers (FYF, 2012). This study revealed that model farmers were more likely to apply a higher amount of DAP and urea fertilizers to cereal crops as compared to non-model farmers. However, the assumption that model farmers have the motivation and the means to try new ideas and technologies, they are risk taker and technology adoption trickle down through their lead role need caution. The present study uncovered that model farmers were significantly better adopters of maize and wheat technology only as compared to non-model farmers, while being model farmers are less important in other crops considered in the study.

Distance to market and an all-weather road, which was a proxy for market inaccessibility, was found to have a significant but negative influence on intensity of technology adoption, indicating that farmers far away from market centres were less likely to adopt technology than those who were located closer to market centres suggesting the market pull of technology adoption. These findings are in agreement with the results of Feleke and Zegaye (2006) Bayissa (2014) and Kassie *et al*., 2013. The negative relationship between distance of the homestead from an all-weather road and fertilizer adoption was reported in other studies. For instance, Gebresilassie and Bekele (2015) found that distance to market centres was negatively and significantly related to adoption of fertilizer. Decreasing the distance from the market decreased the transportation cost of agricultural inputs. Hence, market distance and use of inorganic fertilizer had a negative relationship (see also Ogada *et al*., 2014).

Household level factors

The cash generation capacity of the commodity positively influenced technology adoption intensity. Study analysis implied that households producing tef, maize, wheat and potato for the market were highly probable to adopt the technological package promoted for these crops. Hence, households who sold large proportions of these produce were also more likely to adopt technologies compared to those who produced for subsistence purpose. Ayele *et al*., 2006, reported that farmers who participated in extension programmes and utilized agricultural technologies were well integrated with markets and supplied more produce than non-participants. For sorghum, a divergent picture emerges, namely that farmers mainly produce this for home consumption, hence other factors than the proportion sold have a much stronger effect on the adoption likelihood.

The number of plots on a farm signified the level of land fragmentation and also reduced economies of scale and technology application. In this study, more plots discouraged barley technology adoption significantly. The negative influence of land fragmentation was also reported by Yu *et al*., 2010, which found that land fragmentation was found to be a detriment to fertilizer adoption.

Gender plays a crucial role in adoption (Mwangi *et al*., 1999). A household headed by a woman is shown in this study to have a much lower adoption rate than male-headed households. Some studies have also shown negative influence of farm size on adoption of new agricultural technology. Replacement of subsistence-oriented crops like sorghum and maize with high value crops might be a possible reason (see other authors who reported a negative relation between technology adoption and farm size: Yaron *et al*., 1992; Harper *et al*., 1990. The findings of this study also show that increased land supply influenced technology adoption for tef and crops that were market oriented.

Income is a proxy variable for capital availability for investment. It was hypothesized that households with higher annual gross income would be in a better position to adopt technology as they could invest in improved seed, fertilizer, pesticides and hire labour for various farming operations. Many authors also reported the positive influence of annual income and off-farm income on technology adoption. Although income showed a significant positive effect, the effect was not as high as expected.

Livestock constitutes an important component of mixed farming systems. The results of this study showed that livestock holding measured in tropical units only had a significant (and positive) effect on the adoption of the maize technology package. The positive influence of livestock ownership in maize technology adoption was also reported by Doss *et al*., 2003. Livestock financed fertiliser purchase through income generation or served as collateral for fertilizer credit. Our findings show that livestock positively influenced maize technology package and this result is in agreement with Endale (2010) who reported the significant and positive influence of livestock ownership on levels of technology adoption.

Conclusion

The study identifies factors influencing extension package adoption of major cereals and potato crop among smallholder farmers. The econometric analysis identified three major drivers/inhibitors of crop technology package categorized under (1) factors related to the characteristics of producers; (2) programme and institutional factors; and (3) biophysical environment.

The study showed the presence of spatial variation in crop technology adoption and these differences were mainly attributed to control variables such as agro-ecological difference and location of specific access to infrastructure and other services. The difference between model and non-model farmers in technology adoption was exhibited only for specific crops (maize and barley). Hence, exclusive focus on model farmers and the assumption of technology diffusion through their brokerage is difficult argument to follow, rather extension system should be inclusive and accessible to all.

The study identified control and policy variables as drivers and inhibitors of technology adoption. Given the stable and relatively static nature of control variables, policy makers should focus on policy variables to optimize technology adoption and achievement of policy outcomes. For the realization of technology-push based agricultural transformation priority setting, need identification and effectively exploiting capability of the farmers is important. Technologies offered through the extension system do not always solve the constraints faced by farmers related to increased production and productivity. Issues of market, risk mitigation, conservation and rehabilitation of natural resources and infrastructure development deserve attention to promote demand driven change (Shiferaw *et al*., 2009). Besides the need for proper knowledge transfer through the extension system, these findings emphasize, once again, the need to make technologies accessible to farmers, such as increasing access to credit and membership in cooperatives, as well as improving access to markets and all-weather roads. Technology packages should be adjusted for the type of commodity; not every commodity is suitable for high intensity technologies. A prime example is sorghum, which is grown as a subsistence and food security crop. The research and extension system is urged to design affordable and farmer friendly row making and row seeding technology.

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