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REGULAR ARTICLE

DETERMINANTS OF ADOPTION OF POTATO PRODUCTION TECHNOLOGY PACKAGE BY SMALLHOLDER FARMERS: EVIDENCES FROM EASTERN ETHIOPIA

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ABSTRACT

Potato production plays an important role in improving household income and nutrition and thereby contributes to food security. Despite of this, the current productivity of the crop is below the potential. Low level of use of improved potato technology package is among the causes for low productivity. In this context, this study analysed the factors influencing adoption of potato technology package by smallholder farmers in Gurawa, Haramaya, Kombolcha, Meta, and Habro districts of Eastern Ethiopia. The analysis was based on a household survey conducted on 214 randomly selected potato growing households. A two-limit Tobit model was used to analyse the factors affecting adoption which is measured in an index computed from five components of the technology package. Variation in districts, access to irrigation, farm size, membership to cooperatives, and annual income of the households were found to significantly affect the adoption of potato technology package. Policy makers, planners and development practitioners are required to give due attention to these determinants in order to support smallholder farmers in production and productivity improvements from potato production.

Keywords: Potato technology packages; Adoption index, Two-limit Tobit model, Eastern Ethiopia
JEL: D13, D24, Q12

INTRODUCTION

Potato (*Solanum tuberosam* L.) is among the major food crops produced in the world **(Knapp 2008; Nyunza and Mwakaje 2012)** in which Ethiopia is also inclusive. It is the fourth most important food crop in the world on the basis of production after maize, rice, and wheat with annual production accounts of nearly 300 million tons **(Naz *et al*. 2011)**. Out of these, over half of production occurs in developing countries **(Devaux *et al*. 2014)**. In Ethiopia, for example, the total production from potato was 943,233 tons with an average productivity of 13.5 t/ha. The area under potato was 70,132 ha cultivated by 1.4 million households in the main cropping season of 2015/16. During the same period, it ranks first in area coverage and third in both total production and productivity among the root crops grown in Ethiopia **(CSA 2016)**.

Nutritionally, potato provides more calories, vitamins, and nutrients per unit area than any other staple crops **(Sen *et al*. 2010)**. Hence, it contributes towards efforts of ensuring food and nutrition security. In Ethiopia, potato is becoming a prominent source of income since the crop is the most important cash crop for smallholder farmers in the mid-altitude and highland areas of the country **(Mulatu *et al.* 2005; Gildemacher *et al*. 2009)**. In areas like Hararghe, the economic benefit of potato production is not only limited to smallholder farmers, but also to other actors involved in the potato value chain **(Jaleta 2007; Bezabih 2008; Bezabih 2010; Kebret *et al*. 2015)**. More importantly, in East Hararghe and West Hararghe zones, landholding is very small and as a result land use is highly intensive. Hence, potato production takes place both under rain-fed and irrigation **(Kumilachew and Musa 2016)**. In addition to the agro-ecological potential, East Hararghe zone has a comparative advantage of producing potato due to its high domestic and export markets **(Bezabih 2010)**. Therefore, potato production is a major source of livelihood for various value chain actors in Eastern Ethiopia where irrigation is available and farmers have better access to local and export markets due to its proximity to neighbouring countries like Djibouti and Somalia.

However, potato yields are relatively low in developing countries **(FAO 2013)**. This is true in Ethiopia in general and East Harrghe and West Hararghe zones in particular. **Mulatu *et al*. (2005)** indicated that in Hararghe, the yields of potatoes grown on the research station (30-40 metric tones ha^{-1}) are not realized at the producer's level (11-13 metric tones ha^{-1}). Productivity of the crop is constrained by multidimensional factors such as lack of disease resistant and high yielding varieties with desirable market qualities, limited knowledge of agronomic and crop protection management technologies, and poor post-harvest handling **(Nigussie *et al*. 2012)**.

Besides, low level of adoption of improved potato technology package contributed a lot for low productivity of the crop. Adoption studies conducted in Ethiopia and elsewhere proofed low level of adoption of potato technologies in the country **(Gebremedhin *et al.* 2008; Ortiz *et al*. 2013; Abebe *et al*. 2013)**. Many of these studies have focused on adoption of a single technology components like improved variety adoption. However, adopting a single component of the package like improved varieties may not realize the expected benefits of potato producers. Hence, studies that take into account different technology components as a package are necessary.

This study takes into account different potato technology package including improved variety, row planting, pesticides application, Di-Ammonium Phosphate (DAP) and Urea application. The objective of this paper is, therefore, to assess determinants of adoption of potato technology package in selected districts of Eastern Ethiopia by focusing on Gurawa, Haramaya, Kombolcha, Meta, and Habro districts.

DATA AND METHODS

Description of the study area

The study was conducted in five districts, Gurawa, Haramaya, Kombolcha and Meta from East Hararghe zone and Habro from West Hararghe zone in Eastern Ethiopia.

Gurawa district: Gurawa is one of the districts in East Hararghe zone with high agricultural production potential. The altitude of the district ranges from 500 to 3230 meters above sea level. The district has an estimated total population of 300,661 **(CSA 2013)**. The district is known for its production of staple crops (wheat, barley and Irish potato) and fruit (apple) production **(Nigussie *et al*. 2012)**.

Haramaya district: Haramaya is one of the districts of East Hararghe Zone. The district has an estimated total population of 352,031 according to **CSA (2013)**. The altitude of this district ranges from 1400 to 2340 meters above sea level. It is situated in the semi-arid tropical belt of eastern Ethiopia. The mean annual rainfall received range from 600 to 1260 mm with bimodal nature. The relative humidity varies between 60 and 80%. Minimum and maximum annual temperatures range from 6ºC to 12ºC and 17ºC to 25ºC, respectively. Mixed crop and livestock production system is practiced in the district where maize; sorghum and vegetables crops (including potato) are commonly produced.

Kombolcha district: Kombolcha is also one of the eighteen districts in East Hararghe Zone. The altitude of the district ranges from 1600 to 2400 meters above sea level. The district is strategically located between the two main cities Harar and Dire Dawa. In addition, due to its proximity to Djibouti, the district has access to potential export markets in the area. The total population of the district is 178,058, out of which 88,102 are females **(CSA 2013)**. Lowland and midland agro-ecological zones characterize the district's climate. The district receives mean annual rainfall of 600-900mm, which is bimodal and erratic in distribution. The major crops produced in the district include sorghum, maize, vegetable (potato, tomato, cabbage, onion, and carrot), khat, groundnut, coffee, and sweet potato.

Meta district: Meta is also one of the districts in the East Hararghe Zone. Meta district is known for its potentiality in cash crops like coffee. A projected total population for this district, for the year 2016, is about 318,458; of whom 160,334 were men and 158,124 were women **(CSA 2013)**.

Habro district: Habro is one of the 14 districts located in West Hararghe zone. The district has an estimated total population of 244,444; of whom 126,176 were men and 118,268 were women **(CSA 2013)**. The agro-ecology of the district comprises highland (19%), mid-altitude (50%) and lowland (31%) areas. The mean annual rainfall of the district is 1010 mm and the annual temperature ranges from 5-32ºC.

Sampling procedure

A cross-sectional study design was used. Household questionnaire survey was administered to collect data from the smallholder farmers. Multistage sampling technique was employed. The steps involved were purposive selection of the five districts known for their potato production, followed by random selection of representative Peasant Associations (PA) from each district, where PA is the smallest administrative units in Ethiopia. A total of 214 household heads were randomly selected from a population of potato growing farmers as the final respondents.

Primary data were collected using structured questionnaire that comprises information related to household socioeconomic characteristics, farm characteristics, institutional factors, and technology utilization, among others. The survey was conducted during 2015/2016 production season. Additional information like recommended fertilizer rates were collected from secondary sources.

Methods

Selection of econometric model requires taking into account the nature of the dependent variable, among others. A dependent variable which bears a zero value for a significant portion of the observations requires a censored regression model (Two-limit Tobit model). Such censored regression is preferred because it uses data at the limit as well as those above the limit to estimate regression. Following the work of **Maddala (1997)**, the Tobit model can be derived by defining a new random variable $y*$ that is a function of a vector of variables.
The equation for the model is constructed as:

$$y^* = X_i\beta_i + \varepsilon_i \qquad (1)$$

Where y^* is unobserved for values less than 0 and greater than 1 (called a latent variable). It represents an index for potato technology package adoption, X_i represents a vector of explanatory variables, β_i is a vector of unknown parameters, and ε_i is the error term.

By representing y_i (selected agricultural technology adoption index) as the observed dependent variable, the two limit Tobit model can be specified as:

$$y_i = \begin{Bmatrix} 0 & \text{if } y_i^* \leq 0 \\ y^* & \text{if } 0 < y_i^* < 1 \\ 1 & \text{if } y_i^* > 1 \end{Bmatrix} \quad (2)$$

Censored regression models (including the standard Tobit model) are usually estimated by the Maximum Likelihood (ML) method. The log likelihood function is specified with an assumption that the error term ε follows a normal distribution with mean 0 and variance σ^2. The Tobit coefficients can be interpreted as coefficients of a linear regression model.

In line with this, determinants of adoption of potato technology package were investigated by using Tobit model. The dependent variable in the model is an index value ranging from 0 to 1. A value of 0 indicates non-adopter; index value 1 represents the full adopter of the technology component (adopted without discontinuity); and the values between 0 and 1 indicate the level of the adoption within the limits of Tobit model values.

The dependent variable for potato technology adoption package was an index computed from the use and intensity of use of technologies related to improved variety, pesticide use, row planting, Di-Ammonium Phosphate (DAP) and Urea in potato production. It is a weighted index, censored between 0 and 1, which is computed based on these five technology components (Equation 3).

$$Adop.\,index = \frac{Imp.var. + DAP + Urea + Pest. + Row\ plant.}{5} \quad (3)$$

Where improved variety use intensity is the proportion of potato farm covered by improved variety; DAP use intensity is the ratio of the actual rate of DAP applied on a potato field to the recommended rate of DAP (i.e. 195 kg per ha); Urea use intensity is the ratio of actual rate of Urea applied on a potato field to the recommended rate of Urea (i.e. 165kg per ha); pesticide use is whether the farmers have used herbicides, insecticides, and fungicides; and row planting is whether the farmers have used nearly or exactly the recommended spacing between rows and plants.

As per the theoretical justifications and prior literature, a number of explanatory variables have been hypothesized to influence the adoption of potato technology package. Accordingly, attempts were made to include relevant variables that are expected to influence the decision of adoption of potato technology package by smallholder farmers. The potential explanatory variables hypothesized and included in the Tobit model are those indicated in Table 1.

RESULTS AND DISCUSSION

Household characteristics

Access to irrigation was one of the important constraints in agricultural production, especially in areas like Hararghe where double cropping is common and irrigation water is limited to underground sources. Descriptive result shows that households in Haramaya and Kombolcha have higher access to irrigation (about 87% and 66%, respectively) as compared to respondents from other districts like Meta and Habro (about 5% and 29%, respectively). On average, about 45% of the respondents do have access to irrigation in the study areas (Table 2).

Average land holding in the study area is 0.51 ha which is very low as compared to the holdings in other parts of the country. On average, higher annual income was observed in Kombolcha (about 25,070 Birr), followed by Habro (about 24,380 Birr) and Haramaya district (about 24,350 Birr). The survey result shows that 53% of the households were members to cooperatives. On average, households in the districts had extension contact frequency on weekly (about 31%), monthly (about 30%), fortnight (about 21%) and daily basis (about 10%). About 8% of the respondents had no contact at all (Table 2, Table 3).

Crop technology utilization

Pesticide use, row planting, improved variety use, and inorganic fertilizer usage (DAP and Urea use) were among the package considered in this study. About 50% of the sample households used pesticides on potato. Row planting use level was about 96% while only about 14% of the land under potato cultivation was allotted for improved variety. Table 4 shows the descriptive result of pesticide application and row planting in potato production in the sampled districts of the study area.

DAP use intensity result shows that sampled farmers used about 68% of the recommended level (recommendation rate is 195 kg DAP ha^{-1}). Similarly, urea use intensity result shows that the farmers used 75% of the recommended rates for potato (i.e. 165kg ha^{-1}). This result shows underutilization of these fertilizers which would in turn result in lower yield levels. While considering all the five components of potato technology package jointly (i.e. use of pesticide, row planting, use intensity of improved variety, application of DAP and Urea), the overall adoption index is about 63% of the recommended package.

Determinants for Adoption of Technology Package

The two-limit Tobit model results demonstrated a good fit at 1% level of significance. Moreover, the overall variance inflation factors (VIF) of all the independent variables in the model is less than 10, indicating that multicolliniarity was not a severe problem. According to the model results, variation in district (location), access to irrigation, extension contact frequency, farm size, membership to cooperatives, and annual income were found significantly determining adoption of potato technology package (Table 5).

Variations in district explained the difference in adoption of potato technology package. This could be related to the differences in potato production potential in these locations. Farmers located in more potato production potential districts like Kombolcha are found to be better adopters of potato technology package as compared to those in Gurawa district. On the other side, farmers in Meta district are found to be less adopter of the technology package as compared to those in Gurawa district. These differences were statistically significant at

1% level. The result depicts that location matters in adoption of potato technology package. Other studies on crop technology adoption at various levels also depict the effect of variations in districts on adoption **(Asfaw *et al.* 2011; Asfaw *et al.* 2012; Croppenstedt *et al*. 2003; Jaleta *et al*. 2015; Kaleb and Negatu 2016)**.

Irrigation is an important factor that explains production of potato. Farmers in the study area utilize irrigation for potato production and hence it enabled them to fetch a higher price on the market. In line with this, farmers who used irrigation were found to be better adopters of potato technology package as compared to those who are not using irrigation. The result was statistically significant at 5% level. According, having access to irrigation results in increase of adoption of potato technology package by a factor of 0.072, keeping other factors constant.

Table 1 Summary of the independent variables hypothesized to affect adoption of potato technology package

Variables	Type of Variable	Description of the variable	Expected sign
District	Categorical	List of districts selected for the study (Gurawa, Haramaya, Kombolcha, Meta and Habro)	+/-
Sex of the household head	Dummy	1 if the household head is male, 0 otherwise.	+/-
Age	Continuous	Age of household head (in years)	+
Education	Dummy	The educational status of the head of household, 1 if literate, 0 otherwise	+
Family size	Discrete	Number of individuals in a household	+/-
Farming experience	Continuous	Households farm experience in years	+
Irrigation access	Dummy	Access to irrigation, takes the value 1 if the household has access to and 0 otherwise.	+
Distance from all-weather roads	Continuous	The distance of home from all-weather road, measured in Kilometres.	-
Distance to market	Continuous	The distance of home from market, measured in Kilometres	-
Distance from FTC	Continuous	The distance of home from FTC, measured in kilometres	-
Extension contact	Categorical	Frequencies of extension contact which takes a value 0, 1, 2, 3, 4 and 5 if no contact, every day, every week, every fortnight and every month, respectively	+/-
Number of oxen	Discrete	Number of oxen owned by household	+
Total land size	Continuous	Total land size owned and cultivated by households, measured in ha.	+
Number of plots	Discrete	Number of plots owned and cultivated by households.	+/-
Cooperative membership	Dummy	1 if the household is a member of the cooperative, 0 otherwise	+
TLU	Continuous	Livestock holding, computed using the TLU using a standardized conversion factors	+
Dependency ratio	Continuous	The ratio of dependent members (<15 years & > 64 yrs) to that of the working members (15-64 yrs) in the household	-
Annual income	Continuous	Household's annual income in Ethiopian currency (Birr) obtained from crops, livestock and off-farm activities	+

Note: TLU means tropical livestock unit calculated according to Storck, et al. (1991).

Table 2 Summary statistics of the sample households (categorical variables) (%)

Variables	Gurawa	Haramaya	Kombolcha	Meta	Habro	Total
	Gender of household head					
Female	9.4	14.6	11.5	13.5	14.6	12.7
Male	90.6	85.4	88.5	86.5	85.4	87.3
	Literacy status of household head					
Illiterate	37.5	25	24	32.3	39.6	31.7
Literate	62.5	75	76	67.7	60.4	68.3
	Access to credit					
No access	96.8	96.9	89.2	83.3	68.4	87.1
Access	3.2	3.1	10.8	15.8	31.6	12.9
	Access to Irrigation					
No access	38.5	12.6	34.4	94.8	70.8	54.9
Access	61.5	87.4	65.6	5.2	29.2	45.1
	Membership to Cooperative					
Non member	38.5	43.3	40.0	65.6	45.8	46.7
Member	61.5	56.7	60.0	34.4	54.2	53.3
	Frequency of Extension contact					
No contact	6.9	12.4	14.4	2.4	3.2	7.9
Every day contact	4.6	13.5	14.4	4.8	10.5	9.7
Every week contact	39.1	22.5	22.2	14.3	52.6	30.6
Every fortnight contact	31.0	15.6	27.9	20.2	12.6	21.3
Every month contact	18.4	36.0	21.1	58.3	21.1	30.5

Table 3 Summary statistics of the sample households (continuous variables)

Variables	Gurawa	Haramaya	Kombolcha	Meta	Habro	Total
Gender of household head						
Female	9.4	14.6	11.5	13.5	14.6	12.7
Male	90.6	85.4	88.5	86.5	85.4	87.3
Literacy status of household head						
Illiterate	37.5	25	24	32.3	39.6	31.7
Literate	62.5	75	76	67.7	60.4	68.3
Access to credit						
No access	96.8	96.9	89.2	83.3	68.4	87.1
Access	3.2	3.1	10.8	15.8	31.6	12.9
Access to Irrigation						
No access	38.5	12.6	34.4	94.8	70.8	54.9
Access	61.5	87.4	65.6	5.2	29.2	45.1
Membership to Cooperative						
Non member	38.5	43.3	40.0	65.6	45.8	46.7
Member	61.5	56.7	60.0	34.4	54.2	53.3
Frequency of Extension contact						
No contact	6.9	12.4	14.4	2.4	3.2	7.9
Every day contact	4.6	13.5	14.4	4.8	10.5	9.7
Every week contact	39.1	22.5	22.2	14.3	52.6	30.6
Every fortnight contact	31.0	15.6	27.9	20.2	12.6	21.3
Every month contact	18.4	36.0	21.1	58.3	21.1	30.5

Table 4 Summary statistics for pesticide and row planting use by districts (%)

	Gurawa		Haramaya		Kombolcha		Meta		Habro		Total	
	User	NU*	User	NU*	User	NU*	User	NU*	User	NU	User	NU
Pesticides use	50.0	50.0	83.2	16.2	73.8	26.2	15.8	84.2	-	-	50.0	50.0
Row planting use	98.2	1.8	100.0	0.0	88.2	11.2	100	0.0	100	0.0	96.1	3.9

**NU- non user*

The result is in line with prior study by **Hailu *et al.* (2014)** that depicted a positive contribution of irrigation in adoption of agricultural technologies. The reason behind the result could be mainly due to the fact that using irrigation for growing potato, a crop mainly produced for market, enables farmers to get incentives from the crop.

Farm size was hypothesized to positively influence adoption of potato technology package. However, the current result is against this expectation. The result shows that farm size was negatively affecting adoption of potato technology package. The result is statistically significant at 10% level. This could happen as the production of potato, unlike other crops, requires more intensive production managements that fit into smaller farms. This intensive management could in turn result into a relatively higher productivity that further intensifies adoption of the package. A similar finding was reported by **Yigezu *et al*. (2015)** on adoption of potato technology component. On the other hand, contradicting results were reported by **Alen *et al*. (2000) and Asfaw *et al*. (2011)** on adoption of crop technology components.

Membership to cooperative institutions was found positively driving adoption of potato technology package. Other factors kept constant, being a member of cooperatives was found to favour the farmers' likelihood of adoption of the package by the factor of 0.051, and the result was statistically significant at 1% level. This could happen given the fact that cooperatives are among the strongest social institutions that play important role in adoption of technologies. Crop technology adoption studies also revealed similar results (**Tura *et al*. 2010; Musa 2015**).

Annual income significantly and positively affected adoption of potato technology package in the study area. Farmers with higher annual income are found to be better adopters of potato technology package as compared to those with lower annual income levels. Similar results were reported by **Alene *et al*. (2000), Namwata *et al*. (2010)**, and **Kumilachew *et al*. (2013)**. The possible reason, among others, could be due to the fact that having higher income reduces financial constraints for purchasing inputs required for potato production.

CONCLUSION

This study analysed the factors that affect adoption of potato technology package using two-limit Tobit model. The study was based on data collected from 214 potato growing farmers from Gurawa, Haramaya, Kombolcha, and Meta districts from East Hararghe zone and Habro district from West Hararghe zone.

Package level technology utilization in potato production in the study area was about 63% of the recommended levels.

Table 5 Parameter estimates of the Two-limit Tobit model

Variables	Coefficient	Standard error (Robust)
District: Gurawa district is a reference group		
Haramaya district	0.242***	7.20
Kombolcha district	0.155***	4.13
Metta district	-0.002	0.04
Habro district	-0.156	1.62
Sex of household head	-0.018	0.43
Age of household head (years)	0.003	1.27
Education of household head (dummy)	0.015	0.49
Family size (number)	0.001	0.13
Farming experiences (years)	-0.003	0.99
Irrigation Access	0.072**	2.07
Distance to all weather roads (km)	0.015	1.23
Distance to market (km)	-0.001	0.12
Distance to FTC (km)	-0.003	0.50
Extension contact: No contact is a reference group		
Every day	-0.090*	1.95
Every week	-0.058	1.40
Every fortnight	-0.028	0.65
Every month	-0.056	1.35
Number of oxen owned (number)	0.003	0.14
Farm size (ha)	-0.129*	1.76
Access to credit	-0.003	0.05
Number of plots owned	0.019	1.53
Membership to cooperative	0.051*	1.90
Livestock ownership (TLU)	-0.002	0.43
Dependency ratio	-0.004	0.29
Annual income ('000' Birr)	0.001*	1.68
Constant	0.400***	4.30
Log likelihood	75.43	
LR Chi2 (25)	78.39***	
Number of observation (N)	214	

Note: ***, **, & * implies statistical significance at 1%, 5%, and 10% levels, respectively

The econometric model result revealed that variation in districts, access to irrigation, extension contact frequency, farm size, membership to cooperatives, and annual income of the household significantly affected adoption of potato technology package. Accordingly, having access to irrigation, membership to cooperatives, and income of the household positively affected adoption of potato technology package while farm size affected it negatively.

RECOMMENDATIONS

Access to irrigation is found to affect adoption of potato technology package positively. Hence, it is important to give due emphasis on encouraging farmers to enrich available water points in order to enhance the use of irrigation in potato production in the study area.

Membership to cooperatives play an enormous role in disseminating technologies such as improved seeds and fertilizers and in creating access to information related to the technologies for farmers. It is, therefore, necessary to strengthen cooperative institutions in the area and to encourage farmers to become members to these institutions so that adoption of potato technology package could be enhanced.

Use of mineral fertilizers such as DAP and Urea are still lagging behind the recommendations for potato production in the study areas. This implies that there is a possibility for enhancing potato productivity by encouraging use of these inorganic fertilizers to their recommended levels. Since crop technologies in general and potato production technologies in particular require consideration of location specific factors, attempts in planning technology dissemination should take in to account these realities.

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