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Adoption and Impact of Improved Maize Varieties on Smallholder Farmers' Farm Productivity and Net-Income in Eastern Ethiopia

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Abstract

This study analyzed the impact of improved maize varieties on smallholder farmers' maize productivity and net-income in the Eastern Ethiopia. The primary data were collected from 216 randomly selected sample households using structured interview. The descriptive statistics shows that 55% of sample farmers were adopters. The first stage of ESR model result revealed that livestock size, cooperative membership, and market information, are positively influenced its adoption. However, landholding, Khat farming, seed delivery time and distance to market are negatively influenced its adoption. The second stage estimate of ESR model indicates that adoption of improved maize seed is significantly increased adopters' average maize crop productivity/ha by 2.0 tons and net-income by 49.20%. We concluded that farmers' maize productivity and net-income are greatly improved due to improved maize adoption. Therefore, policy makers should enhance its adoption through enhancing extension services, multi-disciplinary research on Khat farming expansion, credit accessibility, and ensuring the timely supply of improved maize seeds at affordable price and place in the study area in the eastern part in particular and in the country in general.

Keywords:

Adoption, Endogenous Switching Regression, Ethiopia, improved maize varieties.

1. Introduction

Maize has got a great attention in the Ethiopian agriculture since the major drought and famine that occurred in 1984 (Abate *et al.*, 2015). Maize popularity is partly due to its wider adaptability and best productivity per unit area among all cereal crops, high value as a food crop, growing demand for the Stover and source of fuel (Khonje, & Berresaw, 2015).

However, it needs sustainable agricultural production and productivity to feed the ever increasing country's population through the adoption of improved agricultural technologies, including improved maize varieties (Abate *et al.*, 2015; MoANR and ATA, 2017; Smale and Mason, 2014).

Accordingly, about 203 maize varieties had been released to farmers by 2010 and more than100 of those varieties were grown by farmers in Africa of which more than 75 varieties were generated by the Ethiopian national and regional research institutes (Smale and Mason, 2014; MoANR and ATA, 2017).

However, rigorous efforts have been made by policy makers in Ethiopia to bring sustainable economic development through meticulous utilization of improved technology in the past, recent agricultural growth rate is not exceeds the first two digit mainly due to low adoption of improved agricultural technologies (Tekeste & Abebe, 2018; Atilaw and Kifle, 2018). For instance, despite, more than 75 improved maize varieties were developed during the last three to four decades in the country, yet only 25.2% of them adopted (Westengen *et al*., 2019; Ahmed et al.,2017).

Furthermore, according to ATA (2017) and the country's variety release issues from (2010) to (2017), improved maize varieties such as BH660, BH661, Gibe-1, Shala, QP545 etc. and open pollinated varieties (OPV) like Malkas-2, Malkasa-3, Malkasa-4 up 7 are among the maize varieties released and promoted during the last 1 to 2 decades in the country and to the eastern part of Ethiopia. In terms of their yield potential, the hybrid maize yields from 6.5-8.5 and the OPVs yields from 3.0-3.5 tons/ha on respective research stations variety release issues from ((2010) to (2017); MoANR and ATA, 2017). The hybrid maize varieties were promoted to the midland to highland while the OPV maize varieties were promoted to midland to lowland agro-ecologies (MoANR and ATA, 2016; EHZAO, 2017), even though, farmers found in both agro-ecologies used both varieties depending on the prevalence of weather condition to be save from risk due to climate change (Muhammed, *et al*., 2020 ; EHZAO, 2018).

About 41% of the cultivated land is covered by the local and improved maize varieties at the study area (EHZAO, 2017). However, maize yield on farmers' field is less than 1.60 tons/ha (EHZAO, 2017) which is very low when compared with the improved varieties mentioned (CSA, 2012 ; Abate *et al*., 2015). This indicates that, there is a big grain yield gap between the local and the improved varieties in the eastern Ethiopia and need current empirical evidence. The low productivity is mainly due to low adoption of improved maize varieties by the farmers, erratic rainfall (Alemayhu, *et al* 2018; Diriba, 2019).

In this regard, prior studies have attempted to evaluate the impacts of improved agricultural technologies (improved maize varieties), nonetheless, most of them (Becerril & Abdulai, 2010) relied on a single econometric model (PSM) to control the potential differences might occur between adopters and non-adopters due to unobservable and observable analysis. The PSM techniques they used will be inefficient under many cases of impact analyses because of unobservable characteristics (Greene, 2008).

Overcoming such problem and low adoption rate of agricultural technologies needs empirical understanding of its constraints and opportunities to enables policy makers, and input suppliers to undertake innovative adjustments on the improved technology generation and promotion that would enhance its impact on smallholders' farm productivity and net-income. Yet, in Ethiopia, particularly in the eastern part, empirical evidences on the impact of improved maize varieties adoption is poorly understood (Ahemed *et al*., 2017; Alemayhu *et al* ., 2018).

Therefore, the aim of this study was to analyze the impact of adoption of improved maize seed varieties on smallholder farmers' maize farm productivity and net-income, and identify its determinants in the eastern part of Ethiopia.

2. Materials and methods

2.1. Site description

The study was conducted in East Haraghe zone of Oromia Regional State, Ethiopia. The Zone is found between $7^0$32'– $9^0$44' North latitude and 41^0 10'–$43^0$16' East longitudes (MoFED, 2006). Its altitude ranges from 500 to 3,405 meters above sea level. Agro-ecologically, its consists of 11.4% highland, 26.4% mid-land and 62.2% lowland areas (EHZAO, 2017). Its annual rainfall varies from 350 mm to 1000 mm (Haramay weather station, 2017). Its agriculture is dominated by mixed farming that accounts 40%, agro-pastoral 10% and pastoral system 50% (EHZADO, 2018). *Khat* (Catha *edulis*) and vegetables are the major cash crops. About 89.4% of cultivated farm land is dedicated to cereals of which 41.0% is sorghum and 35.6% is maize; and about 11% to others (EHADO, 2018).

2.2. Sampling and data collection methods

This study was conducted during the months of November and December 2019. Multistage sampling techniques were used. Three districts (Fedis, Kersa, and Haramaya) were purposively selected among the 20 districts of the Zone based on maize production potential of the area. A total of 216 sample farmers were determined using Kothari (2004) formula and they were randomly selected from eight *kebeles* that also randomly selected based on proportion to population size using a systematic sampling technique.

$$n = \frac{Z^2 Npq}{e^2\,(N-)+Npq} = \quad n = \frac{1.96^2(76420)*0.5*0.5}{0.05^2(76420)(0.5*0.5)} \approx 216$$

where, N is population size, n is the sample size, Z^2 is the normal curve, e^2 is the desired level of precision, p is the estimated proportion, and q is 1-p.

Primary data was collected through structured interview by trained enumerators on demographic, socioeconomic and institutional factors. Six kebele level FGDs were used to collect first hand information on improved seed utili zation. Smallholder farmers' maize productivity was obtained from the total maize grain production to the ratio of

the total cultivated land used; maize hectarage gross value was estimated based on the nearest local market price; hectarage gross production variable costs' such as inorganic fertilizers, improved seeds, and chemicals were estim ated based on input suppliers' price where as costs of labour, machinery (tractors' hours), local seeds and organi c fertilizer were estimated based on the closest local market prices of the season (2019). Maize net-income was c alculated from the difference between gross income and gross variable costs using excel softwares. Secondary data were gathered from official archives', internet web site and reports related to improved seed adoption.

2.3. Econometric model specification

2.3.1. Adoption Decision of improved maize varieties

The study employed Endogenous Switching Regression (ESR) model to estimate the impact of improved maize varieties adoption on smallholders' farm productivity and net-income. When making an accurate impact assessment of improved seed on smallholders' farm productivity and net income, the observable and unobservable characteristics of adopters (treatment group) and non-adopters (control group) must be compared. However, most impact assessment approaches using non-experimental data (not-randomly) assigned fail to capture observable and/or unobservable characteristics that affect adoption and outcome variables (Greene, 2008; Asfaw *et al.*, 2012; Shiferaw et al., 2014; Mekonen and Karelplein, 2014; Kassie *et al.*, 2014).

This study conceptualize that a farmer producing maize crops either adopts improved maize variety (ies) or not-adopt. Thus, adoption of improved maize seeds by farmer is observed if the expected utility from adoption (U_I) is better than the corresponding utility from non-adoption (U_0), i.e., $U_I - U_0 > 0$. Let Si* be the latent variable that captures the benefit of adoption from improved seed on smallholders' farm productivity by the ith farmer. There are two potential outcomes to the two population units: the outcome with treatment (Y_1) and the outcome without treatment (Y_0). This can be put in a 'potential outcomes framework' as:

$$Y_{I=}(1 - S_I)\ if\ Y_{0i} + S_i Y_{1i} \quad (1)$$

$$Y_{i=} \begin{cases} Y_{1i}\ \ if\ S_{i=}\ 1 \\ Y_{0i}\ \ if\ S_{i=}\ 0 \end{cases} \quad (2)$$

$$S_i^* = \tau Zi + \mu_i$$

$$\text{With} \quad S_i = \begin{cases} 1\ if\ \ S_i^* > 0 \\ 0\ \ \text{if}\ S_i^* \leq 0 \end{cases} \quad (3)$$

That means, if farmers will decide to adopt (Si = 1) if S* > 0, and (Si =0, S* ≤ 0) if farmers will not decide to adopt; where S* represents the expected benefits from adopting with respect to not adopting, Z is a vector of variables that determine the decision to adopt or not to adopt improved seed. Therefore, the first stage of ESR, we use binary Probit for selection and to identify factors affecting adoption of improved maize seed varieties.

To account for selection biases mentioned above, an ESR model was adopted for smallholders' farm productivity and net-income in which farmers face two regimes (4a:1) to adopt and (4b:2) not to adopt. Conditional on selection, the outcomes are represented by a switching regime as follows:

Region1: $y_{1i} = \beta_{1i}X_{1i} + \delta_{1i}\varepsilon\lambda_{1i}\,,\ \ if\ S_i = 1$: (4a)

Region 2: $\mathbf{y_{i0} = \beta_0 X_{01} + \delta_{0i}\varepsilon\lambda_{0i}\,,\quad if\ S_i = 0}$ (4b)

Where $\mathbf{y_i}$ is the amount of average maize productivity in tons/ ha and net-income in ETB in regimes 1 and 2 for adoption and non-adoption, respectively; X_i represents a vector of explanatory variables (exogenous), $\boldsymbol{\lambda_{1i}} = \frac{\emptyset(z_{i\alpha})}{\Phi(z_{i\alpha})}$ and $\boldsymbol{\lambda_{0i}} = \frac{\emptyset(z_{i\alpha})}{1-\Phi(z_{i\alpha})}$ are the inverse mill's ratios (IMRs) captured from the selection equation (Eq-1) to correct for the selection bias in the second-stage estimation (outcome equations); $\boldsymbol{\beta}$ and $\boldsymbol{\delta}$ are parameters to be estimated. The standard errors in Eqs (4a) and (4b) are bootstrapped to account for heteroscedasticity arising from the generated repressors (λˆ). Finally, the error terms of the continuous ε_{1i} and ε_{oi} and selection equations (μ_i) are assumed to follow a tri-variate normal distribution with zero mean vector and covariance matrix i.e. φ (ε_{1i} and ε_{oi} , ηi) (N, 0) defined with:

$$\varphi = \begin{cases} \delta_\mu{}^2 & \delta 2_{1\mu} & \delta 2_{\mu 0} \\ \delta 2_{1\mu} & \delta_\mu{}^2 & \cdot \\ \delta 2_{\mu 0} & .. & \delta_\mu{}^2 \end{cases} \qquad (5)$$

where $\delta_\mu{}^2$ is the variance of the error term in the selection equation (3), (which can be assumed to be equal to 1 since the coefficients are estimable only up to a scale factor), $\delta_{\mu 1}{}^2$ and $\delta_{\mu 0}{}^2$ are the variances of the error terms in farm productivity and net- income functions (4a:1) and (4b:2), and $\sigma_1\eta$ and $\delta_0\eta$ represent the covariance of η_i and ε_{1i} and ε_{0i}. Since y_{1i} and $\mathbf{y_{i0}}$ are not observed simultaneously the covariance between ε_{1i} and ε_{0i} is not defined (Garbero, and Brailovskaya, 2018).

An important implication of the error structure is that, because of the error term of the selection equation (3) η_i is correlated with the error terms of the smallholders' farm productivity per hectare and farm net- income functions (4a:1) and (4b:2) (ε_{1i} and ε_{0i}), the expected values of ε_{1i} and ε_{0i} conditional on the sample selection are non-zero.

An efficient method to fit the ESR is full information maximum likelihood (FIML) estimation (Lokshin and Sajaia, 2004). The FIML method simultaneously consistent estimates of the selection and the farm out come. However, identification of the model requires that there is at least one variable in Z_i which is not included in X_i. More specifically, for the model to be identified, it is important to use variable(s) as selection instrument(s) that directly affect the adoption decision but not affect the outcome variable(s), in this case farm productivity and farm net-come. However, selection of instrumental variable is empirically challenging, in this study, we used access to market information (1=yes) as the instrumental variable; however (Garbero, and Brailovskaya, 2018) used source

of information as instrumental variable in their impact analysis, though in our case it was significant for both. Market information is vital element influencing adoption of a given agricultural technology such as improved seed and its package. Smallholders' inadequate/ or absence of access to market information decreases adoption probability of households by certain percentage. Thus, this variable is more likely to be correlated with the adoption of improved seed, but not correlated with the outcome variables or with the unobserved variable.

2.4. Conditional expectations, treatment and heterogeneity effects

The aforementioned ESR model can be used to compare the expected on farm productivity/ha, and net-income of the farm households that adopted HYVs (6a) with respect to the farm households that did not adopt (6b), and to investigate the expected maize farm productivity/ha, and net-income in the counterfactual hypothetical cases (6c) that the adopted farm households with did not adopt, and (6d) that the non-adopters farm household would adopted. After estimating the model's parameters, the conditional expectations or expected outcomes i.e. maize productivity/ha, and net-income are computed as follows:

For farm household who actually adopted the improved maize varieties (hybrids and/or OPV):

a) $\boldsymbol{E\left(\frac{y_{1i}}{S_i} = 1,\right) = x_{1i}\,\beta_1 \;\; + \delta_{1i}\varepsilon\lambda_{1i}}$ 6a)

For household who were actually didn't adopt improved maize varieties:

b) $E\left(\frac{y_{0i}}{S_i} = 0\right) = x_{0i}\,\beta_0 \;\; + \delta_{0i}\varepsilon\lambda_{0i}$ (6b)

For improved seed adopters, had they decided not to adopt improved seed (counterfactual of 6a):

c) $E\left(\frac{y_{0i}}{S_i} = 1\right) = x_{1i}\,\beta_0 \;\; + \delta_{0i}\varepsilon\lambda_1$ (6c)

For improved seed non-adopters, had they decided to adopt (counterfactual of 6b):

d) $E\left(\frac{y_{1i}}{S_i} = 0\right) = x_0\,\beta_1 \;\; + \delta_{1i}\varepsilon\lambda_{0i}$ (6d)

As indicated in Table 1 we calculate the effect of the treatment "to adopt" on the treated (TT) as the difference between (a) and (c):

7a) TT= E $(\frac{y_{1i}}{S_i} = 1$ –E $(\frac{y_{0i}}{S_i} = 1)$ = $x_{1i}(\beta_{1-}\ \beta_0) + (\sigma_{1n} - \sigma_{0n})\,\lambda_{1i}$,

It represents the effect of improved seeds on smallholders' farm productivity per hectare and net income that actually adopted and didn't adopt improved maize seed varieties;

Similarly, we calculate the effect of the treatment on the untreated (TU) for the smallholders that actually did not adopt the improved maize varieties, had they adopted as the difference between (d) and (b);

7b) TU= E $(\frac{y_{0i}}{S_i} = 0$ –E $(\frac{y_{1i}}{S_i} = 0)$ = $x_{0i}(\beta_{1-}\ \beta_0) + (\sigma_{1n} - \sigma_{0n})\,\lambda_{0i}$

We can use the expected outcomes described in (6a) to (6d) to calculate also the heterogeneity effects. For example, farm households that adopted might have more farm production/ha and net-income than farm households that did not adopt regardless of the fact that they decided to adopt but because of unobservable characteristics such as their skills and/or motivation.

Adapting (Carter & Milon, 2005) to our case, we define as "the effect of base heterogeneity" for the group of farm households that decided to adopt as the difference between (a) and (b),

7c) $BH_1 = E\left(\frac{y_{1i}}{S_i} = 1,\right) - E\left(\frac{y_{0i}}{S_i} = 0\right) = \beta_{1i}(X_{1-}\ X_0) + \sigma_{1n}(\lambda_{1i} - \lambda_{0i})$.

Similarly, for the group of farm households that decided not to adopt, "the effect of base heterogeneity" is the difference between (c) and (d) i.e the counterfactuals difference

7d) $BH_0 = E\left(\frac{y_{0i}}{S_i} = 1\right) - E\left(\frac{y_{1i}}{S_i} = 0\right) = \beta_{0i}(X_{1-}\ X_0) + \sigma_{0n}(\lambda_{1i} - \lambda_{0i})$.

Table 1: Conditional Expectations, Treatment, and Heterogeneity Effects

Outcome variables	Decision stage		Treatment effects
	To adopt HYVs	Not to adopt HYVs	
Adopters' maize productivity t/ha	a) $E\left(\frac{y_{1i}}{S_i} = 1, x_{1i}\right)$	c) $E\left(\frac{y_{0i}}{S_i} = 1,\ x_{1i}\right)$	TT
Non- adopters' maize productivity t/ha	b) $E\left(\frac{y_{0i}}{S_i} = 0,\ x_{0i}\right)$	d) $E\left(\frac{y_{1i}}{S_i} = 0, x_{0i}\right)$	UT
Heterogeneity effects	BH1	BH0	TH
Adopters' maize net-income	a) $E\left(\frac{y_{1i}}{S_i} = 1, x_{1i}\right)$	c) $E\left(\frac{y_{0i}}{S_i} = 1,\ x_{1i}\right)$	TT
Non- Adopters' maize net-income	b) $E\left(\frac{y_{0i}}{S_i} = 0,\ x_{0i}\right)$	d) $E\left(\frac{y_{1i}}{S_i} = 0, x_{0i}\right)$	UT
Heterogeneity effects	BH1	BH0	TH

Finally, we investigate the "transitional heterogeneity" (TH), that is if the effect of adoption of improved seeds is larger or smaller for the farm households that actually adopted to improved seeds or for the farm household that actually did not adopt to the counterfactual case that they did adopt, that is the difference between equations (7a) and (7b) (i.e., (TT) and (TU)).

3. Result and discussion

3.1. Description of variables

Descriptive statistics of explanatory and outcome variables used in this study, were depicted in, Table 2 and 3. Regarding the status of improved maize varieties promoted in eastern Ethiopia for some varieties such as BH-660 and BH-661 from hybrid maize variety (HYV) and Melkas-2 and Melkasa-4 from OPV, about 31% of the sample households adopted the technology in the study area. Of which, 25.5% of the sampled farmers adopted the hybrids and 5.5% the OPV varieties. The result was consistent with the findings of Westengen *et al*. (2019) who analyzed adoption of improved maize varieties in the three eastern African countries including Ethiopia.

As presented in Table 2, the dependent variable is adoption of improved maize seed varieties. In that the influences of explanatory variables on the dependent variable among adopters and non-adopters were hypothesized. Implying that, those variables with significant t-tests or chi-square tests were assumed be negatively or positively influence adoption at the final probit results.

The t-test mean age of the adopters and non-adopters were found to be similar. Average number of household head size was also similar and its t-test was not vary significantly. The t-test result on their level of education shows that the average year attended by the two groups was 4.0 and 3.5 and significant at P<0.05. Overall, adopters have higher level of education than their counterpart (Table 2). In this study, the t-test shows that mean difference between adopters and non-adopters' use of Di-Amonium Phosphate (DAP) and urea fertilizers significant at P<0.05. Similarly, livestock size t- test result shows that mean difference between adopters and non-adopters were significant at P<0.05. Related to farmland size**,** the t-test indicates that the mean difference between adopters and non-adopters was significant at P<0.10. It implies that adopters have less total farmland than non-adopters. It implies that sometimes, there was a case when farmers' who have larger farmland rented out their land due to lack of financial and asset resources (Knife *et al.*, 2018). Thus, larger farmland was assumed to have negative influence on adoption of improved maize varieties at the final model coefficient (Table 2). *Kha*t farming t-test statistics shows that adopters allotted more an average farmland to *khat* farming; and, there was significance mean difference between the two groups and expected to negatively influence adoption. As to on-farm income, adopters obtained more than non-adopters by 24% and significant at P<0.05 (Table 2) and it was expected. Extension contact t-test result shows that mean difference between adopters and non-adopters was not vary significantly. The possible reasons might be low competence of DA and/or poor facilitation of farmers' training center (MoANR and ATA, 2017) as well as other commitment. As to distance to market the t-test shows that the average distance that the non-adopters travel to reach the nearest market was more than the adopters to do and significant (Table 2).

Regarding to institutional factors: Access to credit is believed to reduces liquidity problems that the household could face while intending to purchase agricultural inputs; and hence paves the way for timely application of inputs thereby increase farm productivity (Muhammed, *et al., 2020).* However, the percentage of adopters and non-adopters accesses to credit was less than ten percent and statistically not significant. However, more than half (60.65%) and a quarter of non-adopters were being cooperative membership and significant at P<0.01. As to access to quality seed: the majority of adopters (85.95%) and almost nil (5%) of non-adopters were accessed to quality seed but significant at P<0.10. Similarly more than half of adopter and about one-tenth of non-adopters were accessed to quantit**y** seed from the formal seed system but significant at P<0.01. On the other hand, one-tenth of adopters and non from non-adopters were delivered quality seed timely. Hence, access to seed delivery time was expected to negatively influence adoption of HYV of maize. However, the majority of the adopters and about half of non-adopters were accessed to market information and likely it was expected to have either positive or negative influence its adoption at the final result.

Table 2: Descriptive statistics of variables by adopters and non-adopters

Explanatory variables	Adopters N=119	Non-adopters N=266	t-value	Total sample N =385	
	Mean	Mean		Mean	St.Er
Continuous variables					
Age in year	38.3 (1.02)	37.1 (.677)	0.99	37.5	10.46
Household size	6.9 (.244)	6.92 (.189)	0.05	6.92	2.77
Education in year	4.14 (.258)	3.4 (.20)	2.9**	3.67	3.03
Landholding in ha	0.48 (.021)	0.84 (.33)	0.78	0.67	0.53
Inorganic fertilizers use in kg	167(.091)	127 (.068)	3.3**	144.25	104.39
On-farm income (ETB)	34,488.5 (2026.44)	26,150.90 (1816.44)	3.06** -	29,052.0 -	25766.9 -
Livestock size (TLU)	3.95 (.185)	2.01(.13)	4.14***	2.35	1.98
Distance to nearest market	22.3 (1.2)	24.5 (.99)	-1.27*	22.91	14.27
Khat farming in ha	0.29 (.12)	0.25 (.16)	0.09	0.26	0.173
Extension contact biannually	6.1 (.18)	5.5 (.15)	0.85	4.31	2.21
Categorical variables	**%**	**%**	**χ2 -value**	**%**	**SD**
Access to credit (yes=1) %	8.00	6.50	0.62	6.10	0.241
Cooperative membership (yes)	60.65	25.50	32.7***	29.80	0.458
Access to quality seed (yes)	89.95	5.00	9.30*	29.20	1.065
Access to quantity seed (yes)	62.81	37.70	89.1***	52.20	0.982
Seed delivery time (yes)	11.76	0.00	50.0***	6.70	0.251
Market information (yes)	80.70	48.40	18.3**	59.60	0.91

Note: ***, ** and *, represent significance level at 1%, 5% and 10%;

Value in parentheses ( ) indicate standard Error

Source: Survey computation

Table 3 below represents the descriptive statistics result of farm level outcome variables. The t-test result of the selection equation reveals that, the average maize productivity and net-income of adopters were greater than non-adopters' and statistically significant at P<0.01. In this study the average productivity of hybrid and OPV improved maize varieties was analyzed together since the number of occurrences in the OPV were small and it was 3.6 tons/ha. This indicated that adopters obtained 1.78 tons ha^{-1} maize production than non-adopters (1.6 tons/ha) and earned 49.3% net- income than non-adopters. The result implies that the maize mean productivity ha-^{1} is higher than the national average by 0.40 tons ha-^{1} that was 3.2 tons ha^{-1} however, productivity of the local maize was 1.6 t ha-1 and that by far lower than the average base line (3.2 tons ha^{-1}).

The result might be indicator of the impact of improved maize seed varieties adoption on the smallholder farmers' farm productivity and net-income. However, to determine whether adoption of improved maize variety (ies) increase farmers' farm productivity and net income or not, an impact assessment on demographic, socio-economic and institution factors is needed. This is done by controlling the observed and unobserved heterogeneity that affect the adoption decision and outcome variables. Thus, it's the exact effect on the sample farmers' maize productivity and net income are estimated using the ESR analysis in subsequent section.

Table 3: Descriptive statistics of treatment outcomes on adopters and non-adopters

Outcome Variables		**Adopters,**		**Non-adopters,**		**t-value**	**Total sample**	
Maize productivity ha^{-1}		**N=119**		**N=266**			**N=385**	
	N	Mean	St. Er	Mean	St. Er		Mean	St.Er
Improved maize mean productivity t/ha	119	3.6	0.754	1.6	0.740	38.35***	2.32	0.532
Maize net-income (ETB)	119	11307	278	5632.3	121.7	6.63***	7865.	147.5

Note: *** signifies, significance at 1% level of significance

Source: Own calculation from survey data

3.2. Adoption decision determinants

Before running model regression, the likely existences of multicollinearity problem were checked among the explanatory variables using the Variance Inflating Factor (VIF) for the continuous and the Contingency Coefficients (CC) for the categorical variables. The results of VIF for each of the explanatory variable was found to be less than the standard value of 10 that indicted the non-existence of severe multicollinearity problem among the explanatory variables that entered in the model. Alike, the computation results value of CC checks for the categorical variables also lower than the standard value of 0.9. Thus, the result indicates that there was no multicollinearity problem among the explanatory variables for the case that they entered into the model.

In this study, the dependent variable was adoption of improved maize varieties. The estimate of the first stage ESR model of the coefficients of explanatory variables and their Marginal effects on the dependent variable were depicted in Table 4. The ESR model fits the data reasonably well [Wald Chi-squared = 94.67 and P = (0.000) and pseudo R square result was 0.22] between 0 and 1 and its smallness shows the fitness of the model. The estimated coefficients of the selection terms are significantly different from zero. In that suggesting both observed and unobserved factors influence the decision to adopt improved maize varieties and impact on maize productivity and net-income given the adoption decision.

Both the coefficients and the marginal effect results are depicted in Table 4. The coefficients of the model indicate the direction of the variable influence, while the marginal effects indicate the magnitude of the determinant factors influence on the dependent variables. The study utilized both the coefficients and marginal effects of the model to discuss and interoperate the factors that influence the smallholder farmers' adoption decision probability of the improved maize varieties as hereunder.

Livestock size, cooperative membership, and access to market information were positively and significantly influenced adoption of improved maize varieties as assumed to marginally increased the probability of farmers' productivity and net income; whereas landholding, distance to nearest market, *khat* farming, and seed delivery

time were negatively affected adoption decision of improved maize varieties as expected to decrease the probability of farmers' maize farm productivity and net income that revealed by probit marginal effect (Table 4) .

Cooperative membership: The model marginal effect revealed that cooperative membership marginally increased the probability of farmers' adoption decision of improved maize varieties by 32.3%. The result implies that majority of adopters were members of the cooperative that give them multi-agricultural services such as credit, training, market (input/ package) information provision and motivated farmers to decide and adopt improved maize varieties. The result is concurrent with the findings of Workineh, and Ehite (2020) who conducted research on improved wheat technology adoption and its impact on smallholder farmers welfare in Southern Ethiopia.

Livestock size: The binary probit model coefficient indicated that livestock size positively influenced adoption decision of HYV maize and significant at P<0.01. The parameter estimate was as expected. This is because, the presence of more livestock can solve the liquidity problem that farm households could face while intending to purchase improved farm imputes (maize varieties). Thus as one additional tropical livestock unit increased, the probability of farmers' adoption decision of improved maize varsities increased by 4.5%. The result was consistent with Workineh, and Ehite (2020) who found that, larger number of livestock size positively influenced impact of improved wheat varieties on households' welfare in Southern, Ethiopia.

Landholding size: The probit coefficient result indicated that landholding size negatively affected sample farmers' adoption decision and significant at p<0.10. The result was unexpected; because under many adoption studies farmers who have more landholding assumed to adopt better new technologies than their counter parts. In this study, however, the finding was the inverse. Thus, model output revealed that, a one ha additional land owned by sample farmers decreased their adoption decision probability by 27.0%. This implies that smallholders who have lower landholding are more strive to adopt improved maize varieties to compensate the limitation of crop production due to land shortage than farmers who have more land. On the other hand, farmers who have large landholding might be rented out because of scarce finance or awareness to utilize their land. The result is contradicted with the work of Khonje *et al*. (2015).

***Khat* farming**: The model coefficient sign shows that *kyat* farming was negatively affected farmers' decision to adopt improved maize varieties and significant p<0.10. Thus, according to this model marginal effect result, one additional Ha of *Khat* farming by a household decreased his adoption probability of improved maize varieties by 16.50%. The result is in line with Andersson *et al*. (2012); Dessie (2013) who long been documented similar report that, *Khat* farming competed for many major crops including perennial tree like coffee, inset, eucalyptus mostly in Eastern, Southern and Northern parts of Ethiopia.

Distance to nearest market: The binary probit regression coefficient result indicated that distance to nearest market was negatively influenced adoption decision and significant at $p<0.05$. It indicated that, as seed distribution distance increase by one km, the probability of households' adoption to improved maize variety decreased by 10.10%. The result implies that usually hybrid and open pollinated improved maize varieties produced by the Ethiopian seed and regional seed enterprises; few private and cooperative unions in the country. The Ministry of Agriculture organized them and distributes the seed through long channels to the *kebele* level primary cooperative. For one thing it reaches the last destination very lately. Second, its quantity is not sufficient to satisfy overall farmers. Hence, the farmers who found at distant from the distribution could not get the seed. Thus, farmers' adoption decision to improved maize varieties is minimal, because of distance to nearest market. The result is consistent with the work of (Feleke & Zegeye, 2006) who conducted research on adoption and impact of agricultural technologies in Southern, Ethiopia.

Access to market information: Coefficient from model result revealed that access to market information has positive influence on adoption decision of improved maize varieties and significant at $p<0.10$. This is plausible because access to market information reduce transaction costs incurred by farmers in search of markets for farm inputs. Hence, access to market information was marginally increased farmers' decision probability to adopt improved maize varieties by 4.50%. Similar result is found in the work of Alene, & Berresaw (2015).

Time of maize seed delivery: Model coefficient sign indicated that time of seed delivery negatively influenced adoption decision of improved maize varieties and significant at $p<.01$. Thus, probit marginal effect revealed that a delay of improved maize seed delivery time decreased the households' adoption probability to improved maize varieties by 34.00%. This implied that it may be indirectly influenced the household's maize production and net income. The result was as expected as seed delivery system in Ethiopia passes through long channels and it reaches farmers lately after they planted their own saved seeds (Tarekeng & Mogiso, 2020). The result is parallel with report of (Mulesa *et al*., 2021) who reported that the formal seed distribution channels took longer time to reach farmers when compared with the direct seed distribution time taken in the central Ethiopia.

Access to different seed varieties: Probit model coefficient sign indicated that access to number of seed varieties was negatively correlated with adoption of improved maize varieties. The coefficient sign was as priori. The formal seed system provides only hybrid maize variety including open pollinated varieties (OPV) in the country. Thus, access to number of seed varieties decreased the households' adoption decision probability to improved maize varieties by 6.30% in this study. The result is in line with the work of Bogale *et al*. (2018) who reported the inefficiency of formal seed system to provide different number of improved varieties based on smallholders' interest.

It might be because of that result, access to seed source was positively influenced adoption decision of improved maize varieties.

Table 4: Determinants of improved maize seed varieties adoption decision after binary probit regression, first stage of endogenous switching regression

Variables	Coefficient	Mag/effect	St.Error
Household's age	0.0051	0.001	0.003
Level of education	0.0132	0.003	0.010
Family size	0-.0301	-0.007	0.011
Distance to nearest market	-0.118**	-0.011	0.020
Livestock ownership	0.1672*	0.201	0.014
Land holding	-0.9875*	-0.270	0.109
Use of inorganic fertilizers	0.0176	0.004	0.001
Extension Contact	0.0073	0.002	0.012
Khat farming	-0.1901*	-0.165	0.011
Cooperative membership*	1.093*	0.023	0.067
Access to credit*	-0.2395	-0.089	0.011
Market information*	0.2I01*	0.045	0.134
Seed delivery time *	-0.0943***	-0.34	0.124
Access to quality seed*	0.0890	0.029	0.035
Access to seed quantity*	-0.0665	-0.015	0.036
_constant	-3.9510***	-	-

Note: ***, ** and * represent significance at 1%, 5% and 10%
Source: Survey data model output

3.3. Impact of improved maize varieties on smallholders' farm productivity and net-income

Under this sub section, the second stage of endogenous switching regressions (ESR) model result was discussed based on average treatment on the treated (ATT) and average treatment on the untreated (ATU). The basic outcome variable that associated with the adoption of improved maize varieties was illustrated in Table 5. In this analysis, the mean productivity of improved maize varieties was estimated.

The second stage ESR treatment effect model revealed that adopters' (treated) average maize productivity is greater than the non-adopters by 1.78 tons and net-income by 49.30% compared with their counterpart. On the other hand, had adopters did not adopt improved maize varieties, their maize productivity and net-income would have been decreased by 1.82 tons and 49.3%, respectively. Similarly, had non-adopters decided to adopt improved maize varieties, their maize productivity and net-income would have been increased from 1.6 to 3.17

tons ha^{-1} and net-income from 5632.24 to 8244.15 ETB (32%). The transitional heterogeneity effect was also positive as the difference between the treated (BH_1T) and the untreated (BH_0T) was greater for the farmers with improved maize varieties adopters for maize productivity ha^{-1} and its net-income. That was 0.61 ton and 3,165.32 ETB (Table 5).

Table 5: Impact of improved maize seed varieties adoption on smallholder farmers' productivity and net-income, second stage of endogenous switching regressions output

Outcome variables	Category	Decision			
		To adopt HYVs	Not to adopt HYVs	Treatment effect	t-value
Maize productivity t/Ha	ATT	(a) 3.60 (.36)	(c) 1.78	1.82	38.34***
	ATU	(b) 1.60 (.31)	(d) 3.17	1.57	6.12***
	BHi	BH_1= 2.0	BH_0=1.39	HT= 0.61	-
Maize Net-income (ETB)	ATT	(a) 1 1,307.00	(c) 5,734.67	5,572.33	14.6***
	ATU	(b) 5,632.24	(d) 8,244.15	2,611.91	2.43***
	BHi	BH_1=5,674.76	BH_0=2,509.48	HT=3,165.32	-

Note: *** significant at 1% significance level;

Source: ESR Model output

4. Conclusion

This study investigates the impact of improved maize seed varieties adoption on smallholder farmers' maize productivity and net-income using households' survey focusing in east Haraghe zone. Descriptive statistics indicated that about 31% of the sample households adopted the improved maize varieties. The first stage of ESR result shows that livestock size, cooperative membership, and market information were positively and significantly influenced adoption decision of improved maize seed varieties; whereas landholding, *Khat* farming, seed delivery time and distance to market were negatively and significantly influenced its adoption. However, the second stage of ESR estimation revealed that, probability of adopters maize productivity/ha was increased from 1.6 to 3.6 tons, and net-income increased by 49.3% due to adoption of improved maize seed varieties.

Thus, we concluded that adoption of improved maize varieties significantly contributed to smallholders' economic development by improving average on-farm maize productivity and net-income. Therefore, we recommend that policy makers and seed sector institutions should focus on strengthening and promotion of agricultural technologies like high yielding varieties (HYVs) of maize. Indeed, this is possible through appropriate promotion of the inventory of the released and newly generated varieties, yet enhancing the contributing and solving the constraining determinants like *Khat* farming constraints through multi-disciplinary research approaches. Moreover, this study limited to the east Haraghe Zone focusing on the impact analysis of the

hybrid and OPV improved maize varieties in combination. Hence, we suggest that similar context specific but agro-specific based research should be made on the impact of the hybrid and OPV maize varieties separately and of other major crops varieties in the study area in particular and the region in general.

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