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Productivity and welfare effects of agricultural technologies: A study of maize producing households in Ethiopia using PSM approach

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The purpose of this study is to examine the effect of fertilizer and improved maize varieties of seeds on maize productivity and welfare of maize producing households based on survey data that has been obtained from 337 households in Ethiopia. Results have been estimated by using propensity score matching method. The study indicates that adoption of fertilizer and improved maize varieties increases maize productivity ranging from 9.11-9.95 quintal/ha and enhance welfare of maize producers evidenced by an increase in consumption expenditure of 1021-1297 birr. The implication of this study is the need of unreserved and continuous effort to enhance adoption of agriculture technologies by small holder farmers to reduce the challenge of food security.

Keywords: Productivity, Welfare, Fertilizer, Improved maize varieties, Ethiopia

1 Introduction

Maize is the third important crop, both in terms of production and consumption next to rice and wheat[1,2]. Worldwide, nearly 180 million hectare of land was covered by maize and about 1 billion tons of maize was produced. It is produced in more than 170 countries and used as a stable food for about 1.2 billion people. Maize is Africa's most important cereal crops which feeds more than 300 million people. In Africa, nearly 24% of the farmland is covered by maize crop and about 95% of its production uses as food[3]. In the Eastern and Southern parts of Africa, maize production contributes up to 20% of farm households income[4].

In Ethiopia, maize is first important cereal crop with regards to volume of production and the second most common crop concerning the area it is planted next to *teff*[5]. For instance in 2017/18 main agricultural season, maize grown in 2.13 million ha and 83.96 million quintals of the grain production was drawn from the same crops. However, maize productivity in Ethiopia is low: while the world average is about55 quintal/ha, in Ethiopia it is only 34.2 quintal/ha[3].

Literatures revealed that the rise in maize production in the past decades has been mainly resulted from the increase in the area of cultivation[6]. Recently, however, the arable land is shrinking over time and fallow farming, one strategy for improving soil fertility, becomes impractical[7]. To feed the continuously growing population, therefore, adoption of productivity enhancing technologies are quite crucial.

According to Zeng *et al.* (2015), in the past 4 decades more than 40 modern maize varieties have been disseminated in Ethiopia. However, the rate of adoption by farm households was found to be low [8–10]. Hence, studying the major factors affecting adoption and measuring its impact on productivity and welfare of maize producing farmers is quite important for policy makers.

Studies recommended that agricultural technologies should be adopted simultaneously rather than individually to maximize the benefits of technology adoption[7,11]. Though various studies have tried to estimate the effect of agricultural technologies in maize production, they are mainly relied on single technology[8,9,12–16]. To the best of our knowledge, therefore, this paper is the first study that investigates the simultaneous adoption effect of fertilizer and improved varieties of maize on the welfare of maize producers.

2 Materials and Methods

2.1 Sources and techniques of data collection

The study was carried out by using primary data collected from smallholder maize producers in Awi

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zone of Ethiopia. Awi zone was selected due to its potential for maize production and dearth of agricultural technology related studies. Samples were selected from 3 randomly chosen districts of the zone (in Awi zone there are 9 rural districts). Finally, a total of 337 maize producers were selected based on the population proportion of each district.

The survey data was collected based on structured questionnaire prepared by authors. The questionnaire includes, various factors associated with technology adoption, maize productivity and consumption expenditure of maize producers, among others. Furthermore, prior to the main survey, pilot survey was conducted to confirm the validity of all questions in the questionnaire. Finally, the required data were collected from the selected samples through trained and experienced data enumerators.

2.2 Conceptual framework and estimation techniques

A direct comparison of the outcome variables between non-adopters and adopters is misleading because the difference may not exclusively obtained from adoption but also from other characteristics of farmers. Since technology adoption is not random rather it depends on various factors, self-selection problem may be occurred. In order to overcome this situation, propensity score matching (PSM) technique is useful. It is relevant to resolve the challenge of self-selection that might be resulted from observed difference in the characteristics of treated and control groups[17,18]. PSM compares each observation of the treated group to the control group with similar observed characteristics (propensity scores). Propensity score is "the conditional probability of receiving a treatment given pretreatment characteristics"[19] and it can be written as :

$$P(X) = \Pr(T = 1|X) = E(T|X);\ p(X) = F\{h(X_i)\} \quad \ldots(1)$$

where, T is the indicator of treatment (adoption), X is a vector of observed variables and F{.} is either logistic or normal distribution.

Though, it is not convincing to select probitor logit model over the other, in this study propensity scores was estimated based on the logit model for its mathematical simplicity[20]. The logistic model can be written as:

$$P_i = E(T = 1 \mid xi) = \frac{1}{1+e^{-(\alpha+\Sigma\beta_i X_i)}} \quad \ldots(2)$$

Equation 2 can be written in terms of Logs of odds ratio as follows;

$$L_i = \ln\left(\frac{Pi}{1-Pi}\right) = \alpha + \sum_{i=1}^{k} \beta_i X_i + \mu_i \quad \ldots(3)$$

where, L is logs of odds ratio and k is the number of explanatory variables.

On the basis of the propensity scores, the average treatment effect for the treated (ATT) was computed. It is the mean outcome difference between adopters and non-adopters having similar propensity scores. It can be specified mathematically as:

$$ATT = E\{Y_{iA} - Y_{iN}|T = 1\},$$
$$ATT = E[E\{Y_{iA} - Y_{iN}|T = 1, p(X)\}],$$
$$ATT = E[E\{Y_{iA}|T = 1, p(X)\} - E\{(Y_{iN}|T = 0, p(X)\}] \quad \ldots(4)$$

where, Y_{iA} and Y_{iN} represents the mean outcome value of adopters and non-adopters respectively. $E\{Y_{iA}|T = 1, p(X)\}$ represents the mean outcome of adopters (observable) while $E\{(Y_{iN}|T = 0, p(X)\}$ indicates the mean outcome of the adopters had it not be adopted (counterfactual situation). In this study, two outcome variables, namely maize productivity (quintal/ha) and consumption expenditure were considered.

Finally, tests of matching quality were carried out to check the soundness of matching process. The lower the pseudo R^2, insignificant of the likelihood ratio and the higher the reduction in the mean standardized bias after matching indicates the quality of the matching procedure[19].

3 Results and Discussion

3.1 Descriptive statistics

As it is indicated in Table 1, the average household's age of the whole sample was 45.75 years. On average, age of adopters (44.47) was statistically (10 % level of significance) lower than those of non-adopters (46.87). Majority of sample households were male headed (91.1 %) while only 8.9 % of them were female headed. The 48.86 % of male headed farmers were adopters of fertilizer and improved maize varieties, while the adoption rate of female headed households were only 23.33 %. It revealed that male headed households adopt fertilizer and improved seed more than female headed households (1 % levels of significance). On the other hand, 57.86 % are illiterate, 35.61 % have attended primary education and the rest 6.53 % of them has reached secondary education. The results indicate that those household heads who attended secondary (81.82 %) and primary education (57.5 %) adopted technologies better than the illiterate households (35.9 %) at 1 % significance level. The mean size of the family in the study area was found to be 6.11. The mean family size of adopters (6.52) was statistically greater than that of non-adopters (5.76).

Table 1 — Descriptive statistics of the explanatory variables.

Variables		Non-Adopters (n=180)	Adopters(n=157)	Combined	t-test/ Chi-square test
Age		46.87778	44.471	45.756	1.798*
Sex	Male	51.14%	48.86%	91.1%	7.1565***
	Female	76.67%	23.33%	8.9%	
Education level of Household Head	Illiterate	64.1 %	35.9 %	57.86%	25.6718***
	Primary	42.5 %	57.5 %	35.61%	
	Secondary	18.18 %	81.82 %	6.53%	
Family Size		5.7611	6.5286	6.1186	-3.5573***
Access to Extension service	Yes	44.6 %	55.4%	63.2%	18..0625***
	No	68.55 %	31.45 %	36.8%	
Access to credit	Yes	40.19 %	59.81 %	62.02%	38.6534***
	No	75 %	25 %	37.98%	
Distance to market (km)		6.4230	6.3512	6.3896	0.2504
Landholding size (hectare)		1.0968	1.1827	1.1368	-1.3249
Off farm Income (Birr)		4676.944	4317.261	4509.377	0.35955

Note: ***, and * represents 1% and 10% significance level.

Accessibility of extension service is expected to influence technology adoption positively through provision of better information about the importance of technologies and their efficient utilization. From the total sample households, 63.2 % of farmers were received extension service while the rest 37.8 % were not. The results indicate that those households who received extension service were better adopted to agricultural technologies than their counterparts. Credit availability is a key factor that influences adoption of technology. Particularly for smallholder farmers with low level income, it curbs the shortage of capital for the purchase of improved technologies. Concerning the availability of credit, 62.02 % of the households had access to credit while the rest 37.98 % of the sample households hadn't. As it is indicated in Table 1, the proportion of adopters who had access to credit is statistically greater than that of non-adopters. It implies that accessibility of credit influences fertilizer and improved seed adoption.

The distance of households' village from the market center may influence adoption of technology. As the market distance increased, the lesser was the probability of getting information, buying and adopting agricultural technologies. On average, the distance of the households' village from market center was 6.38 km. However, the difference in market distance between non-adopters and adopters was statistically insignificant. The mean landholding size of the whole respondents was 1.13 ha. On average, adopters had farm size of 1.18 while it was 1.09 for non-adopters. In the study area, averagely, households earned about birr of 4509 per year from off-farm activities such as daily labor work, handcrafts and petty trade. The results indicate, however, that the difference in off-farm income between the two groups was not statistically significant.

Table 2 — Estimates of the logit model.

Variables	Coefficient	Std. Err.	Marginal effect
Age	-0.0157	0.0103576	-0.0031
Sex	0.7006	0.5031815	0.1377
Education			
Primary	0.5213**	0.2614	0.1099**
Secondary	1.4551**	0.6038	0.2944***
Family Size	0.1338**	0 .0653	0.0267**
Access to extension	0.5399**	0.2649	0. 1109**
Access to credit	1.2057***	0.2653	0.2569***
Distance from market	-0.0212	0.0496	-0 .0042
Landholding size	0.2299	0.21952	0.0459
Off-farm income	-8.92e-06	0.00002	-1.78e-06
Constant	-2.3801	0.8864	-
Pseudo R^2	0.1554		
Number of observations	337		
LR chi2(10)	72.36***		
Correctly predicted adopters	70.06%		
Correctly predicted non-adopters	70.00%		

Note: *** and **represents 1% and 5% and 10% significance level

3.2 Determinants of simultaneous adoption of fertilizer and improved varieties of maize

Table 2 displayed the logit model results for the influential factors affecting fertilizer and improved maize adoption. The likelihood ratio (LR) chi-square test (at P<0.01) validates the soundness of the model.

Moreover, the model predicts about 70 % of the observations correctly. Since the coefficients of the logit model are quite difficult for interpretation, marginal effects were computed and interpreted.

Education is believed to help farmers to think critically and use information sources efficiently. More educated households are more accessible for new information and more efficient in practicing new innovations. In this study, education was found to affect simultaneous adoption of fertilizer and improved seed of maize positively and significantly. Compared to illiterates, the probability of adoption increased by about 10.99 % and 29.44 % for those household heads who attended primary and secondary education, respectively. The results agree with similar studies [12,16,21].

Family size influences adoption positively and significantly (at 5 %). The estimated marginal effect shows that increase in the size of the family by one unit will cause a 2.67 % increase in adoption. This may be because adoption of fertilizer and improved seeds are associated with more availability of labor for such practice like raw planting[21].

Extension service was found to be one of the significant variable which affects technology adoption positively. The marginal effect indicates that accessibility of extension service increased the conditional probability of adoption by 11.1 %. This is because agricultural extension services provide better information about the availability, use and importance of the modern inputs to the farmers which in turn affects adoption of technology positively[21,22].

The effect of credit on adoption was found to be positive and significant (at 1%). Availability of credit increases the likely of adoption by about 25.65 %. Availability of credit tackles the financial shortages of farmers for the purchase of modern agricultural inputs and hence improves adoption [23,24].

Other variables included in model, such as age, distance from market, land holding size and off-farm income were found to be statistically insignificant.

3.3 Impact of adoption on maize productivity and welfare of maize producers

Before the estimation of the ATT, the quality of matching estimators should be tested. Once the propensity scores for all observations are estimated, the common support region should be imposed on the propensity score distributions of both adopters and non-adopters.

From the total of 337 observations, only 6 (1.78%) from untreated group (non-adopters) were found to be off support. Likewise, considerable overlap in propensity scores of the two groups was existed (Fig. 1); meaning that the common support condition was satisfied.

Table 3 presents indicators of the matching quality. The results revealed that after matching the mean standardized bias was reduced by about 81-89%, the

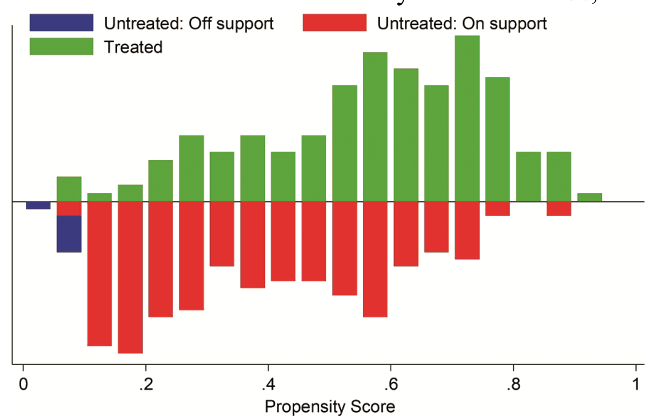

Fig.1 — Commonsupport for propensity scores.

Table 3 —Matching quality indicators.

Matching Algorithm		Pseudo R^2	LR $\chi 2$	p>chi2	Mean std. bias	Percentage of bias reduction
NNM[a]	Before matching	0.155	72.05	0.000***	30.2	81.78%
	After matching	0.009	3.82	0.955	5.1	
NNM[b]	Before matching	0.155	72.05	0.000***	30.2	89.4%
	After matching	0.004	1.49	0.999	3.2	
KBM[a]	Before matching	0.155	72.05	0.000***	30.2	84.10%
	After matching	0.006	2.11	0.995	4.8	
KBM[b]	Before matching	0.155	72.05	0.000***	30.2	83.11%
	After matching	0.005	1.98	0.997	5.1	

NNM[a] = single neighbor matching
NNM[b] = five nearest neighbor matching
KBM[a] = Kernel based matching with bandwidth of 0.03
KBM[b]= Kernel based matching with bandwidth of 0.06
*** Significant at 1%

Table 4 — Impact of fertilizer and improved maize varieties on maize productivity and welfare of maize producers.

Matching Algorithm	OutcomeVariables	ATT	Std. Err.	t-test
NNM-1	Maize productivity	9.11	1.53	5.93***
	Consumption expenditure per adult equivalent	1021.14	4.47	1.66*
NNM-5	Maize productivity	9.71	1.22	7.96***
	Consumption expenditure per adult equivalent	1073.18	496.62	2.16**
KM-0.03	Maize productivity	9.95	1.36	7.30***
	Consumption expenditure per adult equivalent	1296.78	540.95	2.40**
KM-0.06	Maize productivity	9.66	1.27	7.56***
	Consumption expenditure per adult equivalent	1165.71	505.92	2.30**

Note:***, ** and *represents 1%and 5% and 10% level of significance

pseudo R^2 lowered from 0.155 to 0.005 and the likelihood ratio becomes insignificant. It indicates the successfulness of the PSM procedure.

Table 4 presents the simultaneous adoption effect of fertilizer and improved seed varieties on maize productivity and consumption expenditure of maize producers separately. The results show that adoption of fertilizer and improved seed varieties of maize increases maize productivity significantly. The increased in maize productivity due to simultaneous adoption ranges from 9.11-9.95 quintal/ha based on alternative matching algorithms. The findings are consistent with other findings such as[9] in Ethiopia and[12] in Zimbabwe.

Similarly, the estimated ATT results indicate the importance of fertilizer and improved seed adoption in improving the welfare of small holder maize producers. Based on alternative algorithms, adoption increases households' welfare measured by consumption expenditure by an average of birr 1021-1297. Similar studies such as[8,16] in Ethiopia[15], in Mexico and[25] in Tanzania finds a positive and significant impact of improved maize varieties on households' welfare.

4 Conclusions

This study investigates the productivity and welfare effects of fertilizer and improved varieties of maize adoption among maize producing farmers. The logit model estimation results indicate that simultaneous adoption of fertilizer and improved maize varieties influenced by household heads' education level, family size, extension service, and credit accessibility positively and significantly. The PSM approach shows the positive and significant improvement of maize productivity and households' welfare due to adoption. The study found that simultaneous adoption of fertilizer and improved seed in maze production increases maize productivity by 9.11-9.95 quintal/ha. Moreover, per capita consumption expenditure of adopters was higher than non-adopters by about birr of 1021-1297. Hence suitable and continuous extension services that enhance farmers' awareness and motivation should be given for farmers to adopt technologies as a package. In addition, farmers should be encouraged to adopt fertilizer and improved maize varieties through provision of adequate and timely credit for the same purpose. These efforts could in turn tackle the challenge of food insecurity through productivity improvement.

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