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Impact of Improved Wheat Variety on Productivity in Oromia Regional State, Ethiopia

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ABSTRACT

This study examines the impact of improved wheat variety on productivity using 837 sample farm households in Oromia Regional State, Ethiopia. Propensity score matching (PSM) technique was employed since it is an increasingly utilized standard approach for evaluating impacts using observational data. It is found that improved wheat variety adoption appears to significantly increase productivity on the average by 34-38% for farm households in the study area. Thus, the study recommends that use of improved wheat variety could be an effective strategy to enhance productivity and, thereby, production that contributes a lot to the structural transformation of the Ethiopian economy.

INTRODUCTION

Like in many other SSA countries, agriculture in Ethiopia is a basis for the entire socioeconomic structure of the country and has a major influence on all other economic sectors and development processes and hence it plays a crucial role in poverty reduction (Elias et al., 2013; GebreEyesus, 2015). Despite the marginal decline in its share of GDP in recent years, it is still the single largest sector in terms of its contribution to GDP as agricultural GDP constitutes 41% of total country's GDP (CSA, 2014/15). The lion's share of GDP growth can also be attributed to agriculture and, hence, Ethiopia's GDP is largely dependent on the performance of this sector (Endale, 2011). Agriculture is the major supplier of raw materials to food processing, beverage and textile industries (Endale, 2011). It also accounts for 73% in terms of employment (UNDP, 2014) and contributes almost 90% of the foreign exchange earnings (GebreEyesus, 2015). Moreover, the livelihood of about 90% of the poor is fully or partly dependent on agriculture as a result of which, agricultural development will continue to be the basis for economic growth (GebreEyesus, 2015).

In regardto Gebru 2006 citing CSA 2003, out of the total production of agriculture, about 70% comes from crop production and the rest 30% comes from the livestock sub-sector. Out of the total temporary and permanent crops produced in the country, more than 85% comes from three major food crops; cereals, pulses and oilseeds (Gebru, 2006).

According to Abegaz 2011, cereal crops constitute the largest share of farming household's production and consumption activities. Accordingly citing Alemayehu et al., 2009, only five major cereals (barley, maize, sorghum, teff and wheat) account for about 70% of area cultivated and 65% of output produced. Fertilizer use is also concentrated on cereals followed by pulses and oilseeds respectively according to Endale 2011 citing CSA 1995/96-2007/08. In regardto him citing CSA 2008/09, in 2007/08, the national level amount of fertilizer applied in cereals, pulses and oilseeds were 3,962, 160 and 136 thousands quintal, respectively. On the other hand, according to Endale 2011, data from the Ethiopian Seed Enterprise show that improved seeds are mostly used in wheat and maize cultivation with an average of 89 and 42 thousand quintal in the period 1994/95-2005/06, respectively whereas the comparable figure for teff was 2.29 thousand quintals, which is very low. Moreover, Abegaz 2011 citing the Household Income, Consumption and Expenditure Survey of CSA indicated that the five major cereal crops account for 46% of household's total consumption.A recent source of Wikipedia 2015 cited that grains are the most important field crops and the chief element in the diet of most Ethiopians. Accordingly, the principal grains are teff, wheat, barley, corn, sorghum, and millet among which the first three constitute the staple foods of a good part of the population and are major items in the diet of the nomads.Therefore, a closer look at what is happening in cereal production has an important welfare and policy implication in Ethiopia (Abegaz, 2011).

Wheat (*Triticumaestivum L.*) is one of the important grain crops produced worldwide (Nigussie et al., 2015). It has played a significant role in feeding a hungry world and improving global food security (Ketema and Kassa, 2016). Accordingly citing Shiferaw et al. 2013, wheat contributes about 20% of the total dietary calories and proteins worldwide. Kelemu 2017 citing Shiferaw et al. 2011 asserted that changes in dietary patterns and a rapid growth in wheat consumption have been noted over the past few decades in several countries in sub-Saharan Africa. Ethiopia is the second largest wheat producer in sub-Saharan Africa next to South Africa (Nigussie et al., 2015). According to Kelemu 2017 citing CSA 2016, wheat ranked 4th after teff, maize and sorghum in terms of area coverage with 1,605,653.9 hectares and 3rd in terms of quantity production with 3,925,174.135 tons in 2013/14 cropping season in Ethiopia. On the other hand, Mann and Warner 2017 citing Minot et al. 2015 indicated that there are approximately 4.7 million farmers growing wheat on approximately 1.6 million hectares representing between 15 and 18% of total crop area and less than 1% of all wheat production takes place outside the four main regions of Ethiopia according to recent estimates. Wheat is one of the major staple crops in the country in terms of both production and consumption (Kelemu, 2017). Nigussie et al. 2015 citing Berhane et al. 2011 asserted that the crop contributes approximately 200 calories per day in urban areas compared to about 310 calories in rural areas and it accounts for about 12% of the national calorie intake. In this regard, according to Kelemu 2017 citing FAO 2014, it is the second most important food in the country behind maize in terms of caloric intake. Moreover, the domestic consumption of wheat shows the fastest growth trend (from 3.8 million tons in 2010 to 5.4 million tons in 2014) according to USDA data (Kelemu, 2017). Wheat is one of the important cereal crops consumed in different forms in Ethiopia and the rest of the world (Kelemu, 2017). In Ethiopia, wheat grain is used in the preparation of a range of products such as the traditional staple pancake ("injera"), bread ("dabo"), local beer ("tella"), and several other local food items (Nigussie et al., 2015). Besides, according to the same source, wheat straw is commonly used as a roof thatching material and as a feed for animals.

The Ethiopian agricultural sector, as to Gebru 2006 citing EEA 2004, is dominated by small-scale farmers cultivating about 96 percent of the total area under crop, producing more than 90 percent of total agricultural output and 97 percent of food crops. In contrast, large farms contributed in 2007/08 to only 5 percent of total production of the main crops (cereals, pulses, oilseeds, vegetables, root crops, fruits, and cash crops) and to only 2.6 percent of cereal production in particular (Taffesse et al., 2012). In this regard, wheat is an important cereal crop constituting significant proportion of smallholder crop production in Ethiopia (Kelemu, 2017). With these statistics, one can easily infer to what extent the small-scale farmers are the key element in strengthening the effort towards agricultural growth and consequently to the overall economic growth (Gebre-Selassie &Bekele). Due to this, according to them citing DesalegnRahmato 2008, Ethiopia's current development strategy, Agricultural Development Led Industrialization (ADLI), takes the small-scale farmers (who are all rural dwellers) as the key actor responsible for implementing the rural and agricultural development policies.

On the other hand, most smallholder farmers (i.e. 59 percent of total cultivated area) reside in the moisture reliable cereal-based highlands among the five agro-ecological regions of Ethiopia distinguished by agricultural researchers (moisture reliable cereal-based highlands, moisture reliable enset-based highlands, humid lowlands, drought prone highlands, and pastoralist area, i.e.) (Taffesse et al., 2012). Accordingly, with farmers using virtually no irrigation, reliable rainfall is an important condition to achieve good agricultural productivity. In relation to this, as to the same source document, the Meher rainfall season is overwhelmingly important as it contributes about 96.9 percent of total crop production and 95.5 percent of total cereal production in 2007/08. Though only smallholders cultivate crops during the Belg rainfall season, yields are smaller in the Belg than in the Meher rainfall season as 4.5 percent of national ceral production was produced in the Belg rainfall season in 2007/08.

With respect to all these facts, it is not questionable that accelerated and sustained growth in the country's agriculture in general and in the crop sub-sector in particular with special emphasis to the small-scale farmers will greatly help to achieve the various goals of the country (achieving food security, reducing poverty, sustaining foreign exchange earnings, spurring growth in trade and industry, etc. i.e.) (Gebru, 2006; MoFED, 2003; Gebre-Selassie &Bekele).

Moreover, food needs as well as the industrial demand for agricultural products increase due to population growth (Bor and Bayaner, 2009). All these needs, according to them, require an increase in the agricultural production. The growth in agricultural production in Sub Saharan Africa in the past was achieved by expanding the amount of land cultivated (Gebru, 2006). In relation with this, it is well known that in our country there are regions where there are large populations but limited land and vice versa (MoFED, 2003). Accordingly, most of the lands available for settlement are found in the lowlands that lack basic infrastructural facilities and pose serious health hazards. Inaccessibility, water shortages, and infestations of disease-causing insects, mainly mosquitoes, prevented the use of large parcels of potentially productive land in our country(Wikipedia, 2015). With little suitable land available for expansion of crop cultivation, especially in the highlands, future cereal production growth will need to come from increasing land productivity mainly through the supply, duplication and diffusion of continuously improving technology (Ayele et. al. 2006 citing Reardon et al 1996;Taffesse et al. 2012; Elias et al. 2013; Matsumoto and Yamano, 2010).

Cognizant of these as well as the fact that productivity is the major component of growth and a fundamental requisite in many form of planning irrespective of the stage of development and economic and social system as to Gebru 2006 citing Cheema 1978, the national wheat research program has released and disseminated a number of bread and durum wheat varieties since the 1950s and 1960s as to Ketema and Kassa 2016 citing Tesfaye et al. 2001. According to the same source citing CSA 2015b, a closer look at the proportion of the area covered by improved varieties of different crops showed that wheat took the second rank (7.4%) next to maize (46.4%) among cereals. Given the emphasis of increasing crop production through higher fertilizer use, import of chemical fertilizer augmented from 246,722 MT in 1995 to 375,717 MT in 2006 despite the removal of fertilizer subsidies since 1997/98 according to Endale 2011 citing MOARD 2007/08. In this regard, according to Ketema and Kassa 2016 citing CSA 2015b, wheat is the most fertilized crop (82%) among all crops and pesticide application is also most common on wheat as compared to that on other cereal crops.

Even though crop productivity and production remained low and variable in the 90s for the most part, there have been clear signs of change over the past decade (Abate et. al., 2015). Yield levels of all five major cereals increased rapidly from 1999/2000 to 2008/09 and cereal production and yield growth were particularly rapid from 2004/05 to 2008/09 (Taffesse et al., 2012). In this regard, the last 15 years wheat production, productivity and total land area used for wheat production has shown relatively gentle growth (Kelemu, 2017). Accordingly, the average level of wheat productivity for the period of 2000-2014 is about 1.73 ton/ha while the average growth rate in productivity is about 5.93%. During the same period total wheat production has been increasing at 10.14% growth rate per annum (Kelemu, 2017).

However, the commonly used modern agricultural inputs in Ethiopia are chemical fertilizers, improved seeds and chemicals like pesticides and insecticides (Gebru, 2006). Further, the amount of fertilizer applied by most of the farmers is below the recommended level and the use of chemicals like pesticides and insecticides is very negligible (Abate et. al., 2015; Gebru 2006 citing Legesse 1998).

On the other hand, as to Tsusaka and Otsuka 2013 citing FAO 2011, although the production of staple food has been increasing in SSA, the rate of increase has not been high enough to outstrip its high population growth rate as a result of which per-capita agricultural production in the region has declined by about 10% since 1960. These all obviously calls for a further and a better growth in agricultural productivity as well as quality with minimum adverse impact on the environment. Kelemu 2017 citing Shiferaw and Okelo 2011 indicated that of the cereals whose production is soon likely to exceed domestic demand requirements, wheat is the commodity that will most easily find an export market to supply. In view of this prospect, according to him, the need for increasing productivity of wheat is very crucial.

Holistic and appropriate evaluation of the efforts and corresponding results as well as reasons/strengths and weaknesses/ of the past few decades in general and of the past recent years in particular is necessary in order to create a more fertile ground for the fast achievement of the aforementioned goal. In this regard, the role of historical data collected by different agencies like CSA as well as of different socio-economic studies carried out to provide vital policy and related recommendations is indispensable. Studies that assess the contribution of improved technologies like improved crop varieties for the productivity growth of such important and widely cultivated cereals like wheat in Ethiopia in the past recent years are among studies that can be cited in relation to this. However, studies carried out in the country on this issue are not only few but also restricted to piece meal or location specific approach. As a result, the issue has not been satisfactorily and comprehensively assessed at a regional and national level.Thus, the objective of this study is to identify the impact of improved wheat variety on wheat productivity in Oromia Regional State, Ethiopia.

ANALYTICAL FRAMEWORK FOR EVALUATION OF WHEAT VARIETY IMPACT ON PRODUCTIVITY

The construction of the counterfactual outcome, that is, what would have happened to participants in absence of treatment is the main challenge of a credible impact evaluation. It has to be estimated using statistical and econometric methods as this counterfactual outcome is never observed. And propensity score matching technique (PSM) is becoming an increasingly employed approach to construct the counterfactual outcome. PSM uses information from a pool of units that do not participate in the intervention to identify what would have happened to participating units in the absence of the intervention.Pairing treatment and comparison units that are similar in terms of their observable characteristics is the general idea of PSM. When the relevant differences between any two units are captured in the observable pretreatment covariates, which occurs when outcomes are independent of assignment to treatment conditional on pretreatment covariates, matching methods can yield an unbiased estimate of the treatment impact (Cochran and Rubin, 1973 and Rosenbaum and Rubin, 1985).

In PSM, it is assumed that data can be obtained for a set of potential control units, which are not necessarily drawn from the same population as the treated units but for whom the same set of pretreatment covariates, X_i,is observed. If for each unit we observe a vector of covariates X_i and $y_{i0} \perp T_i|X_i, \forall_{i,}$ then the population treatment effect for the treated, $\tau|_{T=1}$, is equal to the treatment effect conditional on covariates and on assignment to treatment $\tau|_{T=1,X,}$ averaged over the distribution $X|T_i = 1$ (Rubin, 1977). Matching units on their vector of covariates, X_i, estimates this equation. Rosenbaum and Rubin (1983) suggest the use of the probability of receiving treatment conditional on covariates. Accordingly, the probability of receiving treatment conditional on covariates is expressed as: let $p(X_i)$ be the probability of a unit i having been assigned to a treatment defined as:

$$p(X_i) \equiv \Pr(T_i = 1|X_i) = E(T_i|X_i) \text{ , then}$$

$$(Y_{i1}, Y_{i0}) \perp T_i|X_i \; f \; (Y_{i1}, Y_{i0}) \perp \; T_i|p(X_i)$$

Heckman, Ichimura, and Todd (1998) suggested the following to determine or compute the treatment effect:

$$\widehat{\tau}|_{T=1} = \frac{1}{|N|}\sum_{i \epsilon N}\left(Y_i - \frac{1}{|J_i|}\sum_{j \epsilon J_i} Y_i\right)$$

where N is the treatment group, $|N|$ the number of units in the treatment group, J_i is the set of comparison units matched to treatment unit i and $|J_i|$ is the number of comparison units in J_i.

DATA

The data utilized for this study is acquiredfrom farm household survey undertakenduring 2015/16 by Ethiopian Institute ofAgricultural Research (EIAR) incollaboration with the InternationalMaize and Wheat Improvement Center(CIMMYT). A total of 837 farm households living inmajor wheat producing areas of 11administrative zones (provinces), 27districts and 65 “kebeles”/villages/localcouncils in Oromia Regional State were interviewed. A multi-stagestratified sampling procedure wasused to select villages from eachagro-ecology, and households from each“kebele”/village. First,agro-ecologicalzones that account for at least 3% of thenational wheat area were selectedfrom the major wheat growingareas ofOromia Regional State, Ethiopia. Second, based on proportionaterandom sampling, up to 21 villages ineach agro-ecology, and 15–18 farmhouseholds in each village wererandomly selected. The data wascollected using a pre-tested interviewschedule by trained and experiencedenumerators who speak the local language and have good knowledgeof the farming systems.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Various variables that were included in the propensity score matching model that describe the major observed characteristics of the sample respondents are presented in the following table. The productivities of improved wheat variety adopters and non-adopters are respectively 1.88 ton and 1.2 ton. Thus, it tentatively shows that there is significant difference in productivity level between those households that adopt improved wheat variety and those that do not adopt the improved wheat variety. Some of the most important demographic determinants that influence adoption of a technology include gender, level of education and age. There exists a significant difference between adopters and non-adopters of wheat technology in terms of these demographic factors as depicted by the descriptive statistics. The average ages of a household head for improved wheat technology adopters and non-adopters are respectively 45 and 48 years old, and tentatively indicating that adoption of improved wheat variety decreases with age. Besides, the descriptive statistics show that literate household heads are more probable in adopting improved wheat variety.The average family size for the sample wheat producing areas is 7.14 that necessitate increased productivity to improve the livelihood of the small holder farmers. Model farmers are also more likely to adopt improved wheat variety than those that are not since they had better linkage with extension workers and higher exposure to new information. Although on the average the proportion of adopters that took credit is more than the proportion of non-adopters that took credit, it is not statistically significant. However, non-adopters of improved wheat variety possesses larger landholding size than those farm households that do adopt improved wheat variety as adopters are technology intensive to compensate for the lower total wheat production by raising productivity level. Those farm households that travelled shorter distance to their wheat plots were more likely to adopt an improved wheat variety. Over and above, those farm households that adopted improved wheat variety used larger amount of herbicide than those households that did not adopt improved wheat variety.

Table 1:Descriptive statistics of important variables used in the probitmodel-Propensity Score Matching

Variables	Unit	Adopters Mean(se)	Non-adopters Mean(se)	Aggregate Mean(se)	t-stat.
Outcome variable					
Productivity	#	1877.69(39.62)	1203.89(74.10)	1794.78(36.71)	-6.16***
Variables that affect probability of adoption					
HHAGE	#	45.11 (0.46)	48.03(1.46)	45.48(0.45)	2.15**
HHSEX (Male=1)	1=Yes	0.91(0.01)	0.93(0.03)	0.91(.01)	0.82
FAMILY_SIZE	#	7.12(0.09)	7.22(0.22)	7.14(0.08)	0.41
HHEDU (Read & write=1)	1=yes	0.70(0.02)	0.60 (0.05)	0.68(0 .02)	-1.90**
MODELFARMER	1=Yes	0.52(0 .05)	0.43(0 .02)	0.49(0 .02)	-1.90**
CREDIT	1=yes	0.04 (0 .01)	0.02(0 .01)	0.03 (0 .01)	-0.79
LANDHOLDING_SIZE	ha	1.88(0.05)	2.31(0 .20)	1.93(0 .05)	2.70***
PLOTDISTANCE	#	14.29(0.85)	17.91(3.73)	14.73(0.88)	1.56*
AMTHERBICIDE	#	0.66(0 .03)	0.43(0 .06)	0.63(0 .03)	-2.44***
TLU	TLU	6.63(0 .18)	7.03(0.49)	6.68(0 .17)	0.78

***, **, * indicate significance at 1 percent, 5 percent and 10 percent level respectively.
Source: Own computation, 2017

Propensity Scores Estimation using Probit Model

The descriptive statistics of the key variables affecting technology adoption has shown a tentative impact of improved wheat variety adoption on increasing productivity. Nevertheless, a mere comparison of productivity has no causal meaning since improved wheat variety adoption is endogenous. And it is difficult to attribute the change to adoption of the improved wheat variety since the difference in productivity might be owing to other determinants. To this end, a rigorous impact evaluation method; namely, Propensity Score Matching has to be employed to control for observed characteristics and determine the actual attributable impact of improved wheat variety adoption on productivity in wheat producing areas of OromiaRegional State, Ethiopia. Propensity scores for adopters and non-adopters are estimated using a probit model to compare the treatment group with the control group. The test for ‘balancing condition’ across the treatment and control groups was done and the result as indicated on figure 1 proved that the balancing condition is satisfied.

Each observation’s propensity scores are calculated using a probit model. The propensity score for adopters ranges between 0.3907763 and 0.9999866while it ranges between 0.3558309 and

0.9704043 for non-adopters. And the region of common support for the distribution of estimated propensity scores of adopters and non-adopters ranges between 0.39077627 and 0.99998665. When matching techniques are employed, observations whose propensity score lies outside this range were discarded. The visual presentation of the distributions of the propensity scores is plotted in figure 1. The common support condition is satisfied as indicated by the density distributions of the estimated propensity scores for the treatment and control groups as there is substantial overlap in the distribution of the propensity scores of both adopters and non-adopters.

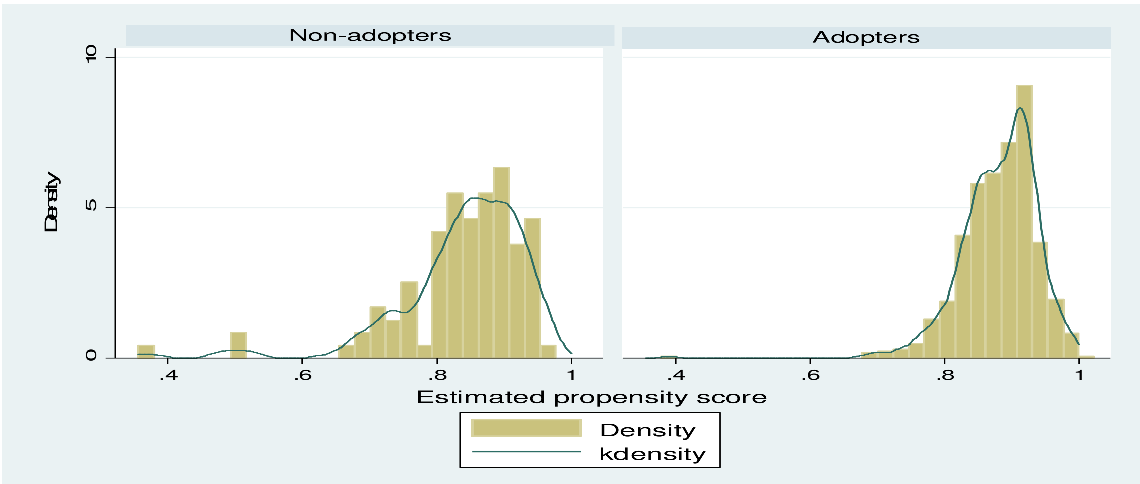

Figure 1: Distribution of propensity scores of adopters and non-adopters

The before and after matching covariate balancing tests presented on table 2 suggested that the proposed specification of the propensity score is fairly successful in balancing the distribution of covariates between the two groups as indicated by decreasing pseudo R^2, mean standardized bias, the insignificant p-values of the likelihood ratio test and satisfied interval value of Rubin's R (ratio of treated to (matched) non-treated variances of the propensity score index) after matching.

Table 2: Propensity Score Matching Quality Test

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	R	%Var
Unmatched	0.072	30.32	0.001	15.7	15.5	0.82	67
Matched	0.049	19.76	0.032	14.2	12.3	1.75	33

* if R outside [0.5; 2]

The treatment effects estimation using a probit treatment model and propensity score matching estimator reveals that adopters of improved wheat variety enjoy on the average a 34% significantly higher productivity than their counterparts, the non-adopters as indicated in Table 3. Over and above, different impact estimators were also employed to check for robustness of estimated treatment effect that disclosed improved wheat variety adoption has a positive and significant impact on productivity. Table 4 depicts the average impact of improved wheat variety adoption on productivity following nearest neighbor matching (NNM), Kernel Matching (KM), Stratification matching and Radius (Caliper) matching techniques. And all the four matching techniques revealed that on the average adopters of improved wheat variety get a significantly higher productivity,ranging from 34-38%, than their counterparts, the non-adopters.

Table 3: Average Treatment Effects estimation using a one way propensity score matching estimator

Outcome Variable	ATE	Std. Err.	z	P>|z|	[95% Conf. Interval]
Inproductivity	0.337	.083	4.09	0.000	[0 .1753469 , 0 .4985762]

Table 4: Average Treatment Effects estimation using other propensity score matching estimators

Outcome Variable	Matching Algorithm	Mean of Outcome Variable Based on Matched Observations		ATT	t-stat.
		Adopters	Non-adopters		
In productivity	Nearest Neighbor Matching	7.37	7.024	0.342	4.12***
	Stratification Matching			0.378	6.09***
	Caliper Matching	7.34	6.99	0.346	4.54***
	Kernel Matching	7.37	6.98	0.383	5.98***

Significance levels (*, **, *** denoting significance level at 10%, 5% and 1% respectively) are based on bootstrapped standard errors with 50 replications.

Source: Own computation, 2017

CONCLUSION AND RECOMMENDATION

This study is undertaken to identify the impact of improved wheat variety adoption on wheat productivity in Oromia Regional State, Ethiopia. It used propensity score matching technique which is a robust impact evaluation technique that identifies the attributable impact to the improved wheat variety adoption. The study also employed and compared various matching algorithms to ensure robustness of impact estimates.Finally, the study concludes that improved wheat variety enabled farm households that adopted it to enjoya higher and significantly positive productivity than their counterparts, the non-adopters. This indicates that improved wheat variety has a huge potential in strengthening the Region's agricultural extension system that targets increasing production and productivity. Therefore, this study recommends towidely scale up improved wheat varietyto allwheat producing farm households, and it should be accompanied by increasing availability of affordable improved wheat technologies for the smallholder farmers to enhance their livelihood.

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