

Mebrahtu, Teka Araya; Lee, Sung-kyu

Article

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*Corresponding author: Sung-Kyu Lee, Department of International Trade, Andong National University, 1375 Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea
E-mail: skl62@hanmail.net

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University of East Anglia, United
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ECONOMIC METHODOLOGY, PHILOSOPHY & HISTORY | RESEARCH ARTICLE

The impact of agricultural package programs on farm productivity in Tigray-Ethiopia: Panel data estimation

Araya Mebrahtu Teka¹ and Sung-Kyu Lee^{2*}

Abstract: Ethiopian government has introduced various agricultural package programs in promoting agricultural productivity of the smallholder farmers. The paper attempts to explore the status and determinants of agricultural productivity and estimate the impact of *integrated* agricultural package programs on farm productivity by using extensive panel data in the Eastern zone of Tigray in Ethiopia. Thus far, there have been no researches attempted to analyze the impact of the integrated agricultural package programs introduced to the farmers on various outcome variables in Tigray region in Ethiopia by using panel data. In doing so, we used two estimation methods: (i) the fixed effect (FE) estimation model to empirically evaluate the impact of household-based agricultural package programs on farm productivity in Tigray region, and (ii) the propensity score matching (PSM) method to estimate the average treatment effect on the treated (ATT). Our econometric estimates show the following two practical results. Firstly, household-based agricultural package programs have a *positive* and statistically significant impact on farm productivity in the Eastern zone of Tigray. This implies that the agricultural household package participant

ABOUT THE AUTHORS

Araya Mebrahtu Teka is an Assistant Professor in the Department of Economics at Adigrat University, Ethiopia. His research areas focus on agriculture, welfare, social protection, climate change, poverty and income inequality, gender, risk and uncertainty, tourism, and migration.

Sung-Kyu Lee is a Professor at the Department of International Trade at Andong National University in Korea. He is a chief editor of *Review of Institution and Economics* published by Korea Institution and Economics Association and also a chief editor of *Korean Journal of Public Choice Economics* issued by Korea Center for Public Choice Study in Korea. He is also an Editorial Board member of the *Journal of Contemporary Management* in Canada. His main research field is public finance, public choice, development, welfare, and institutions.

PUBLIC INTEREST STATEMENT

To curb the problem associated with farm productivity and improve the livelihood of the smallholder farmers in Ethiopia, the government has adopted different household-based agricultural package programs. We attempt to explore the status and determinants of agricultural productivity and estimate the impact of *integrated* agricultural package programs on farm productivity. We used panel data of 789 households in Eastern zone of Tigray who were surveyed in 2012, 2014 and 2016 and applied different econometrics methods to analyze the data. The average farm production is 864 dollars where the package beneficiary households produced 936 dollars and the non-beneficiary households generated about 792 dollars per year. Because of farmers' participation in the programs, they got additional gains amount of 125 to 146 dollars. Participation of the households in the agricultural package programs has a very important role in boosting the farm productivity of the small landholder farmers in the Eastern zone of Tigray.

households have higher productivity than the non-beneficiaries. Secondly, the PSM estimation result ensures that the ATT is positive and statistically significant for the package participant smallholder farmers. In the end, these outcomes provide governments with some useful guides to promote farm productivity in Tigray, Ethiopia.

Subjects: Agricultural Economics; Environment & Economics; Economics and Development; Economics; Development Economics; Environmental Economics

Keywords: ATT; agricultural package; Ethiopia; fixed effect; productivity; PSM

JEL Classifications: D13; N50; O13; Q15; Q18

1. Introduction

Poverty reduction and achieving overall development are the heart of all policies, strategies, and plans of the Ethiopian government. From the inception of the Agricultural Development-Led Industrialization (ADLI) policy framework in 1994, a series of interconnected policies and strategies were formulated and implemented; Sustainable Development and Poverty Reduction Program (SDPRP) which covered year 2002/3 ~ 2004/5, a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) achieved during 2005/05–2009/10 period, and Growth and Transformation Plan I (GTP I) for 2010/11 ~ 2014/15. Based on the critical evaluation of the strong and weak sides of the previous policies and the socio-economic aspirations of the nation, the Ethiopian government has implemented the Growth and Transformation Plan II for 2015/06 ~ 2019/2020. In all these policies and programs, greater attention has been still given to the productivity and welfare of the smallholder farmers.

Headed by the *developmental state* ideology, Ethiopia is aspiring and following the footsteps of the Asian Tigers. Targeting to reach the middle-income country by 2025, Ethiopia has achieved remarkable economic growth, averaging around 10.5 percent since 2004. However, since the Ethiopian economy is agricultural-based, its growth rate is drastically influenced by recurrent drought and low agricultural productivity (World Bank, 2016). In the budget year 2010/11 ~ 2015/16, the Ethiopian economy was growing at an average growth rate of 9.8 percent. Despite the macroeconomic difficulties, drought, and ethnic conflicts, the Ethiopian economy was raised by 8 percent in 2015/16 and 10.9 percent in 2016/17 (Sennoga & Zerihun, 2018).

The economic success achieved in the country helped the incidence of poverty to sharply reduce from 45.5 percent in the year 1995/6 to 23.5 percent at the end of the first growth and transformation plan period (2015/16). However, income inequality, as measured by the Gini coefficient, was raised from 0.298 in 2010/11 to 0.328 in 2015/16 (National Planning Commission[NPC], 2017). While agriculture is the second highest contributor to GDP and the first source of employment and export earnings, its growth and contribution in enhancing the livelihood of the smallholder farmers are not promising. Many factors are influencing the growth of agricultural productivity in Ethiopia. Weak introduction of farming technologies, rain-dependent agriculture, poor utilization of fertilizer, improved seeds, pesticides, landholding, weather, climate change, and others are contributing to the poor performance of the agricultural sector (MoFED, 2014).

To enhance agricultural productivity and improve the livelihood of the small landholder rural people, the government has trained extension workers and allocated them to villages, introducing different agricultural packages, expanding credits services, and providing selected agricultural inputs (CSA, 2013). Even though the government has designed and implemented alternative policy options, still the incidence of poverty and food insecurity is very high, and the country depends on food aid. Agricultural productivity is very low and cannot support to cover the food demand even by the farming communities themselves. Accordingly, more than 10 million people were facing a food

shortage, hunger and malnutrition every year and the numbers are rising greatly if there is weather change like shortage of rainfall, “El-Nino” and others (Ethiopian Communication Minister[ECM], 2015).

Great consensus is lacking on the impact of farm package programs on the productivity of smallholder farmers. A significant number of empirical works supports for the notable contributions of the various forms of agricultural package programs on advancing farm productivity (Dorward & Chirwa, 2011; Kibaara, Ariga, Olwande, & Jayne, 2009; Nuhu, Inusah, Ama, & Sano, 2014). However, other research works also showed mixed and, sometimes, conflicting empirical results on the impact of different farm programs on the productivity and welfare of the households like the works of Maruod, Breima, Elkhidir, and Naim (2013) and Awotide, Abdoulaye, Alene, and Manyong (2015).

For the contribution that agriculture provides to the Ethiopian economy and remaining as the first agenda for the government and international donor agencies, and as a tool for achieving food security, agriculture still attracts the attention of researchers. This paper has an objective of exploring the status and determinants of agricultural productivity and estimate the impact of induced agricultural package programs on the farm productivity of smallholder farmers in the Eastern zone of Tigray-Ethiopia. There are few research works focusing on “agricultural productivity” in Ethiopia; especially they focused on analyzing the impact of fertilizer use on the productivity of maize (Geta, Bogale, Kassa, & Elias, 2013), the effect of nutrition on productivity (Croppenstedt & Muller, 2000), and fertilizer consumption and productivity (Endale, 2011). Farm productivity of households is affected by a multitude of factors and thus studying the impact of a single intervention program does not support to have a conclusive picture of their contributions. Most of the empirical research works are of this type. Besides, significant numbers of the research works used cross-sectional data, faced seasonable variation difficulties, exhibited representativeness problems, and focused at a country level. Agricultural productivity varies across locations, which creates a demand for area-specific studies. Results from generalized studies are misleading in recommending the ways to improve the yields and enhance the welfare of the households. Up to the knowledge of the researcher, no research works are focusing on analyzing the impact of the *integrated* agricultural package programs introduced to the farmers on various outcome variables in Ethiopia, particularly, Tigray Region, by using rich zonal level panel data. Thus, this paper has tried to fill the existing gaps on policy impact evaluation, supporting policy makers working in agriculture and development matters, and enriching the existing literature.

2. Empirical literature review

2.1. Farm productivity and its determinants

Agricultural productivity in the most economics literature is expressed as to the amount of output obtained from given levels of inputs in an economy. Studying productivity, in general, is very crucial as it fundamentally affects the income of households (Fulginiti & Perrin, 1998). Least developing countries are giving due attention to improving the wellbeing of their citizens through the advancement of agricultural productivity by adopting farm technologies. There are no harmony and great consensus about the impact of diffused agricultural package programs on the productivity of smallholder farmers. Empirical results about the determinants of agricultural productivity are discussed here in details.

A study made in India using a time series data (1969/70 to 2005/06) shows that labor, capital, and land are the sources of agricultural productivity growth with output elasticity of 1.96, 1.06 and 0.15, respectively (Tripathi & Prasad, 2008). Findings from Benin focusing on the productivity of maize reveal that access to inputs, capital, and the poor institutional arrangements in which farmers operate are limiting the productivity of maize (Amegnaglo, 2018).

An impact evaluation study made in Malawi (2005/06 to 2008/09) confirms that participation of households in the fertilizer and seed subsidy program supports households to raise maize production and productivity (Dorward & Chirwa, 2011). Similar findings have been found from a panel data analysis from Kenya. From the year 1997–2007, the productivity growth in maize is determined by an increase in fertilizer use, changes in the adoption of high-yielding seed varieties, and an increase in the fertilizer distribution outlets (Kibaara et al., 2009). Supporting this finding is also found in a study made in Southern Ethiopia. Labor, fertilizer use and oxen power are the significant variables affecting the productivity of maize by farm households (Geta et al., 2013).

McArthur and McCord (2017), on their work, to analyze the impact of agricultural inputs on economic growth, supported for the positive and notable contribution of fertilizer use, adoption of modern seeds and access to water as the factors influencing agrarian productivity. Agricultural productivity is noted as an engine for the structural change of countries (Zeweld, Huylbroeck, Hidgot, Chandrakanth, & Speelman, 2015).

However, there are research findings which disprove the positive contribution of improved seeds on agricultural productivity and support mixed results. A linear programming approach study from Sudan shows that compared to the local seeds, the utilization of improved seeds has increased the productivity of some varieties and decreased others (Maruod et al., 2013).

Empirical findings on the link between the health status of households and agricultural productivity show mixed results. A study made in Ethiopia using 430 rural farmers found the existence of significant relationships between the health status of the family, nutrition, and agricultural productivity. As a result, agricultural productivity in Ethiopia is influenced by the distance to the water sources, diet, and morbidity status of the household (Croppenstedt & Muller, 2000). Similarly, a comparative study in Ethiopia made by Ulimwengu (2009) shows that healthy farmers have produced more output per unit of inputs, earn a higher income and able to supply more labor than the sick farmers.

Microfinance services are an anti-poverty program, a source of gender empowerment and an overall driving force for economic development. Microfinance enables rural households to solve their financial problems during the preparation of their farm activities. To this end, microfinance impacts positively agricultural production and productivity in the rural community. Research work from Ghana supports such notable and positive relationship between microfinance and crop production; a GH¢1 increase in microcredit provision to the farmers improves the crop production of the farmers by more than 33.3 Kgs (Nuhu et al., 2014). While total livestock unit and farm size of the rural households have an adverse effect in explaining the variation in cassava productivity, access to credit enhances the productivity among the credit beneficiary households in Nigeria (Awotide et al., 2015).

Family size, the income of the household, level of education of the head, access to credit facilities are the factors influencing agricultural productivity in rural communities of Pakistan (Rahman, Hussain, & Taqi, 2014). However, Ali, Jabeen, and Nikhitha (2016) in their study on the impact of Information and Communication Technology (ICT) on agricultural productivity in the central province of Zambia found that ICT, improved seeds, and access to credit were positive but statistically insignificant in determining farm productivity, and utilization of fertilizers reduces productivity per acre by 0.239.

Governments, international development agencies, and stakeholders also introduced farmer field schools in rural communities to train the farmers on the adoption of technologies and other development related techniques. A study made in eastern Africa, mainly in Kenya, Tanzania, and Uganda, has witnessed the positive impact of such schools on agricultural productivity and other outcomes. Participating in the farmer field school improves the crop production of

the study countries as a pool by 61 percent, and increases the crop production in Kenya by 80 percent (Davis et al., 2010).

Agricultural output and productivity in the farming communities are significantly hampered by the availability and access to water resources. Researchers also look beyond the availability of water potentials to the efficient allocation of the water potential. Governments and communities are using different reforms to enhance the development of water and work for the dynamic allocation of scarce resources. As a result of climate change, countries receive a more varied amount and intensity of rain, which determines and affects the production of crops. In the least developed countries, the areas which are very rich in water resources are also poor regarding health conditions as so many water transmitting diseases and insects which comfortably grown in the rangelands, such as mosquitoes, which affect the productivity of the farmers since malaria epidemics occur easily. There is an excellent consensus in literature for the positive relationship between efficient utilization of irrigation systems and agricultural production and productivity. Even though the magnitude of the impact of irrigation differs across countries, nature, and potential of the irrigation system and other factors, researchers agreed on its positive role to change agricultural productivity in general and crop yield in particular. Empirical findings from various countries also confirm this (Dhehibi, Ahmed, El-Shahat, & Hassan, 2016; Jin, Yu, Jansen, & Muraoka, 2012; Todkari, 2012).

3. Materials and methods

3.1. Description of the study area

Eastern Zone (the study area) is one of the zones found in the Regional Government of Tigray-Northern Ethiopia. The regional government of Tigray has six administrative zones and one special zone, 45 Woreda,¹ and 74 towns and growing towns (BoPF, 2014).

Eastern zone is the third populated zone in the region following the Sothern zone and the Central zone. It has seven districts encompassing both urban and rural settings. Based on the CSA Census 2008 Report (2017 est.), the Eastern zone of Tigray has a population size of 963,432, which is about 20 percent of the regional population. More than 80.6 percent of the population is living in rural areas depending on agriculture as their mainstay of life. The Eastern zone is located in the north tip of Ethiopia and bordered with Eritrea in the North, Afar regional state in the East, South-East zone of Tigray to the South and Central zone of Tigray to the West.

3.2. Nature of data and sample size distribution

The data set used for this study was developed by Adigrat University, the Regional Government of Tigray Bureau of Plan and Finance, Bureau of Agriculture and Rural Development and Dedit Credit and Saving Institution. A panel data set was created from the three waves carried out in 2012, 2014 and 2016. There was no randomization of treatment of the program, and households are joining the programs at a different period. To get the advantage of balanced panel data regression, we restricted the sample to include the observations which were appearing in all the three surveys years. Besides, families who were participating in package programs which need more than one year to get the outcome or benefit from the program are considered as non-participants, especially the tree plantation package. There are eight package programs² available to the rural community to enhance the livelihood of the farm communities by improving farm productivity, ensure food security and asset building. The package programs are improved seed and fertilizer package, livestock fattening package, dairy package, sheep and goat rear package, beekeeping package, irrigation and water harvesting package, poultry package, and tree plantation package. These package programs differ in their nature, size and availability at village level and maturity and harvesting period. The resulting sample included 789 households from seven Woreda each interviewed three times. While 51 percent of the households are participants in the program, 48.4 percent was not participants, and each Woreda's share is available in Table 1.

Table 1. Sample size distribution by districts for three survey rounds

District/Woreda	Package participation					
	Non-members		Members		Total	
	No.	%	No.	%	No.	%
AtsbiWenberta	228	19.9	168	13.8	396	16.7
Erob	45	3.9	45	3.7	90	3.8
GantaAfeshum	129	11.3	180	14.7	309	13.1
Gulomekeda	165	14.4	135	11.1	300	12.7
Hawzen	180	15.7	243	19.9	423	17.9
Klteawlaelo	156	13.6	192	15.7	348	14.7
SaesieTsaedaEmba	243	21.2	258	21.1	501	21.2
Total	1,146	48.4	1,221	51.6	2,367	100.0

Note: Authors' calculation based on 2012 ~ 2016 IRHAPP survey data.

3.3. Empirical productivity model specification

3.3.1. Productivity and fixed effect estimation

The agricultural sector of the smallholder farmers in Ethiopia produces a great number of products like wheat, barley, teff, maize, sorghum, beans, and pea; few among others. To produce a certain amount of cereals on their plots of land, households depend on plot-level variables, community features, access to various forms of services and institutions and other covariates. For the important features, Cobb-Douglas production function has it remains as the well-known production function in production and productivity analysis. Many researchers applied the function in evaluating the structural relationships between inputs and outputs. In the estimation of agrarian productivity, all the factors determining the productivity of agriculture has to be included (Hayami & Ruttan, 1985). This empirical study also considered the most important factors of production, such as the cultivated area of land, chemical fertilizer, a tropical livestock unit, proxy variables for capital input, social, institutional arrangements and access for alternative social services, in the estimation. A significant number of empirical researches applied the Cobb-Douglas production function through the assumptions of homogeneity & unitary elasticity of substitution between the dependent variable and the covariates (Enaami, Ghani, & Mohamed, 2011).

Productivity is a relative concept since its application and meaning differs based on sectors, region, and factors of production considered. Agricultural productivity, here, refers to the total factor productivity associated with the smallholder farmers.

First of all, *Total factor productivity* is computed as the ratio of the monetary value (Birr) of the overall production activity at a period t to the total inputs used (Coelli, Prasada Rao, & Battese, 1998; OECD, 2001). Given that A is the total factor productivity, Y_{it} is the entire production and X_{it} is the inputs used in the production process, and W_{it} is the average price of the input used, then all total factor productivity is defined as:

$$A = \sum_{i=1}^n \frac{Y_{it}}{W_{it}X_{it}} \tag{1}$$

According to Ali Dogramaci (1981), the rate of change in the total factor productivity (v) for a period of 0 to 1 is represented by:

$$v = \frac{\sum_{i=1}^n \frac{Y_{i1}}{W_{i1}X_{i1}}}{\sum_{i=1}^n \frac{Y_{i0}}{W_{i0}X_{i0}}} - 1 \tag{2}$$

Estimation of the total farm yield employs a multi-factor production system. To produce a certain amount of output, a farmer uses N inputs, (such as labor, seed, fertilizer, oxen power), and then the Cobb-Douglas production function expressing such a relationship (Tripathi & Prasad, 2008) is shown as:

$$Y_{it} = \alpha(L_{it}^{\beta_1} K_{it}^{\beta_2}) e^{\mu_{it}} \quad (3)$$

where Y_{it} is the plot level monetary value of the i^{th} household's all farm outputs produced which is expressed in Ethiopian currency (Birr) during period t

L_{it} is the i^{th} labor inputs used during period t ,

K_{it} is the i^{th} capital inputs at a time t ,

μ_{it} is the disturbance or error term,

β_1 and β_2 are output elasticity of labor and capital, respectively.

If we transform Equation (3) in its log-transformation form, it gives us:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \mu_{it} \quad (4)$$

Therefore, in the case of our several independent variables, the relationship between the input and plot level output (productivity) (Huang, Rozelle, Lohmar, Huang, & Wang, 2006; IOAN & IOAN, 2014; Jin et al., 2012; Tripathi & Prasad, 2008) of the generalized trans-log form is explained as follows:³

$$\ln Y_{it} = \vartheta_i + \delta_1 \ln \text{Agril}_{it} + \delta_2 \ln \text{CaL}_{it} + \delta_3 \text{IRR}_{it} + \delta_4 \text{longer}_{it} + \delta_5 \ln \text{TLU}_{it} + \delta_6 \text{Rain}_{it} + \beta \text{HH}_{it} + \gamma_1 \text{Com}_{it} + \gamma_2 \text{Acces}_{it} + \alpha \text{APP}_{it} + u_{it} \quad (5)$$

Fixed effect removes the effect of time-invariant characteristics and helps to assess the net effect of the predictors on the outcome variables. The fixed effect model we used in estimating the impact of the package programs on agricultural productivity is represented by:

$$\ln Y_{it} = \vartheta_i + \beta \text{HH}_{it} + \varphi P_{it} + \delta F_{it} + \gamma V_{it} + u_{it} \quad i = 1, 2, \dots, N \text{ \& } t = 1, 2, 3, \dots, T \quad (6)$$

From Equation (6), $\ln Y_{it}$ represents the gross farm productivity (Birr) of household i at time t ; ϑ_i refers to the household fixed effects which are variables related to the households farming creativity and ability, perception and risk mitigating skill and interest in farming life etc HH_{it} comprises observable household characteristics (age, gender, education level, family size, and marital status), P_{it} is dummy variable for household agricultural package participation (yes = 1), F_{it} is a vector of farm-related variables like land size, fertilizer and pesticide expenses, tropical live-stock unit and others, V_{it} includes village level covariates which include access to different social services, ICT, rain and weather condition and others, and u_{it} is an error term.

Since ϑ_i correlates with the status of package participation, P_{it} , and with the rest of the explanatory variables, the estimating by OLS will lead to having biased estimator. To solve this, namely to remove the impact of ϑ_i , we used the "panel data fixed effect estimation (Demeaning)⁴ method" ((Huang et al., 2006; Jin, Yu, Jansen, & Muraoka) and represent the equation as follows:

$$\ln Y_{it} - \ln \bar{Y}_{it} = \beta (\text{HH}_{it} - \overline{\text{HH}_{it}}) + \varphi (P_{it} - \bar{P}_{it}) + \delta (F_{it} - \bar{F}_{it}) + \gamma (V_{it} - \bar{V}_{it}) + (u_{it} - \bar{u}_{it}) \quad (7)$$

3.3.2. Average treatment effect on the treated (ATT) estimation

The average impact of participating in the farm package programs was estimated using the propensity score matching method (PSM). The PSM helps to control selection bias problems resulting from the non-randomizing treatment to the program. The outcome of the estimation

also validates the estimates from the descriptive statistics and the fixed effect model. In most impact evaluation research works, the focus is on estimating the Average Treatment Effect (ATE) and the Average treatment effect on the treated (ATT). The first one refers to the average impact of the package programs for randomly selected households in the population. However, the ATT indicates the average gain for that who get the treatment, which is the focus of this study. To ensure the robustness of the estimates in the PSM, we used the four algorithms (Nearest_Neighbour, radius, stratification, and Kerner) of the propensity score matching method.

After observations have been matched using their propensity score, the score shows the probability of participating in the package programs in the last period given variable X and status of participation (D), estimation was followed. The probit regression estimation method was applied to analyze the determinants of participation. For panel data with open treatment where individuals can enter and exit from the program, both treatment and control observation will not maintain their first status. As a result, the impact evaluation using propensity score matching will employ different treatment and control groups across the years. It depends on the years of treatment and the nature of participation status of the household, which requires to construct various treatment and control groups to compute the period wise treatment effect (Nguyen, 2012). The treatment effect which is ATT has been estimated using the four matching techniques, and is represented by (steps are stated in the verification of PSM assumptions):

$$ATT = E(Y_i^1 - Y_i^0 | D = 1) = E(Y_i^1 | D = 1) - E(Y_i^0 | D = 1) \quad (8)$$

ATT represents how much did agricultural package program participants benefited compare to what would have happened without participating in the program (counterfactual). From the ATT equation, data on $E(Y_i^1 | D = 1)$ is observable and available from the agricultural package programs participants. However, we cannot find $E(Y_i^0 | D = 1)$ directly as the data on non-package participants enables to identify $E(Y_i^0 | D = 0)$. Thus, we cannot observe the difference between the $E(Y_i^1 | D = 1)$ and $E(Y_i^0 | D = 1)$ for the same household at the same time.

The effectiveness of PSM estimators as a feasible estimator for impact evaluation depends heavily on two assumptions (Rosenbaum & Rubin, 1983):

(i) Conditional Independence Assumption (CIA):

The CIA states that given a set of observable covariates (X) which are not affected by participation (in this study, household agricultural package program); potential outcomes (agricultural productivity) are independent of participation assignment. That is the agricultural package program beneficiaries' outcome and non- beneficiaries' outcome is independent of the treatment status.

$$Y^1, Y^0 \perp D | X \quad (9)$$

$$E(Y^1 | P, D = 1) = E(Y^0 | P, D = 0)$$

It implies that the non-beneficiaries' outcomes can be used as an unbiased estimation of the counterfactual outcome for the package program beneficiaries. Non- beneficiaries have the same average outcomes as package participant households would have had if they did not receive the program, after controlling for all pre-program observable household and community characteristics that are correlated with the program participation and the outcome variable (Gilligan, Hoddinott, & Seyoum, 2008).

(ii) Common Support Assumption (CSA):

The CSA means that no explanatory variable is allowed to predict treatment perfectly. If the above two assumptions are satisfied, then, after conditioning on the propensity score, the

Y^1 distribution observed for the matched non-beneficiaries can be substituted for the missing Y^0 distribution for the agricultural package program.

$$0 < P = \Pr(D = 1|X) < 1 \tag{10}$$

Matching individuals based on observed covariates might not be desirable or even feasible when the dimensions of the covariates are many. To overcome the problem of dimensionality, instead of matching along X , we can match along $P(X)$. Given that the propensity score is a balancing score, the probability of participation conditional on X will be balanced such that the distribution of observables X will be the same for both participants and non-participants. Consequently, the differences between the groups are reduced to only the attribute of participation assignment, and unbiased impact estimates can be produced (Rosenbaum & Rubin, 1983). Simultaneous use of the assumptions (9) and (10) gives:

$$Y^1, Y^0 \perp D | P(X) \tag{11}$$

As long as outcomes are independent of participation given observables, then they also do not depend on participation given propensity score. Therefore, the multidimensional matching problem is reduced to a one-dimensional problem. The distribution of potential outcomes will be balanced among participants and counterfactuals (Heckman, Ichimura, Smith, & Todd, 1998; Rosenbaum & Rubin, 1983).

Building on these underlying assumptions, Propensity Score Matching provides a valid method for estimating $E(Y^0|D = 1, X)$ and obtaining unbiased estimates of ATT (Smith & Todd, 2001; Heckman et al., 1998).

Following the Krasuaythong (2008), the parameter of interest here is the average treatment effect on the treated (ATT). Therefore, applying the composite assumption [11] the true ATT, based on PSM, can be written as follow:

$$ATT = E_p(X) (Y_i^1 - Y_i^0 | D = 1, X) \tag{12}$$

$$ATT = E_p(X) [(Y_i^1 - Y_i^0) | D = 1, p(X)] \tag{13}$$

$$ATT = E_p(X) [E(Y_i^1 | D = 1) - E(Y_i^0 | D = 0, p(X))] \tag{14}$$

which finally can be expressed as Equation (8).

The perception, here, is that: Two individual households with the same probability of participation will show up in the participants and non-participants samples in equal proportions by propensity scores. The first term on the righthand side of the above expression (Equation 12) can be estimated from the agricultural package participants and the second term from the mean outcomes of the matched (i.e., based on propensity score) agricultural package non-participant households.

4. Results and discussion

4.1. Description of socioeconomic characteristics of the household

The sample households have different socio-economic characteristics where some variables have statistically significant variations among the agricultural package program adopters and non-adopters. As indicated in Table 2, the average age of the head of the household is 47.31 year for the package non-members and 47.55 years for the package program beneficiary households. The mean family size is 5.59 and 5.57 persons for the package adopter and non-adopter households,

Table 2. Socio-economic features of households

Welfare and household feature	Status of Package Participation		
	Non-member	Member	Diff [†]
Age of the head of the family (years)	47.31 (11.26)	47.55 (11.29)	-0.247 (-0.53)
Family size	5.576 (1.982)	5.589 (2.027)	-0.013 (-0.16)
Level of education (years)	2.079 (2.924)	2.020 (2.900)	0.059 (0.50)
Gender of head of household (1 = male)	0.784 (0.412)	0.815 (0.389)	-0.031* (-1.90)
Labor man days	118.4 (89.19)	121.3 (88.80)	-2.9 (-0.80)
Shock experience(1 = yes)	0.613 (0.487)	0.621 (0.485)	-0.008 (-0.37)
Death of child under 5 (1 = yes)	0.0113 (0.106)	0.0147 (0.121)	-0.0034 (-0.73)
Number of days family member had a serious illness in the last 12 months	2.265 (1.518)	2.283 (1.498)	-0.018 (-0.29)
Death of mother (1 = yes)	0.0192 (0.137)	0.0164 (0.127)	0.0028 (0.52)
Months of secured access for food	8.718 (3.746)	9.067 (3.233)	-0.349** (-2.42)
Having savings of various forms (1 = year)	0.541 (0.499)	0.609 (0.488)	-0.068*** (-3.33)
<i>Number of observations</i>	1,146	1,221	2367

Note: 1) mean coefficients; sd in parentheses.

2) level of significance * $p < .10$, ** $p < .05$, *** $p < .01$.

3) * t statistics in parentheses.

respectively. Gender of the head of the household has an impact on the welfare of the families. The average years of schooling are 2.05 year, which is very low and did not vary depending on the participation of the head on farm package programs.

The degree of respect, compassion, and auspices towards female-headed households differ depending on the social interactions, the root, and scheme of cooperation, and the values that communities give to gender. 81.5 percent of the agricultural package beneficiaries and 78.1 percent of the nonbeneficiaries are headed male households where the difference is statistically significant at 10 percent level of confidence.

Table 2 also indicates that the farmers' health condition, which is expressed by the child mortality, maternal mortality and the experience of illness for the last 12 months before the survey year, did not differ on the status of households' package participation. Only 1.13 percent of the non-package member households and 1.47 percent of the beneficiaries had lost a child for a health-related problem during the survey years. Almost two women out of one hundred have passed away in the Eastern zone of Tigray for health-related issues. 22 and 20 mothers were died in the agricultural package non-participants and participants, respectively, across the survey years.

Furthermore, the total number of hours that members of the rural community get a severe illness, based on their experiences and rating, is less than 60 hours. 2.265 days was the average number of days that the non-package participant household members suffer from illness. Whereas, the households who are participating in the agricultural package programs have average illness period of 2.283 days (Table 2).

Community-level variables, like the experience of the household for shocks and labor working days of the families spent at their farmlands, did not differ among the households. Generally speaking, more than 61 percent of households have experienced shocks, which can significantly influence the welfare of their family members.

These shocks were crop damages, lost and death of livestock, an outbreak of epidemic disease, flood, and severe drought.

Households have different motives and reasons to make savings. The agricultural package program beneficiary households have more savings (cash and kind) than the non-adopters at 1 percent level of significance. 60.9 percent and 54.1 percent of the package member households and nonadopters have savings of various forms in the intention to smooth consumption and, more critically, livelihood in the future. 90 percent of the households made saving to cover their consumption for the summer season, marriage plans, commemorations, religious festivity, and other expenses.

The proper availability of access to food and essential food services is one indicator of the welfare of households. Households do not have all months of sufficient availability and access to food. While the package beneficiary households have 9.1 months of adequate food, the non-members also have 8.7 months. The package beneficiary households have more months of enough and plentiful food than the non-beneficiary households which are statistically significant at the accepted level of confidence (5%).

4.2. Land cultivation and input utilization

Throughout the Ethiopian history, land ownership and distribution took on different forms. At the current time, as stated in the Ethiopian Constitution Article 40–3, the land belongs to the public and the state. There is no private ownership of land; however, the farmers have the “use right” which includes farming, leasing, renting and granting to a family member, but not entitled to sell and exchange. Rural households own land in different forms: through land distribution, a transfer from family members, and rent and sharecropping.

Rural farmland redistribution was carried out in 1992, and consecutive reallocations at locality level are regularly happened depending on the availability of land. Land distribution takes into consideration the family size and fertility of the land. It also gave considerable attention to the composition of the family members as well; children, adolescent, and matured people were treated differently. The regional government prohibits dual land ownership (meaning that farmland only belongs to the rural inhabitants) in pursuit of fairness and the desire to enhance the productivity of land through the household’s investments and follow-ups on their farm in a nearby place.

In this study, we found that the average arable land holding is less than a hectare (0.876 hectares). Table 3 indicates that package participant households have significantly higher landholding (0.929 hectares) than the non-participants (0.823 hectares). Size of the land owned by the farmers increased across the survey years. The existence of a statistically significant difference in the size of landholding does not justify the fair distribution of land among the households in Tigray and needs further research.

The households’ landholding increased at an average rate of 18.88 percent in the survey years, and in the year 2016, it rose by 31.41%. Landholding size of the households is increased due to the landless members of a family get land and make use of un-arable land for farming purposes in the rural areas.

Estimated results from Table 3 show the “existence” of a relatively steady percentage growth rate of cultivated land; it was 96.8 percent in 2012 and raised to 97.6 percent in 2016. Being the households’ land holding is small, at an average, more than 97.3 percent of the land was under cultivation during 2012–2016. When we assess the percentage of land cultivated by the status of package participation rate, the findings ensure the “non-existence” of significant differences.

Table 3. Cultivated land, quantity and expenses on inputs: 2012 ~ 2016

Variable\Year	2012			2014			2016			2012-2016		
	NP	P	Package	NP	P	Package	NP	P	Package	NP	P	Package
Land owned(ha)	0.658	0.816		0.781	0.855		1.03	1.12		0.823	0.929	
	(t = -2.544**)			(t = -1.82*)			(t = -1.434)			(t = -3.276***)		
Cultivated land(ha)	0.631	0.797		0.753	0.831		1.004	1.096		0.796	0.908	
	(t = -2.6794***)			(t = -1.9374*)			(t = -1.5195)			(t = -3.460***)		
Fallow land(ha)	0.027	0.019		0.028	0.024		0.028	0.021		0.027	0.021	
	(t = 1.2827)			(t = 0.5287)			(t = 0.529)			(t = 1.4538)		
Cultivated land(Rented-ha)	0.069	0.088		0.142	0.145		0.247	0.317		0.152	0.183	
	(t = -1.35)			(t = -0.117)			(t = -1.944**)			(t = -2.074**)		
Seed expenses(Birr)	2,040.4	2,884.1		3,502.3	3,972.3		2,132.96	2,519.85		2,558.55	3,125.39	
	(t = -3.3833***)			(t = -1.564)			(t = -1.5118)			(t = -3.594***)		
Fertilizers expenses(Birr)	189.6	1829.0		1190.7	3076.9		496.95	1690.49		625.759	2198.79	
	(t = -23.84***)			(t = -17.59***)			(t = -12.406***)			(t = -27.344***)		
Fertilizer(Kg)	9.17	107.1		53.43	142.17		32.5	100.8		31.7	116.684	
	(t = -25.41***)			(t = -18.214***)			(t = -12.945***)			(t = -30.187***)		
Pesticides(l)	0.23	0.58		0.47	2.43		0.611	0.833		0.435	1.28	
	(t = -2.015**)			(t = -4.204***)			(t = -0.894)			(t = -4.523***)		
Labor(man-days)	139.1	143.695		108.6	110.15		107.468	110.129		118.395	121.324	
	(t = -0.762)			(t = -0.235)			(t = -0.431)			(t = -0.801)		
N	382	407		382	407		382	407		1146	1221	

Note 1) Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.

2) NP and P represent for package non-participants and package participants, respectively.

3) Values in brackets are t-statistics.

4) Significance: *** 1 %, ** 5 %, * 10 %.

Accordingly, agricultural package program participant and non-participant households cultivated 97.7 percent and 96.7 percent of their holdings, respectively.

Farmers used both improved and local seeds on their farmland. Rural households spent a significant amount of money on buying seeds depending on the accessibility, price and the interest of the farmer. Seeds are the milestones for ensuring farm productivity of rural people. As a result, either they save better seeds or buy from the market, government seed suppliers, cooperatives, and private to use during the sowing season. Seventy percent of the survey households saved improved and local seeds, and the remaining 30 percent did not. 44.15 percent of the respondents did not use any of the improved seeds during the survey periods, and 25.48 percent also used only one type of improved seed in their farmland. 15.29 percent and 10.48 percent of the households were using two and three types of improved seeds during the survey years (Table A1). Only 4.61 percent of the respondents were using more than four kinds of improved seeds in the three survey rounds. The three most important crops that households were using improved seeds are wheat (30.38%), white teff (24.29%) and maize (21.46%). The farmers have harvested more than 16 varieties of crops from their land. Comparing the number of crops that farmers are harvesting with the application rate of improved seed for each type of crop is incomparable. The limited accessibility and availability of the improved seeds at a reasonable price and quality are the most detrimental factors for the adoption of improved seeds.

According to Table 3, except the year 2012, there was no statistically significant difference in the amount of money spent to purchase seeds among the agricultural package participant (P) and non-participant (NP) households. On average, farmer households spent Birr 3,125.39 (P) and Birr 2,558.55 (NP) for the purchase of seeds during 2012–2016.

Ethiopia imports chemical fertilizers to cover domestic demand. There is no industry which produces fertilizer in the country. Urea and DAP (Di-Ammonium Phosphate) are the only fertilizer varieties available in Ethiopia for more than four decades. After 2013, an additional variety of NPS (nitrogen-phosphoric fertilizer containing sulfur) was introduced to the Ethiopian market. DAP is the highest consumed fertilizer, followed by Urea. However, consumption of DAP showed a decreasing trend as farmers are substituting with NPS since 2014/2015. Tigray constitutes 6.8 percent of the national fertilizer consumption. Since 2010/11–2015/16, regional and local fertilizer application was growing at an average rate of 12.54 percent. The highest consumption rate was observed in 2012/2013 (46.54%), and the lowest was in 2014/15 by 5.8 percent (IFDC, 2015).

Fertilizer is used for the production of teff, barley, wheat, maize, sorghum, and other cereals. The nature and type of crops and the fertility of the land determines the amount of fertilizer used on the farm. There is a statistically significant difference between the package participant and non-participants on the rate of farm inputs utilization.

As depicted in Table 3, the average fertilizer consumption rate of the households is 74.2 Kg, which varied across the years. This average is much lower than the national fertilizer application rate and the recommended average standard fertilizer use per hectare of land.⁵ In the first round of the survey, households used 58.12 kg of fertilizer (Urea and DAP) on their farmland, which rose to 97.8 kilograms and finally reduced to 66.6 Kg in 2016. On average, the amount of fertilizer use increased by 18.2 percent. The quantity of chemical fertilizers used remarkably differs between the package participant members (116.7 Kg) and non-member households (31.7 Kg) across all the survey years. The price of fertilizer is, profoundly, influenced by the international market. As a result, following the continuous devaluation of Birr to US dollar, the price of fertilizer is rising, which might affect the fertilizer application rate of the households. The effect is expected to be much severe on the poor, very poor, and many vulnerable families. In 2012, households' average expenditure on fertilizer was Birr 1,009.3.⁶ Application of fertilizer increased in the second round, which led the total fertilizer expenses to grow by more than 110 percent. In 2016, following the reduction in the fertilizer consumption rate, households spent Birr 1,412.3 for the purchase of chemical fertilizers. Furthermore, fertilizer expense was raised by 31.3 percent during 2012–2016.

There is a similar trend in the application rate of pesticides and herbicides during the survey years. Households used less than a liter (0.85L) of pesticide chemicals to their land. Package participant households apply more liters of pesticide chemicals on their farmland than their counterparts. In 2012, non-package participant households used less than a quarter of a liter of chemical pesticides, while the members used around 0.58 liter. In spite of the subsidiary level of chemical pesticide application by the farmers, both member and non-member households raised their use rate in 2014. While the non-participant households doubled their application rate, the members raised it by more than five folds. Besides, in 2016, non-member households increased pesticide use to 0.611L, but use rate of beneficiary households sharply declined to 0.833 liters. This indicates that there is room for the households to use more chemical pesticides on their land if the limited access, financial constraints, and other challenges have been solved.

In this study, we found that the labor used in the farmland, measured by person-days, is very similar between the agricultural package participant and non-participant households. The average labor used was 119.86 days per person across the survey years. In 2012, families spent 141.4 days per person to cultivate their lands. This rate was reduced by 22.64 percent and 0.5 percent in 2014 and 2016, respectively. This reduction in labor working days might be due to the reallocation of household labor to another sector, off-farm employment, safety networks, and related activities.

4.3. Farm production status

Farmers in the Eastern Zone of Tigray have relatively small, mountainous and significantly degraded farmlands. Households fought with the natural and human-made calamities to produce varieties of crops on their farms.⁷ Since families are producing different crops within a year, the total agricultural production is computed and stated in its monetary values. Table 4 indicates that agrarian output is growing at an average of 8.13 percent. In the year 2014, agricultural production was increasing at the highest rate of 33.26 percent and reduced by 17.01 percent. In 2012, the average agricultural production was 17,087.4 Birr which was raised to 21,463.9 Birr in 2014 and finally reduced to 17,615.09 Birr in 2016.

Comparative statistics in Table 4 also show that there is a statistically significant difference in the total farm output level of the households participating in agricultural package programs and the non-participants. The difference is in favor of the participant households in all the survey years. At average, 2012–2016, agricultural package participant households produce additional 2,879.92 Birr worth products than their counterparts. The magnitude of the difference in agricultural production is decreasing from 4,067.79 Birr in the first round to 1,850.21 Birr in the third wave. The average productivity of land in the study area is 20,337.79 Birr. In the first and second waves, the yields of land were mounting in magnitude but turned down in the third wave. In 2012, the production per hectare of land was 21,173.6 Birr, which was raised by 20.1 percent in 2014 and reached Birr 15,923.14 in 2016. Further, except for the year 2016, the productivity of land was not found to be statistically different between the package participants and non-participant households. However, the sign was supporting the package participant households. The productivity of labor was estimated and found to be 854.87 Birr. It was growing at more than 230.57 percent during the survey years. In fact, like the growth in output, the productivity of labor did not depict solid moves. It was increased by more than 720 percent in 2014 and sharply went down by 63.30 percent in 2016. The highest productivity of labor growth realized in 2014 is not a miracle; instead, figures like these mostly happen in situations where labor is underemployed.

Moreover, households decision to use other farm inputs is also influenced by the expectations and availability of rain in the area. Since farmers are mainly practicing rain-fed agriculture, the highest output growth rate in the year, 2014 might have resulted due to the good rainy season in the Eastern Zone. Agricultural productivity also varied with the status of farmers to apply chemical fertilizers at their land. At average, chemical fertilizer adopter households produced 3,049.13 Birr more output than the non-users.

Table 4. Total product based on the status of package participation, gender & input use and productivity across the years:2012-2016

Variable/Year	2012			2014			2016			2012-2016		
	Mean(Birr)	t-test	Mean(Birr)	t-test	Mean(Birr)	t-test	Mean(Birr)	t-test	Mean(Birr)	t-test	t-test	
Status of participation package	Non-member	13,019.61		18,742.16		15,764.88		15,842.21				
	Member	17,087.4	-2.68***	21,463.9	-2.038**	17,615.09	-1.172	18,722.13	-3.36***			
Production	Mean	15,117.95		20,146.15		16,719.3		17,327.8				
	Growth rate (base-2012)	33.26		-17.01		3.64		8.13				
	Female	14,279.5		10.59		14.62		19.49				
	No	13,994.28		19,901.83		16,567.3		17,041.88				
	Yes	16,656.67		19,928.51		15,065.08		15,814.18				
Status of fertilizer use	Difference	-2662.39	-1.731*	-340.04	-0.244	-3872.92	-2.4**	18,863.31	-3049.13	-3.56***		
	No	13,959.4		18,709.14		16,465.21		16,154.43				
	Yes	16,640.03		21,268.51		16,892.66		18,371				
	Combined	15,117.95	-1.748*	20,146.15	-1.902**	16,719.3	-0.27	17,327.8	-2.58***			
		(692,97)		(759,30)		(766,23)		(2257,150)				
The average product of the land	NP	20,633.3		24,889.99		15,702.07		19,902.27				
	P	21,439.65		25,829.00		16,072.16		20,619.09				
	Combined	21,173.6	-0.52	25,437.06	0.1482	15,923.14	-1.68*	20,337.79	-0.96			
	Growth rate (base-2012)	-		20.1		-37.4		27.7				
The average product of labor	NP	173.9963		1379.017		277.1031		589.77				
	P	199.1483	-0.648	1694.194	-0.35	792.3275	-1.37	854.87	-0.87			
	Growth rate (base-2012)	-		723.64		-64.31		32.39				
		-		723.64		193.95		289.1				

Note: 1) Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.
 2) Values in brackets are observations for No and Yes, respectively.
 3) Significance: *** 1 %, ** 5 %, * 10 %.

There is a statistically significant disparity on the productivity of the farmers based on the status of fertilizer application in the years 2012 and 2016. Fertilizer-user households were able to make a productivity difference between 2,662.39 Birr in 2012 and 3,872.92 Birr in 2016, respectively. In 2014, there was no supporting evidence for the existence of statistically significant variation among the fertilizer users and non-users.

Access to finance also affects the decision of households to use agricultural inputs. The low-income families are facing financial constraints to purchase fertilizers, improved seeds, chemicals, and hiring labor during the preparation and harvesting seasons. Non-governmental organizations are providing monetary support to poor farmers in the region; however, their coverage is sharply limited. A significant number of families are also visiting the local money lenders to finance the purchase of farm inputs. However, Dedebit Credit and Saving Institution (DECSI) is the instrumental financial institution that the rural households considered it as not only the source of financial support but also the base of sovereignty, strength, equality, and success.

There is a meaningful difference in the productivity of the DECSI agricultural loan user and non-user households. The estimated values in Table 4 indicate that DECSI's agricultural loan users were producing 2,216.67 Birr more output than the DECSI non-member households. Such differences were persistent in 2012 and 2014. In 2016, even though the difference is not statistically significant, productivity is higher in DECSI member households.

4.4. Impact of package participation on farm productivity

4.4.1. Determinants of agricultural productivity-fixed effect

The findings from the descriptive analysis indicate potentially the existence of productivity gains resulting from the availability of agricultural package programs and prepare a way through which farm package programs provide to determine agrarian productivity. There is a definite difference in the farm output produced by the households between the package participant households and those who do not use. This observed difference in productivity might not be entirely due to the participation of the household in the package program. It might be due to other observable and unobserved household, community, and farm level differences among the families.

Regression analysis is substantially required to identify the impact of the agricultural package programs on the productivity of farmers by controlling covariates. The data is very rich in providing information on a plot level and seasonal productivity, the application of varieties of farm inputs in each plot cultivated and overall investments carried out by the household which are the bases to carry out fixed effect estimation. There are two package programs, water harvesting package and farm input package, are provided to households to enhance farm productivity and promote the welfare of the rural community. The package programs are designed to be holistic and highly integrated programs which are very crucial in addressing the needs of those who own land. Since families are producing different types of the crop at their land, the monetary value of the farm outputs was used in our estimations. To evaluate the impact of the household agricultural package programs, we used the "fixed effect regression model." Tests for multicollinearity, cross-sectional dependence, and the Hausman test for the fixed and random estimation choice diagnostic tests were carried out. Besides, to reduce the concerns of heteroscedasticity problems, we used the white, robust standard errors in our estimation.

Here the dependent variable is the log of farm productivity (output/input); and household variables, village level factors, and plot level characteristics have been controlled in the analysis. As indicated in Table 5, all the variables have the expected sign, and 13 variables were found statistically significant in affecting the productivity of farmers; participation in household-based agricultural package programs impacted productivity positively.

Table 5. Fixed effect estimation of the impact of agricultural package programs on crop productivity

Explanatory variable	Dependent Variable: log of agricultural productivity				
	(1)	(2)	(3)	(4)	(5)
Package member (1 = yes)	1.497*** (0.231)	1.461*** (0.230)	0.490** (0.220)	0.442** (0.218)	0.437** (0.218)
Family size		-0.158*** (0.0556)	-0.107** (0.0511)	-0.0859* (0.0511)	-0.0853* (0.0508)
Log of landless youth			1.125*** (0.189)	1.068*** (0.188)	1.079*** (0.188)
Log of cultivated land			0.545* (0.309)	0.615** (0.309)	0.657** (0.307)
Log of fertilize used			0.231*** (0.0263)	0.262*** (0.0276)	0.259*** (0.0277)
Log of TLU			1.024*** (0.106)	0.946*** (0.109)	0.953*** (0.108)
Log of chemical pesticides used			0.859*** (0.143)	0.887*** (0.149)	0.875*** (0.150)
Access to irrigation(1 = yes)			0.559 (0.442)	0.479 (0.430)	0.443 (0.427)
Log of man-labor days			-0.0429 (0.0574)	-0.0791 (0.0583)	-0.0816 (0.0582)
Access to common road(1 = yes)			0.606*** (0.218)	0.555** (0.215)	0.586*** (0.215)
Experience of sickness(1 = yes)				-0.781*** (0.227)	-0.753*** (0.229)
Mobile subscription(1 = yes)				0.480** (0.217)	0.504** (0.218)
Participation in local institutions(1 = yes)				0.532** (0.223)	0.671** (0.281)
Access to the animal clinic(1 = yes)				0.756*** (0.292)	0.731** (0.293)
Participation in off-farm income(1 = yes)					-0.578** (0.252)
Experience of shocks(1 = yes)				No	Yes
_cons	6.284*** (0.119)	7.685*** (0.749)	3.807*** (0.737)	3.425*** (0.750)	3.546*** (0.752)
N	2356	2356	2356	2356	2356
R ²	0.024	0.041	0.208	0.222	0.226

Note: 1) Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.
 2) Household variables (gender, age, age square, marital status, literacy) are not reported.
 3) Standard errors are robust.
 4) Significance: *** 1 %, ** 5 %, * 10 %.

According to Table 5, when we controlled for the household level features (column 2), participation in agricultural package programs remains significant to determine agricultural productivity at a 1 percent level of significance. Since crop yields are also affected by plot level variables, we controlled such variables (column 3). Participation in the agricultural package programs (package

enables to raise output by 49.0 percent, which is statistically significant at 5 percent level of significance. Since the synergy of different economic units affects the farm productivity of rural households, controlling these factors is very crucial. Further controlling of community and village level factors, like access to social services, animal clinics, road, and ICT, reduced the impact to be 44.2 percent (column 4). We are finally controlling for land quality (column 5); after controlling for rain and weather variables and the status of the head of the household in off-farm income schemes, the impact of the program raised by 43.7 percent.

In this study, except family size, we did not find any evidence for the impact of household characteristics on productivity. Family size is found statistically significant to determine productivity at 10 percent level of significance. A 10 percent increase in family size would reduce productivity by 0.853 percent. This might happen when there are new additional children or unproductive member (aged or disabled) joining the household. Landless youth members of a family affect productivity positively. This result supports the findings of Awotide et al. (2015). A one percent increase in the number of landless members of the household increases productivity by 1.079 percent. It is a statistically significant variable determining productivity at a 99 percent level of confidence.

This result might raise the question since the landless youth members are considered to be unproductive. In fact, this study finds that landless youth members perform a positive role in shouldering the responsibility of their parents in the rural community. It is entirely in line with conclusions supporting the positive impact of labor substitution in determining productivity. This finding also touches the social and family responsibilities that old and socially and economically disadvantaged rural families expect when their children become mature. In most cases, mature female members of the household, despite their landless state, marry and leave their parent's house. However, in this culture, the male matured member either marry later or bring his partner to his parent house, thereby increasing his intensity of tasks and responsibilities.

Agriculture, by its nature, needs energy and power to cultivate, which deteriorates when age increases, and much challenging for women to plow their land. A significant number of studies show that productivity declines with age; and female-headed households, divorced or widowed heads are also less productive compared to their counterparts. However, since age, age square, marital status and gender of the head are insignificant variables to affect productivity, these support the reason for the existence of labor substitution/shift of responsibility from the aged, female, divorced and widowed heads of the households to their children and siblings. Besides, sharecropping is common in the study area, and the households who were not capable of cultivating their land also granted their land to others, mainly to the families who are perceived as wealthy such those who are having more oxen and young members. Those all support for the positive contribution of the landless youth in the determination of farm productivity and general raising households' income. Except for the impact of family size on productivity, our results did not support the findings from Pakistan done by Rahman et al. (2014).

Studies support for the positive correlation between healthy heads of the households and their agricultural productivity. Our finding is also in line with the significant number of empirical results which support the inverse relationship between poor health status and productivity of farmers. In the Eastern Zone of Tigray, families who got severe sickness to have 7.53 percent lower productivity compared to the healthy farmers.

On the other hand, the participation of the head of the household on off-farm activities reduces farm productivity by 5.78 percent. This has happened as the amount of labor expected to work on the farm is shifting to participate in other income sources, and farmers do not spend their time and energy on farming at the appropriate time.

Four plot level factors were found to be statistically significant variables determining agricultural productivity in the study area. A 10 percent increase in cultivable land of the household increases productivity by 6.57 percent. The positive impact of an increase in cultivated land on log farm gross revenue is consistent with the findings of Pufahl and Weiss (2008). McArthur and McCord (2017) and Zeweld et al. (2015) found evidence for the positive correlation of fertilizer and other farm inputs on productivity, and on helping to transform the agricultural sectors. In this study, our empirical analysis witnessed the positive contribution of the application of chemical fertilizers and pesticides to enhance agricultural output. The estimates indicate that a 10 percent increase in fertilizer expenses raised agricultural productivity by 2.59 percent. Due to the low utilization rate of pesticides and herbicides, poor harvesting and storing systems, it is believed that least developing countries lost more than 50 percent of their farm products. In this study, we found that application of pest and herbicides promotes production at a 99 percent level of confidence. A one percent increase in the monetary expense for pesticides increases productivity by 0.875 percent. The farm input related findings are consistent with the empirical works of Amegnaglo (2018), McArthur and McCord (2017) and Kibaara et al. (2009).

Livestock has a core value in the livelihood of rural households. They are assets used in their farmlands and are also sources of prestige, respect, and acceptability in the community. A farmer who owns livestock, especially oxen, can plow his land on time, which helps seedlings to grow well. As a result, it is expected to have a positive impact on agricultural productivity. Our findings also prove this idea at the highest level of confidence. A one percent increase in tropical livestock unit (TLU) progresses the yields of the farmer by 0.953 percent. This finding also supports the work of Geta et al. (2013).

Considering the accessibility of water and its efficient utilization, most researchers agreed with the positive contribution of irrigation on productivity. However, we did not find significant evidence to support such findings. In spite of the expected sign access to irrigation assumes, it remains insignificant. Access to irrigation is found at a lower rate. Only 6.8 percent of the households have access to water harvesting opportunities, including river diversions, ponds, and wells. However, the percentage of families who have access to irrigation water sources declines from time to time. In 2012, households who have access to irrigation was 14.12 percent, which sharply dropped to 3.95 percent in 2014 and 3.0 percent in 2016. This reduction in the percentage of irrigation users indicates the lack of availability of water due to various reasons like drying up of water sources. Irrigation user households produced 672 Birr worth of fruits and vegetables. This money is minimal compared to the average income from crop production. The revenue from the sale of fruits and vegetables has valuable information indicating to what extent the irrigation practices and investments are at the lowest rate in the study area. Thus, our finding is against the works of Dhehibi et al. (2016); Jin et al. (2012); and Todkari (2012).

Village and community level variables are determining the farm productivity in Northern Ethiopia. Adoption of communication technologies, access to roads, animal clinics, and credit and financial institutions positively impacted productivity. Beyond their impact on the economy of society, those variables are critical to strengthening the social, cultural, and customs of the population. Mobile phone subscribers have 5.04 percent higher agricultural productivity than non-subscribers. Farmers who have mobile phones can quickly get information about the price, supply, and demand for inputs and outputs. They can also get information about weather conditions, the outbreak of diseases, and insects which affect productivity. As a result, farmers can prepare mitigating mechanisms for every possible risk and make momentous and profitable decisions. These findings support the existing works of Ali, Jabeen, & Nikhith (2016).

Roads are usually the blood vessels of an economy. They make a notable contribution to speeding up the provision and distribution of inputs and outputs in the rural economy. Rural farmers who have access to ordinary roads which are functioning well throughout the whole year enjoy 5.86 percent more productivity gains than their counterparts. The provision of agricultural inputs to rural farmers is fundamentally affected by the availability of roads. Due to lack of viable roads, a significant number of

villages might not get the inputs on time, and there were situations where farm inputs have been delivered to the districts after the sowing season has passed.

Financial institutions which are working to support the rural people are known for their positive contribution to the welfare and productivity of farmers. Households have access to microfinance institutions in the study area. As discussed in the descriptive analysis, DECSI provides various financial products to the farmers through its non-collateral loan system. Agricultural input loan beneficiary households produced 6.71 percent higher output than the non-beneficiaries. This impact is not small in magnitude and is statistically significant at a 95 percent level of confidence. Concerning the effects of microfinance institution on farm productivity, we found a consistent result with other findings (Ali et al., 2016; Awotide et al., 2015; Nuhu et al., 2014; Rahman et al., 2014).

The establishment of animal clinics helps households get veterinary services at nearby places and easily control when epidemic diseases break out. The livelihood of the rural people is significantly tied with animals. The health situation of the animals affects the welfare, productivity, and the psychological makeup of the agricultural community. More than anything else, the health of animals used directly in their farmlands matters for the farmers. Access to animal clinics is also statistically significant variable affecting farm productivity at 1 percent level of significance. Households that have access to animal clinics have 7.31 percent higher productivities than the families that lack such services. Our finding is consistent with the significant number of research works carried out on the impact of animal clinics on the farm productivity of rural people.

4.4.2. Average impact of household package participation on productivity—PSM model

Impact evaluation studies intend to estimate the average effect of the program under consideration on the outcome variable. Since treatment to the agricultural package program was not randomized, the estimates might be biased. Propensity score matching (PSM) is the widely applied non-experimental method of impact evaluation, which is used to estimate the average effect of the program of interest. This method is a valuable tool to reduce the differences between the treated and control groups due to selection biases and pre-treatment variables. The propensity score matching compared the mean outcome of the treatment and matched control groups based on pre-treatment covariate similarities (Caliendo, 2006; Pufahland Weiss, 2008).

To evaluate the robustness of the main results based on the fixed effect regression model and the descriptive statistics, we further used other impact evaluation methods. Since the matching method is a non-parametric method, it does not require linearity assumptions on the outcomes which mainly exist in regression models (Bockerman & Ilmakunnas, 2007). Based on probit regression model in Table 6, households' decision to participate in the agricultural package programs is influenced by the gender of the head, access to primary road and credit services and having a landless member s of a family.

Accordingly, male-headed households have the highest probability of participating in agricultural package programs. Farmers who have access to the whole year community road have a higher likelihood of participation in the package programs. Moreover, the rural households who are getting agricultural input loans from DECSI increased their probability of participating in the program. Finally, having landless members of the family also affect the decision of households to participate in the package programs. Families are interested in curbing the unemployment problem of their members.

To proceed for the estimation of the average treatment effect on the treated (ATT), we checked the underlying assumptions of PSM. All the assumptions of propensity score matching (the conditional independence and balancing property) have been achieved, and the region of the "common support" lies on [0.37,104,248, 0.64,942,071]. The distribution of the propensity scores of becoming household package participants is strongly balanced. There are 7 blocks, and the mean propensity score is not different for treated and controls in each block (see Appendix).

Table 6. Determinants of household package participation

Explanatory	Dependent variable: Package participation _dummy
Family size	0.0000591 (0.0129)
Gender of head	0.117* (0.0649)
Age of the Head of the HH	-0.0021 (0.0153)
Access to the common road	0.00433** (0.00177)
Age_square	0.0000208 (0.000154)
Access to DECSI loan	0.209*** (0.0561)
Having landless above 18 years (dummy)	0.183*** (0.0523)
_cons	-0.0823 (0.383)
No. observations	2367
Prob > chi2	0.0000
LR chi2(7)	36.72

Note: 1) Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.

2) The value in brackets is robust standard errors.

3) Significance: *** 1 %, ** 5 %, * 10 %.

After the matching, the covariates which were influencing households' decision to participate in the agricultural package programs remain insignificant. As a result, both the explanatory variables did not differ based on the status of participation; there is no meaningful difference between the treated and the matched control groups. It ensures the reduction of the discrepancies between the treated and control groups resulting from pretreatment variables, which could lead to selection bias. Thus, the matching again succeeds in making the distributions of the covariates similar. The average treatment effect on the treated (ATT) is computed using the PSM with the nearest neighbor, Kernel matching, radius matching, and stratification matching. We estimated the ATT using all the matching algorithms. This technique is valuable and was used to check the robustness of the PSM results as well.

Table 7 indicates that the estimated average treatment effect on the treated is statistically significant for the four PSM algorithms at more than 5 percent level of significance. In the Nearest_Neighbour matching, the treated households were matching with 648 control households. In the three remaining methods, the number of control groups was 1,140. Since each method utilizes a different algorithm of estimation, the magnitude of the ATT also differs. However, for the robustness issue, depending on the nature of the data using two or more methods is advisable. As a result, the findings of the PSM coincide with estimates of the fixed effect regression. The magnitude of the ATT ranges from 2,554.8 Birr to 2,916.39 Birr for the different PSM methods. Using the Nearest_Neighbor matching, the average impact of the program on those who get the treatment is 2,554.8 Birr and 2,858.0 Birr when the radius matching method is employed.

As a robustness check for the ATT evaluation using PSM, we estimated the impact using the Kernel and stratification Method. Both approaches support the estimation results of the first two methods. Kernel matching method provides the highest ATT estimation amounts to 2,916.4 Birr,

Table 7. ATT (Birr) estimates for average yield, wheat, barley, and teff cereals

Matching Method	Treatment	ATT			
		Total Yield	Wheat	Barley	Teff
Nearest_Neighbour		2,554.8**	1,325.30	-916.3	161.6
Radius	Agricultural	2,858.0***	1,233.5**	-742.1	221.4
Kernel	package program	2,916.4***	1,260.1**	-222.9	478.9*
Stratification		2,819.5**	1,329.7**	-239.4	241.9

Note: 1) Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.
 2) Significance: *** 1 %, ** 5 %, * 10 %.

which is strongly significant at a 99 percent level of confidence. Furthermore, the stratification method supports the estimates of the three matches with ATT amount of Birr 2,819.5.

The ATT estimation result ensures that the household-based agricultural package programs have a positive impact on farm productivity of the smallholder farmers. Farmers produce different quantities and types of crops during one harvesting season. In this study, we found a significant difference in the treatment effect on the production of wheat. As a result, the ATT (1,260.1 Birr to 1,325.3 Birr) for the productivity of wheat grain is statistically significant favoring the beneficiary households. However, we did not find a meaningful impact (ATT) for barley and teff, which are the two other primary crops in the study area. These findings verify the effectiveness of the package program to improve the farm yields for the selected crops.

5. Conclusion

To improve the livelihood of the majority of the population, it requires the formulation and implementation of policies and strategies conducive to enhancing farm productivity and diversifying the income schemes. As a result, the Ethiopian government introduced different package programs to promote farm productivity at smallholder farmer level. To study the impact of integrated household-based agricultural package programs on productivity, we used a balanced panel data of three rounds (2012–2016) in the Eastern zone of Tigray. The impact was analyzed using the fixed effect and the propensity score matching method. The data comprises households of various sorts of economic, social, level of education and marriage features from seven districts in the zone. The sample size was 789, and 51.5 percent of them were agricultural package program participant households. The average age of the heads is 47.43 years, and the mean family size is 5.58 persons. Also, 79.97 percent of the sample households were male-headed, 78.96 percent are married, and 50.15 percent are illiterate heads.

Participation in the agricultural package programs have a prominent impact in boosting agricultural productivity of the smallholder farmers and helped farmers to plant crops having access to improved seed. The estimates of the average treatment effect on the package participant households (ATT) rests on the range from 2,554.83Birr to 2,916.4Birr. At an average, agricultural production was estimated at 17,327.8Birr, which is increased by 8.3 percent per year and grown at 33.04 percent during the favorable harvesting year. The average landholding of the households is less than a hectare (0.876ha), and more than 97 percent was under cultivation every year. There are a poor utilization of chemical fertilizers (75 kg/ha) and pesticides (0.85 l/ha), which are smaller by far than the national average and the scientific standards (170kg/ha). The quantity of fertilizer use increased at an average rate of 36.4 percent a year. More than 44 percent of the sample farmers were using local seeds; 25.48 percent and 15.29 percent of them were using selective seeds for one and two crops, respectively. The involvements of households in water harvesting activities and irrigation practices are very low. The credit utilization behavior (52.3%) of the tenants is found lower compared to the access and availability of microfinance services at their locality (100%). A very insignificant number of families (6.33%) are practicing irrigation and benefiting

from alternative water sources. The rate of utilization of irrigation activities is significantly declining from time to time due to lack of water. The poor availability of water, low motivation of farmers to practice irrigation, and weak support of the regional government to expand irrigation facilities, are the factors hindering irrigation development. The agricultural household package participant households have higher productivity, used more farm inputs, used credit facilities and cultivated more lands than the non-beneficiaries. The size of cultivated land, the amount of money spent for the purchase of chemical fertilizers and pesticides, the number of livestock owned, access to animal health clinics, microfinance institutions and rural roads, mobile-phone subscriptions and the number of landless household members are actively determining the agricultural productivity of the smallholder farmers. To perk up the productivity of smallholder farmers, the following options are very important: expanding the scope of the farm package programs, supplying “demand driven” farm inputs, improve access to irrigation and credit facilities, securing land ownership, and introducing performance-based agricultural support schemes.

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Conflict of Interest Statement

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Author details

Araya Mebrahtu Teka¹

E-mail: arayamebrahtu@gmail.com

ORCID ID: <http://orcid.org/0000-0003-4738-8359>

Sung-Kyu Lee²

E-mail: skl62@hanmail.net

¹ Department of Economics, Andong National University, 1375 Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea.

² Department of International Trade, Andong National University, 1375 Gyeongdong-ro, Andong-si, Gyeongsangbuk-do 36729, Korea.

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Correction

This article has been republished with minor changes. These changes do not impact the academic content of the article.

Notes

1. Note that “Woreda” is the lower administrative organization in Ethiopian government structure which is similar to districts; a group of woreda forms a zone.

- The package programs are (i) improved seed and fertilizer package, (ii) livestock fattening package, (iii) dairy package, (iv) sheep and goat rear package, (v) beekeeping package, (vi) irrigation & water harvesting package, (vii) poultry package, (viii) and tree plantation package.
- $\ln Y_{it}$ = the log of total farm output produced by i^{th} household during period t , $\ln \text{Agril}_{it}$ = the log of i^{th} household agricultural labor inputs during period t , $\ln \text{Cal}_{it}$ = the log of a cultivated land area of the i^{th} household during period t , IRR_{it} = status of access to irrigation for the i^{th} household during period t , dummy, $\ln \text{Fer}_{it}$ = the log expenses of chemical fertilizer used by the i^{th} household during period t , $\ln \text{TLU}_{it}$ = the log of the number TLU owned by the i^{th} household during period t , HH_{it} = household features during period t , Com_{it} = community variables during period t , Access_{it} = access for different social services during period t , Rain_{it} = status of rain and weather condition, dummy, APP_{it} = dummy if HH is a member of the agricultural package program.
- The demeaning and first difference approaches of the fixed effect estimation yields the same estimates for two-period data but different for multiple periods. With the first differencing approach, we introduce serial correlation of the error terms, so the demeaning approach is mostly preferred.
- The fertilizer application rate varies on the type of cereal. In 2014/15, at the national level, the application rate for maize was 177 Kg/ha, 147 Kg/ha for wheat and 110 Kg/ha for teff. However, the average recommended rate of fertilizer is 200 Kg (100 Kg of Urea plus 100 Kg of DAP) for small cereals and 300 Kg/ha (200 Kg of Urea plus 100 Kg of DAP) for maize (IFDC (International Fertilizer Development Center), 2015).
- Birr is the Ethiopian currency, and the official exchange rate was 1\$ = 17.67 Birr in 2012, Birr 20.1 in 2014, 22.2 Birr in 2016 and 27.56 Birr in 2018. The prices in this paper are zone level average prices and adjusted for inflation.
- The most typical crops are barley, wheat, maize, teff, sorghum, karka'et (mix of wheat and barley), chickpea, beans, linseed, lentil, and others.

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Appendix

Table A1. The number of improved seeds used by households across the years

Number of Varieties of improved seeds used	Year			Total
	2012	2014	2016	
0	417	185	443	1,045
	39.9	17.7	42.39	100
	52.85	23.45	56.15	44.15
1	208	165	230	603
	34.49	27.36	38.14	100
	26.36	20.91	29.15	25.48
2	114	173	75	362
	31.49	47.79	20.72	100
	14.45	21.93	9.51	15.29
3	34	191	23	248
	13.71	77.02	9.27	100
	4.31	24.21	2.92	10.48
4	16	40	6	62
	25.81	64.52	9.68	100
	2.03	5.07	0.76	2.62
5	0	14	2	16
	0	87.5	12.5	100
	0	1.77	0.25	0.68
6	0	19	3	22
	0	86.36	13.64	100
	0	2.41	0.38	0.93
8	0	2	0	2
	0	100	0	100
	0	0.25	0	0.08
9	0	0	7	7
	0	0	100	100
	0	0	0.89	0.3
Total	789	789	789	2,367
	33.33	33.33	33.33	100
	100	100	100	100

Note Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.

Table A2. Test of covariate balancing for becoming package participation

Variable	Unmatched Matched	Mean		%reduct		t-test	
		Treated	Control	%bias	bias	t	p> t
Family size	U	5.5889	5.5759	0.6		0.16	0.875
	M	5.5889	5.5692	1	-51.8	0.24	0.809
Gender of HH	U	0.81,491	0.7836	7.8		1.9	0.057*
	M	0.81,491	0.83,702	-5.5	29.4	-1.44	0.15
Age of HH	U	47.554	47.307	2.2		0.53	0.594
	M	47.554	47.103	4	-82.5	0.99	0.323
Access to common road (dummy)	U	19.876	21.417	-10.5		-2.55	0.011**
	M	19.876	20.757	-6	42.8	-1.52	0.129
Age square	U	2388.8	2364.7	2.1		0.52	0.604
	M	2388.8	2346.1	3.8	-77.6	0.93	0.351
DECSI	U	0.34,726	0.27,312	16.1		3.9	0.000***
	M	0.34,726	0.34,562	0.4	97.8	0.09	0.932
Landless (Dummy)	U	0.59,787	0.52,531	14.7		3.56	0.000***
	M	0.59,787	0.60,606	-1.7	88.7	-0.41	0.679

Note 1). Authors' estimation based on 2012 ~ 2016 IRHAPP survey data.

2). Significance: *** 1 %, ** 5 %, * 10 %.

Table A3. Hausman fixed-random test

	(b) fixed	(B) random	(b-B) Difference	sqrt(diag (V_b V_B)) S.E.
Package member (1 = yes)	.437221	.6125575	-.1753365	.1424765
fm1sex	.1640707	.2221391	-.0580684	.2212134
couple	-.3625592	.1122483	-.4748076	.227915
Age of the head of family	-.0097241	.003948	-.0136721	.0061496
Level of education of the head	.0935252	.1269932	-.033468	.1384654
Family size	-.0853195	-.0565245	-.028795	.0302862
Log of cultivable land	.6565567	.5031597	.153397	.1911423
Log of fertilizer use	.2585699	.2572772	.0012927	.0192288
Log of tropical livestock unit	.9531148	.907503	.0456118	.0651828
Log of pesticides used	.8752014	.5999312	.2752702	.1051406
Access to irrigation	.4434603	.4882678	-.0448075	.2632707
Log of labor-days	-.0815813	-.0414201	-.0401613	.0354683
Experience of sickness	-.7527993	-.7743914	.0215921	.1342331
Log of number of landless members	1.079478	.9955537	.0839245	.114941

(Continued)

	(b)	(B)	(b-B)	sqrt(diag (V_b V_B)) S.E.
	fixed	random	Difference	
Participation on off-farm	-.5783319	-.5675801	-.0107518	.1451235
Mobile subscription	.5040738	.3751397	.1289341	.1280472
Access to community road	.5859474	.3,436504	.242297	.1347255
Participation on local institution	.6707986	.5240058	.1467928	.1619562
Access to animal clinic	.7314755	.4198984	.3115771	.188582
Experience of shocks	-.2565024	-.2563	-.0002023	.1581745

Note: Authors' estimation based on 2012 ~ 2016 IRHAPP survey data

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$$\chi^2(20) = (b-B)'[(V_b - V_B)^{-1}](b-B)$$

$$= 42.39$$

$$\text{Prob} > \chi^2 = 0.0025$$

Figure A1. Distribution of propensity scores of becoming package participant in the region of common support.

Note: Authors' estimation based on 2012 ~ 2016 IRHAPP survey data

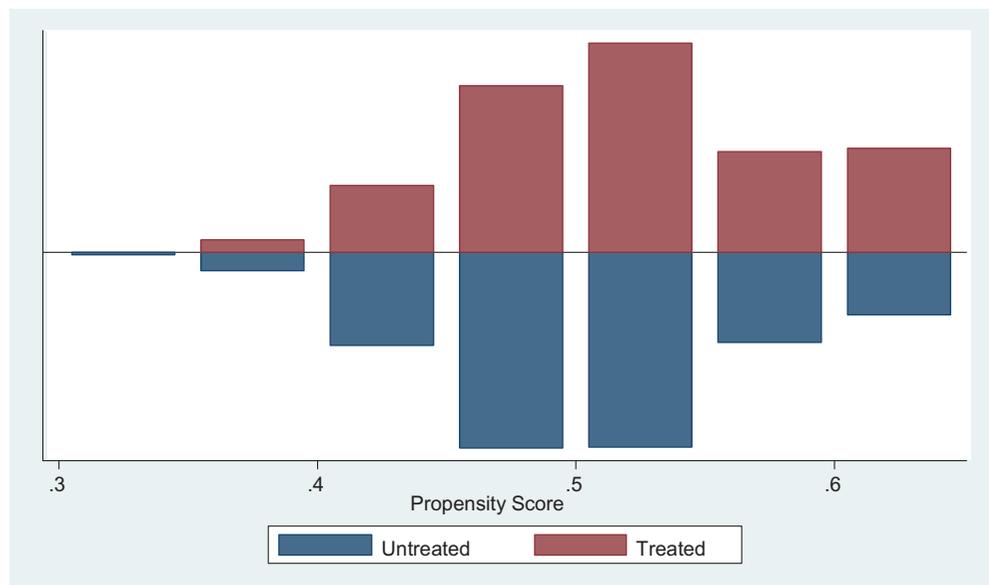


Table A4. Description of the estimated propensity score in the region of common support

	Estimated propensity score				
	Percentiles	Smallest			
1%	0.3,895,271	0.3,710,425			
5%	0.4,135,626	0.3,710,425			
10%	0.4,417,032	0.3,721,042	Obs		2361
25%	0.4,676,497	0.373,205	Sum of Wgt.		2361
50%	0.5,228,751		Mean		0.5,162,942
		Largest	Std. Dev.		0.0615866
75%	0.5,548,351	0.6,467,456			
90%	0.6,099,343	0.6,469,232	Variance		0.0037929
95%	0.6,233,331	0.6,482,505	Skewness		0.0707778
99%	0.6,441,044	0.6,494,207	Kurtosis		2.446,183

Note: Authors' estimation based on 2012 ~ 2016 IRHAPP survey data



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