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Impacts of Extension Services and Social Capital Influence on Conservation Agriculture Adoption and Household Food Security Improvements

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Abstract

There are limited empirical studies that explore how agricultural extension services and local institutions influence conservation agriculture adoption and household food security. Hence, this paper aims to investigate the potential impacts of extension services and local institutions (social capital) on conservation agriculture and food security. A cross-sectional data is collected from 350 randomly selected farmers in northern Ethiopia. The propensity matching method and endogenous switching regression are used to control for selection bias from observed and unobserved factors. Results indicate that extension services and social capital have significant and positive effects on adopting conservation agriculture and improving household food security. Farmers under the treated groups have higher per capita food consumption, per capita expenditure and food security levels than counterpart farmers. Besides, the rate of adoption of conservation agriculture for the treated farmers is relatively higher than for other farmers. This confirms that extension services, formal institutions and informal groups have motivated farmers to adopt conservation agriculture and replenish risks of food insecurity shocks. Therefore, governments, researchers, academicians, NGOs, development practitioners and others actors should exert utmost efforts and investments to empower local institutions and strength agricultural extension services, which are viable options to stimulate farmers to adopt sustainable agriculture in drought-prone areas of the country.

Keywords: Extension services • Relational capital • Group membership • Agriculture • Food security

Introduction

In Sub-Saharan Africa (SSA), food insecurity has been a frequent challenge. Nearly 0.8 billion people are undernourished worldwide. Of this, about 98% are living in low-income countries. Nearly 30% are in Africa, of which, 53% are living in East Africa. Since Ethiopia is a parcel of East Africa, about 25% of its population is living below the national poverty line. Food insecurity has often occurred due to a high dependence on unpredictable and unreliable natural factors, limited resilient capacity to risks of hazards, drought and shocks, unbalanced distribution and endowment of natural resources, and limited access to financial and market services. Besides, population pressure, the occurrence of pests/diseases and limited landholding size are other factors. Other authors also linked food insecurity problem with a lack of good governance, land tenure security and democracy [1-12].

To ensure food security and protect the livelihood of the poor, improving the adaptive capacity of agriculture to drought, diseases and pests, and climate change is imperative [13-16].

Investments in agriculture can enhance food security, overcome poverty and spur economic growth. Accordingly, agricultural growth is a good pathway to break food insecurity trap. In turn, disseminating yield increasing technologies like drought/disease-tolerant varieties, chemical fertilizers, pesticides, and herbicides is one way to achieve agricultural growth. For example, in some Asia and Latin America countries, these inputs were found to enhance agricultural productivity, reduce the adverse effects of weeds and diseases, ensure food security and accelerate economic growth and able many people to move out of poverty [17-20].

Since these external inputs are unaffordable for smallholders and inaccessible to those who live in marginal and remote areas, use of sustainable agricultural practices, such as soil and water conservation measures, use of organic fertilizers, plantation of multipurpose trees, and management of grazing and communal areas is identified as a suitable and feasible option that fits smallholder farmers. These farming practices have often used locally available resources and are based on farmers' knowledge and skills. They have the potential to improve agricultural productivity, save financial resources that would have been used to purchase these intensified or external inputs and to reduce environmental problems such as erosion, degradation and CO_2 emission [21-25].

However, the adoption of these farming practices remains low in many low-income countries because of supply-sides (e.g., lack of information and market inefficiencies) and other constraints. Since market in SSA is usually imperfect and many institutions are often missing, cooperative societies, extension services, farmers' organizations, and other local institutions are found to replace these missing institutions. Investments in extension systems and local institutions have often played crucial roles in improving agricultural productivity and sharing loss from unforeseen events. Provision of information and improvement of farmers' bargaining power was found to solve market inefficiency. Besides, local institutions were found to educate farmers about suitable farming practices, and to increase net returns and household welfare [26-32].

In Ethiopia context, the government has set agriculture-based development programs to facilitate agricultural growth, lift people out of food insecurity and bring overall economic development. Following this, many cooperative societies have been flourished to solve input and output market inefficiency. Besides, demonstration and training based agricultural extension system has been introduced. In doing so, Farmers' Training Centre (FTC) has established at village level to provide technical support and information regarding technology application and climatic conditions. Furthermore, many Agricultural Technical Vocational Education and Training (ATVET) centers have opened in the country to improve the knowledge and skills of extension agents and upgrade their educational levels. Consequently, agricultural extension services and local institutions are important areas of research in Ethiopia, especially their roles in enhancing awareness and facilitating coordination and communication, which are normally difficult in SSA [33,34].

Having these backdrops in mind, how extension services and local

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institutions (social capital) influence the adoption of conservation agriculture are less researched empirically. Whether these have impacts on household food security also remain in Ethiopia under investigation. Therefore, this paper aims to assess food security levels between adopters and non-adopters of conservation agriculture. Impact of extension services and local institutions on conservation agriculture adoption and food security is also investigated. In this study, extension services and social capital are hypothesized as no effect conservation agriculture and household food security.

Literature Review

This study is one of the few empirical studies that assess the impact of social capital and extension services on conservation agriculture adoption and household food security. So, the paper is expected to have a knowledge contribution to contemporary literature by providing micro-level empirical evidence on the impact of extension services and social capital. Many countries have been deployed considerable human resources and invested more financial resources in public extension services to transform subsistence agriculture into market-oriented production systems. Consequently, the result of the paper is expected to have policy lessons in providing information on whether investing in extension services and local institutions worthwhile in motivating farmers to adopt conservation agriculture thereby improving food security.

Conceptual framework and model estimation

Theoretical framework of technology adoption: In literature, impact evaluation is often modelled based on the expected utility maximization framework. Farmers can use technology or treatment, for example, access to extension services and actively participate in local institutions to maximize their expected utility from it (Ui). They decide to choose it if the utility from adopting the technology 'j' exceeds from not adopting it 'k', *viz*., (Uij(X)>Uik(X), implying ATT=Uij(X)-Uik(X), where ATT=average treatment effect and k≠j). The net (true) impact of receiving treatment on outcome variables is given as follows:

$$ATT=E(W_1 i-W_{0i}/T=1) => E(W_{1i}/T=1)-E(W_{0i}/T=1) \quad (1)$$

Where W1 and W0 are the outcomes for treated and untreated farmers and T is a treatment. E (W0/T=1) refers to the outcome of treated farmers had they not been treated once they treated. But it is missing. It is difficult to get information on the counterfactual situations in a non-experimental and cross-sectional survey. Farmers may not be randomly assigned to treatment, rather based on prior information, preference and others, such as innate managerial and technical abilities in using the technology. A failure to account for this may generate selection bias leading to over-/under-state the true impact of the treatment [35,36].

Measuring incidence, depth and severity of household food insecurity: Food security is defined as 'a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. Variation of food security results from a difference in demographic characteristics, availability of physical resources and institutional factors, and technology uptake, extension services and formal and informal institutions. In this study, household food insecurity access scale (HFIAS) is used to assess the food insecurity situations in the areas [1,2,8,27,32]. Besides, the incidence and severity of food insecurity are assessed by the Foster-Greer-Thorbecke (FGT) as follows:

$$HFS_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{\theta - Y_i}{\theta}\right]^\alpha \quad i=1,2,...q \quad (2)$$

Where 'HFS' is household food security, *'n'* is the number of sample size, *'q'* is food insecure people (poor), 'θ' is a threshold level or food insecurity line that serves as a cut-off point between food secure and food insecure, *'Y_j'* is indicators of food security used, and 'α' is sensitivity parameter or policymaker degree of aversion to inequality among the poor. Three food insecurity indices are identified, first, headcount index (α=0) shows the incidence/extent of food insecurity to reflect the share of farmers below the threshold level. This is easy to understand and communicate although it fails to capture the intensity to which individual outcome falls below the food insecurity line. Second, food insecurity gap (α=1) indicates the depth/intensity of food insecurity to providing information regarding how far farmers are from the food insecurity line. This does not capture a difference in the severity of food insecurity among the poor. Also, it does not capture the transfer of resource among the poor, for example, if the resource is transferred from the poor to the least poor, the food insecurity gap remains unaffected. Squared food insecurity gap (=2) shows the severity of food insecurity by giving more weight to the poorest of the poor even if it is not easy to interpret. These three indices reflect availability, stability, accessibility and utilization of food [23,37,38].

Counterfactual analysis and conditional expectation in impact evaluation: In the absence of random assignment for treatment, different evaluation approaches (e.g. two-stage Heckman model, semi-parametric matching method, inverse probability weighted adjusted regression and endogenous switching regression) can be used to evaluate the aftermath of policy reforms. These can be corrected selection bias resulting from observable and unobservable factors and estimate the true impact of the treatment. In the propensity score matching (PSM), selection bias from observed factors can be eliminated by comparing the expected outcomes between treated and untreated groups following two steps (a) calculate the propensity score of treatment for each observation (b) estimate average treatment effect for the treated (ATTT) and untreated (ATTU) by matching each treated to untreated (counterfactual) with a similar propensity score. Once farmers are matched no systematic differences in unobservable factors between treated and untreated farmers is assumed. PSM does not require distributional and linear functional assumptions. However, it does not capture hidden bias. It is highly dependent on overlapping and unconfoundedness assumptions. Therefore, PSM may not yield efficient and unbiased estimates if there is misspecification in the propensity score model [7,12,39,40].

Endogenous switching regression (ESR) is applied to address PSM limitations. ESR explicitly captures unobserved bias by estimating the selection and outcome equations simultaneously using the full information maximum likelihood. ESR follows two stages: treatment is modelled using a multinomial/binary model (selection equation), and OLS selectivity correction model (continuous/categorical) is used to estimate the impact of treatment on outcomes [32,35,36]. The outcome that is derived from the treatment is given in two regimes (1 and 2) as follows:

$$\begin{aligned} REG\_1 &: E(W_{1i}/T_i=1) = \alpha_1 Y_{1i} + e_{1i} \\ REG\_2 &: E(W_{0i}/T_i=0) = \alpha_0 Y_{0i} + e_{0i} \end{aligned} \quad \text{and } T_i^* = \beta X_i + v_i \quad (3)$$

Where is an unobserved latent variable defining for treatment, is its observed factors, is the vector of covariates affecting treatment, and is the outcome indicators of treated and untreated farmers, is a vector of exogenous variables that affect the outcome and is the error term of the outcome equations. The error terms in the selection (v_i) and outcome equations (e_i) are assumed to have a trivariate normal distribution with mean zero and a covariance matrix of:

$$\begin{bmatrix} \sigma_{e_1}^2 & \sigma_{e_1e_0} & \sigma_{e_1v} \\ \sigma_{e_0e_1} & \sigma_{e_0}^2 & \sigma_{e_0v} \\ \sigma_{ve_1} & \sigma_{ve_0} & \sigma_v^2 \end{bmatrix}, \text{ where } \sigma_{e1e0}=\sigma_{e0e1};\ \sigma_{e1v}=\sigma_{ve1};\ \sigma_{ve0}=\sigma_{e0v} \quad (4)$$

Where $\sigma_{e_i}^2$ a and σ_v^2 are estimable scale factor and assumed to be unity while cov (e_1,e_0) is not defined because Wi and W0 cannot be observed simultaneously. The correlation between the error terms of the selection and outcome equations is assumed not zero cov (e_1,v) ≠ 0and cov (e_0,v) ≠ 0. This suggests the presence of selection bias. The expected values of the error terms of the outcome equations are non-zero and given as follows:

$$E(e_{1i}/T=1)=\sigma_{e_1v}\frac{\varphi(\beta X_i)}{\Phi(\beta X_i)}=\sigma_{e_1v}\lambda_{1i}\Leftrightarrow\lambda_{1i}=\frac{\varphi(\beta X_i)}{\Phi(\beta X_i)}$$
$$E(e_{0i}/T=0)=\sigma_{e_0v}\frac{\varphi(\beta X_i)}{1-\Phi(\beta X_i)}=\sigma_{e_0v}\lambda_{1i}\Leftrightarrow\lambda_{0i}=\frac{\varphi(\beta X_i)}{1-\Phi(\beta X_i)} \quad (5)$$

Where $\varphi(.)$ and $\Phi(.)$ show the standard normal density and standard normal cumulative functions. The switching approach addresses this selection bias by estimating the Inverse Mills Ratios (λ1i and λ0i) and the covariance terms (σe1v and σe0v) as stated in eq.5. These are included in the outcome equation as auxiliary terms (eq. 6). If σe1v and σe0v are statistically significant, treatment decision and the outcome are correlated. ESR is appropriate. The null hypothesis (absence of selection bias from observable factors) is rejected.

In the second stage of ESR, two basic questions are addressed, namely, how would the outcomes have affected had the treated farmers had not received treatment? What would have happened the outcomes of untreated farmers if they had received treatment? The conditional expectations for outcomes of the treated farmers with counterfactual hypothetical (untreated farmers) are computed and estimated as follows:

Actual adopters: E (W1i/T=1) =α1Y1i=αe1vλ1i=u1i (6a)

Actual non-adopters: E (W0i/T=1) =α0Y0i=αe0vλ0i=u0i (6b)

Counterfactual adopters: E (W0i/T=1) =α0Y1i=αe0vλ1i=u1i (6c)

Counterfactual non-adopters: E (W1i/T=1) =α1Y0i=αe1vλ0i=u1i (6d)

Eq.6a and eq.6b denote the actual expectation observed in the sample, and eq.6c and eq.6d are the counterfactual expected outcomes. The average treatment effect on the treated (ATTT) is the difference between eq.6a and eq.6c and given as:

ATTT=E (W1i/Ti=1) =Y1i (α1-α0) = λ1i (σe1v-σe0v) (7)

The effect of treatment on the untreated farmers (ATTU) is calculated as a difference between eq.6b and eq.6d and is given as follows.

ATTU=E (W1i/Ti=0)-E (W0i/Ti=0) =Y0i (α1-α0) =λ0i (σe1v-σe0v) (8)

As stated by Carter and Milon, the effect of base heterogeneity effect for the group farmers that decided to receive treatment is defined as a difference between eq.6a and eq.6d and given as follows: [41].

HE1=E (W1i/Ti=1) -E (W1i/Ti=0) = α1 (Y1i- Y0i) + σe1v (λ1i- λ0i) (9)

The effect of base heterogeneity on the group farmers who decided not to adopt is defined as the difference between eq.6b and eq.6c and given by:

HE0=E (W0i/Ti=1) -E (W0i/Ti=0) = α0 (Y1i- Y0i) + σe0v (λ1i- λ0i) (10)

The transitional heterogeneity effect is computed as a difference between eq.7 and eq.8 (ATT-ATU), indicating if the effect of receiving treatment is larger or smaller for farmers that treated or untreated in the counterfactual case that they did adopt (see Annexe A).

Research Methodology

Sampling framework and survey design

This study was conducted in Atsibwemberta district, northern Ethiopia, where its elevation ranges from 1003 to 3069 meters above sea level with a mean annual temperature of 18ºC and 400 mm for annual rainfall. Farmers often grow wheat, barley, maize, lentils, chickpeas, peas, and beans for home consumption and, very recently, for marketing due to an expansion of agro-industries in the country. Livestock, especially small ruminants and apiculture are also reared. The area is one of the drought-affected areas in the country. Since the area is predominantly characterized by hillsides, it is highly susceptible to soil erosion and land degradation. Various soil and water conservation measures and alternative water harvesting schemes have implemented for years to reduce degradation and enhance productivity [10].

In the district, there are 18 administration villages. These villages are categorized into two groups based on agroecology: these villages located in the temperate zone (16 villages) and the warm temperate zone (two villages). Felege Weyni, Habes, Hayelom, Michael Emba and Ruba Feleg from the temperate zone and Eira from the warm temperate zone were randomly selected. During the survey, these villages had about 9230 household heads and the required sample size (n=350 farmers) was determined following the Yamane sample size determination formula. After the sample size was proportionately allocated to each selected village, the respondents were selected from the sampling frame of each village using a systematic random sampling method.

A survey was carried out to assess the adoption of conservation agriculture and overall food security status. A draft questionnaire was prepared, which was evaluated by extension agents, and pretested by ten randomly selected farmers to ensure its validity and language. After improving the quality of the questions based on these prior assessments, a face-to-face interview was conducted by experienced and trained enumerators under constant supervision from the research team. The questionnaire covered a wide range of variables: demographic variables, rural facilities, farm characteristics, socio-economic variables, institutional factors, food security indicators, and improved farming practices. The data regarding food and non-food consumptions were collected for the preceding year covering 12 months using a carefully calibrated frequency of buying that varied across purchased food items and the amount spent during each period.

Different procedures are used to address the research objectives. Initially, K-means clustering analysis is used to classify farmers based on their access to extension services, and local institutions. Farmers in the same clusters are more similar in the objects to each other than in other clusters. Household food insecurity access scale (HFIAS), which is easy and less costly to implement than other food security approaches, for example, supply and demand approach, anthropometric method, household coping strategies and dietary diversity index, is used to assess farmers' food security situations in the areas. The equality of mean approach (chi-square test for categorical variables and sample t-test for continuous variables) is applied to compare food security status between conservation agriculture adopters and non-adopters. Besides, the incidence, depth, and severity of food insecurity are computed and estimated using the Foster-Greer-Thorbecke approach. Propensity score matching and endogenous switching regression are used to evaluate and estimate the true impact of treatment variables (social capital and extension services) on outcome variables (conservation agriculture and food security) [42].

Measuring target variables and validating their qualities

In this paper, membership in local institutions and access to agricultural extension services are target variables. These are latent (unobserved) constructed from observed variables in the dataset. Twenty observed variables are included in the questionnaire, which is responded by a five-point Likert scale ('none', 'rare', 'sometimes', 'usually' and 'very often' or 'none', 'slightly', 'somewhat', 'high' and 'very high') to measure these latent variables. A Bartlett principal component analysis with oblique target rotation is applied to construct these latent variables from these observed variables. Eleven observed variables are loaded into three latent variables, considering one and above Eigenvalue. Five variables that capture the level of informal learning, relationships, bonds, and communication from various community groups who are important for farmers, such as friends, neighbours, relatives, and informal groups are loaded into a factor named as 'relational capital'.

Three statements that showing the influence of formal organizations, such as farmers' associations, saving and credit associations, resource user groups and cooperatives are loaded into a factor known as 'group membership'. A factor of 'extension service' is derived from three variables that explain the level of frequency that farmers have contacted with agricultural extension agents and confidence in their knowledge and skills (see Annexe B).

These 11 observed variables that are loaded into these three latent variables explained 75% of the available variance in the original 20 variables. Relational capital accounts for 31% of the total variance while 19% for group

membership. The Kaiser-Meyer-Olkin is 71% with Bartlett's test of Sphericity ($P(\chi^2)=0.000$). Factor loading, Cronbach alpha, and variance extracted are used to check the reliability and convergent validity of these observed variables that correspond to each latent variable. The coefficients of average factor loadings and variance extracted exceeded the minimum value. The coefficients of Cronbach alpha (α) for these latent variables were above 0.7. The normality assumption was checked by Skewness and did not deviate from the univariate normality assumption. The Doornick-Hansen test for multivariate normality (Chi-square=1.536 and P P(2)=0.128) did not lead to a rejection of the null hypothesis of the normality assumption. Multicollinearity was also tested by 2-tailed Pearson moment correlation and contingency coefficients and found statistically uncorrelated. Therefore, statements that correspond to the derived latent variable have common parts. They are reliable and valid to explain these latent variables.

Socioeconomic characteristics of respondents

Food security approximated by per-capita food consumption, per capita expenditure and self-reported household food insecurity scale (HFIAS), and conservation agriculture adoption captured by the use of crop rotation with legumes and intercropping farming systems are outcome variables of this study. Annexe C presents the summary statistics of the outcome and explanatory variables. During the survey, nearly 64% of farmers had adopted conservation agriculture to enhance productivity and yields, and termed them as 'adopters or treated' and the remaining did not adopt and named as 'non-adopters or control'. Non-hierarchical (k-means) cluster analysis is used to classify farmers based on their similarities in accessing to extension services, and participation in informal and formal institutions [43]. For example, nearly 60% of farmers (n=210) had frequent contacts with extension agents ('high access') while the remaining had either rare or sometimes access to extension agent ('low access'). Around 64% of farmers (n=224) had noticed a substantial influence of formal organizations on their decisions and behaviours and therefore had active participation in these organizations ('active member') while the remaining had either passive or no participation and they did not understand their importance ('passive member'). About 69% of farmers (n=242) had high and strong interpersonal relationships, and communication with local community groups, such as families, fellow friends, relatives, neighbours, and endogenous groups ('strong bond'), while the remaining had weak interpersonal relationships and communication among informal groups ('weak bond'). of the total respondents, about 82% were living in villages that are found in the temperate zone. Around 58% were male-headed households. The average household size was about 5 persons with a mean age of 48 years. About 46% were literate with mean schooling of 2.2 years. The average landholding size was 0.56 hectare and 2.4TLU for livestock asset. About 12% owned a television or radio for information purpose. Around 45% were situated within a radius of 80 minutes walking distance from input-output market, and about 47% were located 6 km away from nearby farmers' training centres (farmer-school). About 63% had access to all-weather roads within a mean distance of 6 km. Nearly 67% had primarily engaged in agriculture for their livelihoods and about 47% had additional income from small business, selling of firewood and charcoal, and causal works (nonfarm income). Moreover, farmers were requested to express their attitudes towards risks (natural hazards, human risks, technology risks, market volatility, and financial shocks) using a five-point Likert scale ('very unlikely to take risks', 'unlikely to take risks', 'not sure about', 'prepared to take risks' and 'highly prepared to take risks'). Nearly 32% of farmers were unwilling and very unwilling to take any risk and renamed as risk-aversion and the remaining are either willing and very willing to take risks (risk-seeking) or undecided whether to take or evade risks (risk-neutral). About 56% had often suffered from drought, diseases, pests and other shocks that adversely affect their crops, livestock, and people and this is named as 'stress'. About 45% of farmers had received credit from banks and the remaining either did not need any credit or no access to credit services.

Equality of means (chi-square test for categorical variables and sample t-test for continuous variables) is used to understand a statistical difference across variables. The mean differences for per capita expenditure, per capita food consumption, food security levels and conservation adoption are statistically higher for farmers who have frequent access to extension services, who have strong social ties and networks with local communities, and who are active participants in formal organizations than other farmers. Active members are found relatively to be better educated, have good access to all-weather rural roads, have more livestock assets and have better access to financial credits. Farmers who have frequent contact with extension agents (high access) are more of male-headed households, can read and write, and are located near to input-output market and all-weather rural roads than the counterpart farmers. Male-headed households, farmers who have more livestock assets and large landholdings, and farmers who are located close to the input-output market have strong relationships and networks with local community groups. These can either enhance farmers' awareness or create opportunities to engage in non-agricultural activities. But these results cannot be used to conclude and make valid inference unless confounding or unobserved and observed factors are controlled well.

Results and Discussion

Household Food Insecurity Access Scale (HFIAS) differences between conservation agriculture adopters and non-adopters

Farmers' food security situations are assessed using HFIAS, which is based on their experience on food availability and accessibility and is constructed from nine generic, sequential, standardized and heterogeneous questions detecting access to food variety, quantity, and quality. These questions follow two procedures: a dichotomous question as to whether food insecurity has occurred over the last four weeks (yes or no); and how frequently this has occurred ('rarely', 'sometimes' and 'often'). HFIAS result has shown food insecurity access, domain and prevalence conditions (see Annexe D). In the question whether 'there was no food to eat of any kind due to lack of resources', there was a day with no food to eat, for example, around 3% of adopters and 4% of non-adopters ran out of food often. Nearly 3% for adopters and 6% for non-adopters had sometimes experienced food shortages over the last 30 days. About 12% rarely ran out of food and hardly suffered from lack of foodstuffs. However, about 83% for adopters and 77% for non-adopters had never experienced food shortages over the last four consecutive weeks.

These nine questions have reorganized into three domains to reflect whether farmers have sufficient, quality and variety food: food anxiety (Q1) showing uncertainty about food supply over the last four weeks; insufficient food quality (Q2-Q4) revealing preference, quality and varieties of food; and inadequate food quantity (Q5-Q9) to elucidate food intake practices and physical consequences. In the anxiety food domain, 32% of adopters and 38% of non-adopters had concerns about fulfilling their food needs (rarely, sometimes and often). Nearly 26% of adopters and 31% of non-adopters had no access to quality and diversified foods. About 25% of adopters and 28% of non-adopters had no access to sufficient food supply. A similar finding was reported in Kenya by Kabunga. More than 70% of farmers had access to quality, sufficient and preferred food, and had no problem of food insecurity over the preceding month [38,44].

HFIAS score is calculated for each respondent by assigning a number from zero (never occurred) to three (often occurred) and summing these numeric codes, which theoretically ranges from zero (never faced food shortages) to 27 (often faced food shortages). This helps to estimate categorical food insecurity dimensions (prevalence) for making geographic and social-group targeting decisions [37,44]. USDA has classified the food insecurity dimensions into four food security levels, namely, highly food secure (HFIAS=0), slightly food secure ($1 \leq HFIAS \leq 3$), occasionally food insecure ($4 \leq HFIAS \leq 10$) and chronically food insecure ($HFIAS \geq 11$). About 27% of adopters and 26% of non-adopters had experienced none of the food insecurity conditions over the last 30 days (highly food secure). Farmers are moderately food insecure if they have sacrificed quality more frequently: sometimes or often eating a monotonous diet or undesirable foods, and rarely or sometimes reducing the size or number of meals. However, they have never experienced any of the three most severe conditions: running out of food, going to bed hungry and going for a whole day and night without eating. Nearly 40% had slightly food

secure, either sometimes worried about having enough food or rarely unable to eat preferred food and eat a more monotonous diet than desired. Nearly 6% of adopters and 12% of non-adopters were severely food insecure, where they had either often reduced the size or number of meals or rarely experienced any of the three most severe food insecurity conditions.

In the literature, HFIAS is criticized for its non-inclusive measurement of food insecurity. It does not address the utilization and stability dimensions of food security. The experience of farmers over 30 days cannot be used to assess long-term stability and seasonality aspects. Kabunga argued that HFIAS does not show how foods are prepared and consumed; address whether the food fits farmers' traditions and culture; and show the intra-household distribution and feeding practices with foods, and whether the farmers have sanitary facilities. However, these limitations do not reduce its merit. While evaluating its feasibility and usefulness, it generates results closely correlated with other food security measuring methods, for example, supply and demand approach, anthropometric method, dietary diversity index and Foster-Greer-Thorbecke. Since it is validated through multi-years studies in Bangladesh and Burkina Faso, the results are accurate and harmonized with other results. HFIAS has been widely adopted to assess the impacts of development projects seeking to improve food security. If the assessment is undertaken during an off-harvesting season when farmers are often faced with food shortages, the results can show the temporal dimension of food supply, access, and stability dimensions. Hence, the results are valuable since the survey was carried out during the off-harvesting time with careful questioning by experienced enumerators [37,38,44].

Incidence, depth and severity of food security between conservation agriculture adopters and non-adopters

This section explores the incidence, depth and severity of food insecurity between conservation agriculture adopters and non-adopters. Given the above-four food insecurity dimensions, highly and fairly food security are jointly renamed as 'food secure', while occasionally and chronically food insecurity are jointly transformed into 'food insecure'. Nearly 71% of conservation agriculture adopters were food secure and 64% for non-adopters. The chi-square test (P-value=0.0296) reports that there was a significant difference in food security levels between adopters and non-adopters. In the Foster-Greer-Thorbecke approach, two-third mean is used to determine the food insecurity line or threshold level, which is a cut-off point to distinguish food secure from food insecure group, and this was birr 1153 for per capita food consumption and birr 2107 for per capita expenditure. While used per capita food conservation, about 33% of adopters were food insecure and 40% for non-adopters. Using per capita expenditure, 35% of conservation adopters were food insecure and 43% for non-adopters. Thus, the proportion of food secure was nearly 1.3 times higher for adopters than for non-adopters.

The depth (intensity) of food insecurity indicates how far the food insecure farmers are below the threshold level. Using per capita expenditure, the intensity of food insecurity ranged from 13% for non-adopters to 8% for adopters, using per capita food consumption, it ranged from 11% for non-adopters to 8% for adopters. The intensity also indicates how many funds are required to mobilize to eliminate the existing food insecurity. This targets the poor to bring them to the threshold level, which is known as the minimum cost of eliminating food insecurity. For example, the food insecurity gap using per capita expenditure threshold level is 10% and 39% of farmers (n=137) are food insecure and birr 29000 has to mobilize and distribute to every food insecure farmer to eliminate the existing food insecurity in the areas. Besides, the severity of food insecurity also ran from 3% to 5% for both conservation agriculture adopters and non-adopters. The intensity and incidence of food insecurity varied between adopters and non-adopters but the severity of food insecurity did not differ. Since this redistribution approach is solely a one-time event, and may not permanently resolve the problem, it would be better to look for other pro-poor strategies to eliminate household food insecurity (Table 1).

What factors determine access to extension services and local institutions?

This section assesses and evaluates the factors that influence farmers' access to extension services and actively participate in local institutions. Both PSM and ESR models have generated very similar results especially concerning a significant level and sign although the magnitude is slightly variable. As shown in Annexe E, the coefficients of most variables, example, access to credit, education, non-farm income, market, farmer-school and risk attitudes, have the expected signs and are found to significantly affect these treatments. Extension agents have provided farmers with information and motivated them to adopt conservation agriculture. Education, occupation, livestock ownership, credit access, the incidence of pests/diseases, and proximity to farmer school have significant positive roles in influencing the likelihood of farmers to frequently contact with extension agents. Large household size has encouraged farmers to have strong relations with local community groups even if it is unlikely to motivate them to join formal organizations.

Also, gender has a significant impact on access to agricultural extension services and to have strong interpersonal relationships. Male-headed households are more likely to frequently access to extension agents than female-headed households. Females are often engaged in house duties while males are involved in outside activities. Females have the potential to create strong bonds and networks with neighbours, families, friends, and relatives than males. This may be linked to socio-cultural norms and traditional practices in Ethiopia. Moreover, education is among the driving forces for farmers' decisions to adopt conservation agriculture. Literate farmers are less likely to frequently access to extension agents. Since extension agents have often distributed chemical fertilizers, educated farmers might be preferred other strategies, like manure, compost, and physical conservation structures. Literate farmers are unlikely to want to spend time and resources in establishing strong ties and relations with local community groups. Rather they are more preferred to join formal organizations because they are easily aware of their potentials. Besides, risk-averse farmers (risk aversion) and farmers who often suffer from

Table 1. Incidence, depth and severity of food insecurity across adoption levels (percent).

Food security indicators	Adopters (n=225)	Non-adopters (n=125)	Total (n=350)
Household food insecurity access scale (HFIAS)			
Food secure	0.71	0.64	0.68
Food insecure	0.29	0.36	0.32
Per capita food consumption			
Food secure	0.67	0.6	0.64
Incidence	0.33	0.4	0.36
Depth	0.08	0.11	0.1
Severity	0.03	0.05	0.04
Per capita total expenditure			
Food secure	0.65	0.57	0.61
Incidence	0.35	0.43	0.39
Depth	0.08	0.13	0.1
Severity	0.04	0.03	0.03

pests/diseases (stress) are more likely to access to extension services and to be active members of formal organizations to share risks, obtain support and exchange information.

Livestock and non-farm income are other variables in the three treatment equations. The decision to access to extension services is positively affected by livestock ownership and negatively influenced by non-farm income. Both have a linkage with the risk of food insecurity. Livestock are sources of food and income. Farmers can earn additional income from non-farm activities. Livestock have also significant positive impacts on relational capital. If farmers have more livestock, they are more likely to access extension services to get sanitary services, drugs, and veterinary services. They are also more likely to have high bonds and relations with neighbours and friends because they share communal pasture areas and have common interest regarding livestock production. Farmers who have income from non-farm activities have strong relations and networks with neighbours, friends and other groups because they can exchange information about these activities. However, these farmers are less likely to access to extension agents because of time constraint. A distance to farmers' training centre (FTC) has significant positive impacts. The propensity to frequently access to extension services, and to participate in formal organizations is by far higher for farmers who are located near to FTC within one-hour walking distance than counterparts since they have better access to information.

However, agroecology, access to formal media (e.g. ownership of TV/radio), the gradient of the farmlands, and access to all-weather rural roads seemed to play insignificant roles in farmers' decisions to access to extension services and local institutions. Access to agricultural extension services and participation in local institutions were found not to vary across the warm temperate and temperate zones (spatial effects). Also, ownership of television or radio did not influence the probability of farmers to access to extension services and inspire farmers to join local institutions (media effect) due to affordability and availability issues. Furthermore, about 75% of farm plots were with a gentile or steep slopes showing farmers might not easily understand the effects of flat slopes on receiving these treatments (plot effect).

Extension service and local institution effects on conservation agriculture and household food security

This section explores the impacts of treatment (social capital and extension services) on outcomes (conservation agriculture and food security) using PSM and ESR approaches. Both approaches confirm that the treatments had significant and positive effects on the adoption of conservation agriculture and household food security. Although it cannot be known prior, self-selection bias has occurred from both observed and unobserved factors. Hence, the hypothesis of the absence of sample selectivity bias was not rejected. The outcome variables were affected by multiple and interrelated factors. The coefficients of most variables that are hypothesized to influence conservation agriculture adoption and household food security had the expected signs. Demographic characteristics (household size, gender, and education), physical resources (livestock and farm size), and rural services were found to significantly determining farmers' decisions to adopt conservation agriculture and improve their food security level. While observed factors determining the outcomes, a clear difference has been seen in the coefficients of outcomes between the treated and untreated farmers. This shows the presence of heterogeneity in the samples (Appendix B). The outcome functions are different between the treated and untreated farmers. For example, household size and education had positive and significant impacts on per capita expenditure, and adoption of conservation agriculture for farmers who have access to extension agents and are active members of formal organizations. However, similar evidence was not found for the counterpart farmers (not presented here).

Table 2 presents the treatment effects of extension services, group membership and relational capital on per capita expenditure, per capita food consumption, conservation adoption, and household food security level. Access to extension services was found to increase the adoption of conservation agriculture by 9% using PSM, and 34% using ESR. Having strong interpersonal relations and networks with neighbours, friends, families, and relatives increased adoption of conservation agriculture by about 5% using PSM and 8% using ESR specifications. The corresponding figures for group membership were about 11% using PSM and 42% using ESR. When farmers who were passive members of formal institutions had active members, their rates of adoption for conservation agriculture had increased by about 42%. The variation in ATT between PSM and ESR has indicated the presence of selection bias from unobserved factors. Therefore, extension services and local institutions could motivate farmers to adopt crop rotation with legumes and intercropping farming systems to improve agricultural productivity.

Agricultural extension services and social capital have positive and significant impacts on food security, which is approximated by per capita expenditure and per capita food consumption. The direction of the treatment effects on outcomes is mostly consistent across both specification models, although the magnitudes differ largely. For example, the impact of group membership on per capita expenditure of the treated farmers ranged from Birr 190 using PSM to 886 using ESR. The figure for extension services was birr 386 using PSM and birr 1760 using ESR. However, farmers who had strong social relations and networks (relational capital) had not significantly higher per capita food consumption than that of the counterfactual farmers. If the treated farmers did not have access to agricultural extension services, their average per capita food consumption and per capita total expenditure decreased by birr 668 and 1760, respectively. These figures seem small in magnitudes but practically imperative for poor and smallholder farmers, because they are statistically significant.

Concerning household food security level, social capital and extension services had significant and positive effects on household food security level (food secure vs. food insecure). The average treatment effect of extension services ranged from 8 percentage points by PSM to 23 percentage points using ESR. The results of both approaches confirm that the percentage of food secure was higher for these farmers who had frequent contacts with extension agents than for counterfactual farmers. Similarly, the effect of relational capital on household food security level was about 0.07 points in both PSM and ESR estimates. Farmers who had strong networks and relations with local community groups (informal institutions) were 7% more likely to be food secure than for counterfactual farmers. The probability of farmers to be food secure would have been declined by 17% if active members of formal institutions had become passive (non-) members. Besides, higher per capita food consumption and total expenditure can lead to higher food security. Thus,

Table 2. The coefficients of the average treatment effect of the treated (ATT): PSM and ESR.

Outcome variables	Propensity score matching			Endogenous switching regression		
	Extension services	Relational capital	Group membership	Extension services	Relational capital	Group membership
Conservation technology	0.09(0.026)***	0.05(0.031)*	0.11(0.042)**	0.34(0.14)**	0.08(0.03)**	0.42(0.02)***
Per capita expenditure	386(85)***	537(139)***	190(73)**	1760(732)**	1710(275)***	886(97)***
Per capita food consumption	173(56)***	332(194)*	81(23)***	668(76)***	287(224)	195(63)***
Household food security level	0.08(0.026)***	0.07(0.048)	0.05(0.024)**	0.23(0.09)**	0.07(0.03)**	0.17(0.06)**

Notes: Bootstrapped standard errors in ESR and robust standard errors in PSM are reported in parentheses. ***, ** and * represent statistically significant at 1%, 5% and 10% levels.

extension services and social capital may have both direct and indirect effects on household food security.

Overall, extension services and social capital have significant positive impacts on the adoption of conservation agriculture and household food security. When untreated farmers had received treatments, farmers' adoption rates of conservation agriculture would have been higher, thereby their per capita expenditure, per capita expenditure and the probability of being food secure would have been increased. The proportion of food secure farmers is relatively higher for conservation agriculture adopters than for counterparts. Since food insecurity is still a development agenda in Ethiopia, farmers can move out of the vicious cycle of food insecurity if policymakers, development practitioners and other concerned actors have crafted pro-poor specific strategies especially that inspire them to adopt sustainable agriculture. Therefore, investing in agricultural extension services, and empowering local institutions are paramount and promising for promoting the adoption of conservation agriculture and enhancing household food security levels (Table 2). Sensitivity analysis for quality of matching and exclusion restriction Robustness and reliabilities of matching algorithm In the matching method, it is pivotal to check whether the estimated ATT is robust and the unconfoundedness (conditional independence) and common support condition (overlapping) are satisfied [45]. Table 3 suggests that different algorithms are robust. For example, the propensity score for extension service lies within an interval of [0.2747-0.9174] for treated farmers while [0.2471-0.9086] for untreated farmers, and 12 observations lay outside the common support of [0.2747-0.9086]. The propensity score for relational capital lies with an interval of [0.4250-0.8932] for treated farmers and [0.4046-0.8829) for untreated farmers, and only seven observations lay outside the common support of [0.4250-0.8829]. For group membership, the treated farmers lie within an interval of [0.4609-0.8716] and untreated farmers [0.4530-0.8336] and about 20 observations lie outside the common support interval. Thus, the estimation of the propensity score (first stage estimation) guaranteed a sufficient overlap in the distribution of the propensity score between treated and untreated groups.

The covariate-balancing test verifies whether the covariates (variables) used in PSM is balanced and the presence of differences is eliminated. The standardized mean difference for the covariates reduced from 12% pre-matching to 3.4% post matching for extension services, while from 10.3% before matching to 2.4% after matching for relational capital. For group membership, the most significant differences in the covariates in the unmatched samples are eliminated after the matching procedure, and the standardized mean bias reduced from 9% pre-matching to 1.8% post-matching. The joint significance of all covariates for these variables is not rejected before matching for all target variables ($P>\chi 2$: 0.011-0.035) even if no systematic differences between treated and untreated farmers after the matching process ($P>\chi 2$: 0.248-0.884). Thus, a significant reduction in the mean standardized bias for all algorithms after matching confirms that results are sensible and the distribution of covariates between treated and untreated groups is balanced (Table 3). Sensitivity and qualities of ATT to hidden bias with the presence of unobservable characteristics, the impact of treatments on outcomes might not be correctly and explicitly shown. The Rosenbaum bound sensitivity test (rbounds) that is the odds ratio of differential treatment assignment due to unobserved variables is performed to check if the impact of the treatment is distorted by hidden factors. The critical levels of gamma have shown the impact difference between treated and control groups and hypothesized no difference in treatment impact due to unobserved selection biases, i.e., how the magnitude of the treatment effect changes with an increase of hidden biases. In a study free of hidden bias, Γ or gamma equals unity. Table 4 presents the critical value of the sensitivity analysis. For example, farmers that have similar covariates must differ in their odds of group membership by a factor of 7%-55% to offset the positive and significant effect of formal institutions on the adoption of conservation agriculture. Therefore, since the critical levels appear sufficiently high, the ATT estimates for household food security and conservation agriculture seem robust to unobservable covariates [36,40,45] (Table 4).

Heterogeneous impact of extension services and local institutions in PSM While computing estimated ATT, extension services and local institutions are assumed to have homogenous effects on food security and conservation agriculture. However, farmers even in the same treatment may differ in their response to the same intervention due to unobserved heterogeneities, like risk-taking capacity, motivations and internal competence [46,47]. Consequently, the Stratification Multilevel method (SM), Matching-Smoothing method (MS) and Smoothing-Differencing method (SD) and other algorithms can be used to evaluate heterogeneous effects of policy reform and avoid self-selection bias. In SM estimation method, for example, the propensity scores are initially calculated based on the given covariates and then splits the whole range of propensity scores obtained into different strata and assumes homogeneity within these strata. The effect of the treatment is interpreted through the comparison of outcome variables between the treatment and control groups across each of the strata. After the estimations in each of the strata are calculated, a linearity trend is estimated to show whether the treatment has established a positive or negative functional effect over the propensity scores [47]. As shown in Appendix C, adoption of conservation agriculture, per capita expenditure and per capita food consumption decreased while the rate of household food security increased significantly especially between strata 2 and 5 with increasing propensity score of access to agricultural extension services. Similarly, rates of conservation agriculture adoption and household food security level increased but per capita expenditure and per capita food consumption decreased significantly between strata 2 and 5 with increased propensity score of farmers who are active memberships of local

Table 3. Quality and balancing (robustness) test of matching algorithms (radius calliper=0.01).

Matching criteria	Extension services	Relational capital	Group membership
Number of treated	209	242	223
Number of control	141	108	127
Pseudo R^2 before matching	0.077	0.084	0.103
Pseudo R^2 after matching	0.008	0.037	0.028
Likelihood ratio chi-square test (X^2) before matching	35.8 ($P>X^2$=0.011)	125.2 ($P>X^2$=0.015)	31.6 ($P>X^2$=0.035)
Likelihood ratio chi-square test (X^2) after matching	3.1 ($P>X^2$=0.562)	22.8 ($P>X^2$=0.248)	12.0 ($P>X^2$=0.884)
Mean standardized bias before matching	11.9	10.3	19
Mean standardized bias after matching	3.4	2.4	1.8

Table 4. The sensitivity of average treatment effect of treated to unobserved bias (Γ= 0.05).

Outcome variable	High vs. low access to extension services		Active vs. passive member in institutions		Strong vs. weak relational capital	
	ATT	Gamma value	ATT	Gamma value	ATT	Gamma value
Conservation agriculture	0.09	0.99-2.64	0.05	1.07-1.55	0.11	1.18-2.74
Per capita expenditure	386	1.06-1.52	537	1.06-1.53	190	1.07-1.33
Per capita food consumption	173	1.02-1.05	332	1.16-1.53	81	1.07-1.22
Household food security level	0.08	1.01-1.24	0.07	0.97 - 1.75	0.05	1.02-2.17

institutions. Hence, extension services and local institutions have statistically heterogeneous treatment effect on conservation agriculture and household food security.

Imposing exclusion of restriction in endogenous switching regression In ESR, the treatment effect model to be identified and get more robust parameters, it is recommended to use at least one explanatory variable that is not included in the outcomes. Accordingly, soil fertility, television or radio ownership and agroecology are used as excludable variables. While considering the adoption of conservation agriculture as an outcome variable, access to radio/television is included in the treatment but omitted from the outcome because media ownership was found not to affect the adoption of conservation technology. In per capita food consumption, per capita expenditure and food security levels, these three variables are included in the treatment but not in the outcome because these variables did not have direct links with food security. A simple falsification or rejection test is used to check the validity of these variables. If these variables are suitable, they will affect the treatment decisions but not the outcomes. The results are reported as follow: media ownership on conservation adoption (LR $\chi 2(1)=0.66$ and $P(1)=0.42$) and all these variables jointly on self-reported food security level (LR $\chi 2(3)=3.76$ and $P(\chi 2)=0.29$), per capita food consumption ($F(3,346)=0.86$ and $P(F)=0.46$), and per capita expenditure ($F(3,346)=0.97$ and $P(F)=0.41$). Therefore, these variables are considered as suitable jointly. They are significantly different from zero in the treatments although they are insignificant in the outcome equations [18,28,32,35,41].

Conclusion

This paper examines the potential impacts of extension services and local institutions on adopting conservation agriculture and improving household food security using PSM and ESR. The major factors that influence farmers' access to agricultural extension services and local institutions include demographic characteristics, farm conditions and rural services. The treated farmers have systematically different characteristics compared to untreated farmers, for example, in education, which is a source of variation between treated and untreated groups. According to PSM, conservation agriculture and household food security are significantly higher for treated farmers than untreated farmers. Even after controlling for all confounding factors using ESR, farmers who have frequent access to extension services and those who have active participation in the local institutions have a higher adoption rate of conservation agriculture, and higher probability to be food secure than counterfactual farmers. If treated farmers had not received treatments, they would have been lower probability to be food secure and lower rate of adopting conservation agriculture. This confirms the potential roles of receiving treatments in motivating farmers to adopt conservation agriculture and improving food security. Consequently, conservation adopters are in a better position in terms of conservation agriculture and food security than for non-adopters.

It is known that agriculture is a prime sector in Ethiopia. About 80% of its population (0.11 billion) are living in rural areas. Nearly 90% of these rural people are poor and smallholders and thereof do have less access to agricultural extension services. Many farmers are also passive participants in local institutions. Beside several institutions like local markets are often imperfect and many institutions, such as input markets and information centres are either absent or missing. Hence, the results of this study have important implications because extension services and local institutions have positive spill over effects in enhancing awareness, relaxing financial constraints, supplying inputs, and motivating farmers to adopt conservation agriculture. Therefore, government, NGOs, researchers and development practitioners should formulate specific strategies, for example, agricultural extension services should be leveraged and promoted. Extension agents should be capacitated technically. Social and physical infrastructure should be expanded especially in rural areas. Capacity building and information centres should be established in rural areas. Local institutions should be empowered and supported technically, financially and materially to exploit their potentials and opportunities to promote the adoption of conservation agriculture and improve household food security in the drought-prone and water-deficient areas.

Even if these results are still useful and valid for the selected villages and also other areas with similar farming practices and socio-cultural conditions, the study is subject to some limitations. For example, since the data recording system is weak, perception data for total expenditure, food consumption and self-reported food security level might suffer from recall errors and therefore the results might mislead when compared to the actual recorded data. Besides, the results are unlikely to automatically extrapolate to the entire country because the results are needed reassessment and readjustment. Moreover, the impacts of the treatments (extension services and local institutions) would have been nearly true or perfect if a longitudinal data was used than cross-sectional data. Therefore, further investigation is suggested using a large sample size and panel data from a wider geographical coverage. This would help policymakers, NGOs, researchers, academicians and development practitioners to get real and useful information on how agricultural extension services and local institutions promote sustainable agriculture and improve household food security.

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