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Synergistic Impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies. Lessons from Malawi and Zimbabwe

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Synergistic Impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies in southern Africa

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Abstract

Institutional credit and extension services are critical inputs that can reduce scaling challenges in agricultural development interventions if accessed by farmers. Using household level survey data from Zimbabwe and Malawi, this article seeks to contribute to the existing literature by examining impacts of separate and joint access to credit and extension services on climate-smart agricultural (CSA) technologies adoption. Using inverse-probability weighting regression adjustment and propensity score matching this study found out that access to either extension or credit significantly progresses CSA technology adoption. However, access to extension services only proved to be more effective in enhancing CSA technology adoption than access to credit alone. More importantly, results show enhanced collective impact of simultaneous access to credit and extension on CSA technology adoption. Further, joint impacts of credit and extension on adoption were found to be less pronounced in youthful and women farmer groups compared to their old and male farmer group counterparts respectively. Results call for prudent policy and institutional strategies in improving access to credit and extension services in Malawian and Zimbabwean smallholder farming that are mindful of disadvantaged groups such as youth and women farmer groups in order to improve adoption and upscaling of CSA technologies. Possible options include; improving number of extension workers at village level, increasing youth and women extension agent numbers, capacity building of extension personnel and institutions, and increasing financial support to national extension programs.

Key words: climate smart agriculture technologies; institutional services; impact; gender and youth; southern Africa

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1. Introduction

Climate-Smart Agriculture (CSA) is an agricultural development paradigm widely promoted in developing regions including Southern Africa to transform agriculture under a changing climate (FAO, 2013; Hansen et al., 2018; Nkonya et al., 2018). A CSA approach, aims to transform agricultural systems and support food security under a changing environment by providing context-specific, socially acceptable and flexible solutions for adaptation and mitigation to the changing environment (Lipper et al., 2014). The approach works on three basic principles including (a) increasing agricultural productivity in a sustainable way, supporting equitable improvements in farm productivity, income, food security and overall development, (b) strengthening the resilience of agricultural and food systems to climate change and variability effects, and (c) plummeting net greenhouse emissions from agricultural activities where possible (Lipper et al., 2014; McCarthy and Brubaker, 2014).

Numerous agricultural technologies and practices such as improved water management technologies, stress-tolerant livestock and crop species (e.g. drought tolerant maize), conservation farming, agroforestry, crop and livelihood diversification, index insurance, improved soil health and fertility management practices and others are components of the CSA approach. In Zimbabwe and Malawi for instance, stress adapted crop varieties, improved soil fertility and health management, conservation farming, diversified cropping systems, intercropping, and small scale irrigation are amongst top priority CSA practices promoted to improve climate resilience of smallholder agriculture. The aforementioned CSA practices have the potential to improve simultaneously farmer socioeconomic outcomes and environmental benefits.

Encouraging enough, evolving evidence from studies carried out in developing countries where various CSA practices have been promoted is showing positive impacts of CSA practices on biodiversity, and livelihood outcomes including poverty reduction (Hansen et al., 2018). For instance, in Zimbabwe and Malawi literature have shown positive impacts of climate stress adapted maize varieties (e.g. Drought tolerant maize) on crop productivity, household incomes and food self-sufficiency (Katengeza et al., 2019; Lunduka et al., 2017; Makate et al., 2017b). Furthermore, cereal and legume intercropping and crop or livelihood diversification have been reported to yield positive dividends on farm productivity, livelihood outcomes and environmental benefits in both countries (Kassie et al., 2015; Makate et al., 2016; Smith et al., 2016). Conservation agriculture which is also highly promoted in the two southern African countries is reported to yield positive economic, social and environmental dividends at farm household level (Senyolo et al., 2018; Tambo and Mockshell, 2018; Thierfelder et al., 2016).

Developing evidence of significant social, economic and environmental benefits from adoption of CSA in developing regions particularly southern Africa is a welcome development for agricultural transformation under augmented climate related stress confronting agricultural systems. However, adoption of the various CSA technologies including improved legume varieties, drought tolerant maize varieties, cereal-legume intercropping, conservation agriculture among others in developing regions and particularly in Zimbabwe and Malawi are still reported to be low (FAO, 2018; Makate et al., 2017a; Westermann et al., 2015). An exception is that of drought tolerant maize in Zimbabwe and Malawi which has relatively higher adoption rates compared to other countries in the southern Africa region. Government support programs such as command agriculture in Zimbabwe and intensive subsidy

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programs in Malawi are often attributed to higher adoption rates of drought tolerant maize. Low adoption rates can be attributed to failure to embrace CSA practices of demonstrated effectiveness into agricultural systems, donor funding dependency syndrome on CSA scaling activities, weak formal and informal information systems (e.g. weak extension service systems), lack of effective agricultural supportive policy and institutional strategies (e.g. credit, property rights and market institutions) among other challenges (Ajayi et al., 2018). Of interest to this study are weak institutional support services particularly credit and extension which are important determinants of innovative technologies adoption in smallholder agriculture in Africa (Hassan and Nhemachena, 2008).

Access to agricultural extension and credit services is critically important for improving the propensity for farmers to adopt CSA technologies. On one hand, agricultural extension services are important for availing information on new technologies and hence reducing information asymmetries associated with new technologies (Anderson and Feder, 2007). On the other hand, credit access is an important gateway for easing smallholder farmer liquidity constraints in financing farming operations. Credit access for the farmer increase her/his economic opportunities (World Bank, 2001) and it is the most important pathway a farmer can access much needed complementary inputs for CSA such as fertilizers, germplasm (seed) among other inputs (Swaminathan et al., 2010). It therefore implies that access to credit and extension can lower scaling challenges and improve adoption of CSA technologies of demonstrated effectiveness in smallholder farming in Zimbabwe and Malawi. Much of the literature on CSA practices adoption have shown access to credit and extension as important determinants of CSA adoption (e.g. (Mango et al., 2018; Partey et al., 2018; Totin et al., 2018; Ugochukwu and Phillips, 2018)) however, little focus in literature has been put on evaluating the impact of access to extension and credit particularly, simultaneous access to both institutional services on adoption of CSA technologies.

Given this brief background, this study seeks to evaluate the impact of (i) access to credit only, (ii) access to extension services only and (iii) the possible synergistic impact of simultaneous access to credit and extension on adoption of climate smart agriculture technologies.

The rest of the paper is organized as follows: section two (2) outlines the research methodology, while section three (3) present study results and discussions. Section four (4) concludes the article and give study recommendations.

2. Research methodology

2.1.Data and study area

Data for this study comes from 1173 smallholder farming households gathered from Zimbabwe and Malawi. Six hundred and one (601) farming household make up the Zimbabwean sample whilst 572 smallholder farming households make up the Malawian sub-sample (See Figure 1). The data was collected in Zimbabwe and Malawi in 2011/12 period as part of the European Commission (EC) through the International Fund for Agricultural Development (IFAD) funded project titled: Increasing smallholder farm productivity, income and health through widespread adoption of integrated soil fertility management (ISFM) in the great lake regions and southern Africa (EC-IFAD project). The simple random sampling technique was used to select districts in selected provinces in both Zimbabwe and Malawi. The lowest sampling unit was the household. Final data collection was done at the individual farm household level.

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[insert Figure 1 here]

Resident agricultural extension officers in randomly sampled districts provided a list of villages and households found in respective districts. Simple random sampling techniques were then used to select villages and farming households that were interviewed. Data collection was in the form of face-to-face administration of structured questionnaires. The surveys collected vital information on several aspects of crop production, crop management, adoption of improved agricultural technologies including climate change adaptation technologies, returns from farming, farmer livelihoods, access to institutional services, and various other aspects. Adoption of drought tolerant maize varieties, conservation agriculture and improved legume varieties was part of the information elaborately gathered by the survey.

2.2.Variable selection

2.2.1. Explanatory variables

Following literature that have explicated correlates of access to extension services (Aker, 2011; Wossen et al., 2017) and credit services (Petrick, 2004; Shoji and Aoyagi, 2012), a number of variables were used as covariates to explain access to extension and credit services in the multinomial logit regression used as the first stage in evaluating impact of multiple treatment. Precisely, land size holding, ownership of a bicycle, income, distance to the nearest town, age and education of household head were used as explanatory variables. Further details on definitions of the variables are shown in Table 1.

2.2.2. Treatment variables

In this study access to credit only, access to extension only, access to both extension and credit simultaneously and no access to both are the four treatment variables used. Farmers who had no access to both extension and credit services are used as the control group. Access to credit was measured as a dummy variable with a value of 1 indicating whether the farmer had accessed credit through formal (e.g. government microfinance institutions) or informal institutions (e.g. community groups, family and or friends) and 0 otherwise. As for extension, the study considered both government and private extension services access. Access to agricultural extension was therefore measured as a dummy variable equal to 1 indicating farmers who had received extension advice from any of the considered sources and zero otherwise. Access to both extension and credit was measured as a dummy variable indicating those farmers who accessed both extension and credit services in the two preceding seasons considered for this study. Table 1 give a full description of the three treatment variables used in this study.

2.2.3. Outcome variables

Adoption of climate smart agriculture (CSA) technologies is the main outcome variable used in this study. Precisely, adoption of conservation agriculture (CA), drought tolerant maize (DTM), improved legume (IL) varieties (e.g. groundnut, and common bean), intercropping (INTER) (maize-legume intercropping), and CSA adoption index are used as outcome variables in this study. Adoption of CA, DTM, IL and INTER were measured as dummy variables with a value of 1 indication adoption and 0 otherwise. CSA Adoption index was measured as the number of CSA practices the farmer adopted in two preceding seasons. A full description of the outcome variables is also given in Table 1.

2.3.Empirical approach

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This study employed regression adjustement with inverse probability weighting (IPWRA) and Propensity score matching (PSM) to control for selectivity bias likely in estimating impact of institutional extension and credit services access on CSA technology adoption. Access to institutional services (extension or credit) is not randomly assigned, and many farmers may receive or may not receive institutional services depending on unobservable or observed characteristics. Consequently, those who receive treatment (extension or credit) or combination of the treatments (e.g. extension + credit) may differ systematically with those who did not receive which can bring self-selection bias when estimating the impact of access to the institutional services. Accurate appraisal of impacts therefore, requires controlling for both unobservable and observable characteristics through random assignment of individual farmers into treatments to overcome selection bias. Unlike many studies that rely on binary treatments, this analysis involves four possible scenarios ((i) no access to either extension or credit (ii) credit access only, (iii) extension access only, (iv) access to both extension and credit) treated as treatments. As a result, this study applied the IPWRA method and PSM (as a robustness check) which are two matching estimators capable of controlling for selectivity bias with multiple treatments (StataCorp, 2015; Tambo and Mockshell, 2018). The IPWRA estimator simulataneously estimates treatment and outcome equations to account for non-random treatment assignment or selection bias. It make use of weighted regression coefficients to compute treatment effect and the weights used are inverse probabilities of treatment (Wooldridge, 2010). The IPWRA is advantageous in estimating impact of multi-valued treatment due to its double-robust property, which allows the treatment effect to be consistently estimated as long as either the treatment or outcome model is correctly defined (StataCorp, 2015; Tambo and Mockshell, 2018; Wooldridge, 2010). The IPWRA estimator estimate impact of treatment in the following three steps (StataCorp, 2015):

a) Suppose that the CSA adoption outcome model is specified as a linear regression function of the form $Y_i = \beta_i + \theta_i X_i + \epsilon_i$ for $i = \{0\ 1\}$[1] and the propensity scores estimated using multinomial logit regression are given by $p(X; \hat{\Upsilon})$. Socioeconomic, demographic, institutional, and location defining (regional) variables guided by relevant literature were used as predictors in the multinomial logit regression model as stated earlier. Location defining variables were included to control for regional heterogeneities.

b) The second step will then employ linear regression to estimate the parameters $(\beta_0, \theta_0\ )$ and (β_1, θ_1) using inverse probability weighted least squares as follows:

$$\min_{\beta_0,\theta_0} \sum_i^N \left[{(Y_i - \beta_0 - \theta_0 X_i)} \big/ {p(X; \hat{\Upsilon})} \right] \text{ if } D_i = 0 \qquad [1]$$

$$\min_{\beta_1,\theta_1} \sum_i^N \left[{(Y_i - \beta_1 - \theta_1 X_i)} \big/ {p(X; \hat{\Upsilon})} \right] \text{ if } D_i = 1 \qquad [2]$$

c) The third step involve calculating the Average Treatment Effect on the Treated (ATET) by subtracting the two equations (1& 2) as follows:

$$ATET = \frac{1}{N_w} \sum_i^{N_w} \{ (\widehat{\beta_1} - \widehat{\beta_0}) - (\widehat{\theta_1} - \widehat{\theta_0}) X_i \} \qquad [3]$$

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[1] Where 0 is the control (no access to both extension and credit) and 1 is the treatment (multiple treatment in our case (i) access to credit only; (ii) access to extension only; and (iii) access to both extension and credit).

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where $(\widehat{\beta_1}, \widehat{\theta_1})$ are the estimated inverse probability weighted parameters for treated farming households while $(\widehat{\beta_0}, \widehat{\theta_0})$ are estimated inverse probability weighted parameters for the untreated farming households (control group), then D_i is the treatment indicator; hence $D_i = 1$ and $D_i = 0$ represent treated and control groups respectively. Finally, the total number of treated households is represented by N_w.

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After estimating the main results using IPWRA and PSM estimation approach, IPWRA estimates were then estimated by country, age and gender status of farming households. This was done to compare the results among women farmers and young farmers groups which are often reported to be disadvantaged in African agriculture (Murray et al., 2016; Sumberg et al., 2014).

The IPWRA approach due to its unique doubly robust property was preferred and hence was treated as main estimation approach, however, PSM was also applied to assess the robustness of the main findings. PSM as an approach is commonly used to assess the treatment effects of interventions or technology adoption. It involves matching treated observations with a control group based on observable characteristics. Following Lechner (2002) and Tambo and Mockshell (2018) PSM with multiple treatment was applied. With PSM ATET is estimated as follows:

$$ATET = E[Y(1) - Y(0)|D = 1] \qquad [4]$$

where $Y(1)$ and $Y(0)$ are outcome indicators (CSA adoption) for treated and untreated observations respectively and D is a treatment indicator as previously defined. However, we can only observe $E\{Y(1)|D = 1\}$ in our data set and not $E\{Y(0)|D = 1\}$. This implies that, we cannot observe outcomes (CSA adoption levels) of treated households (i.e. with access to institutional services) had they not received treatment, once they have already received the treatment. Simple comparison of CSA adoption levels of smallholder farmers with and without treatment status will introduce bias in estimating impacts due to selection bias (Caliendo and Kopeinig, 2008; Lechner, 2002; Makate et al., 2017b; Wossen et al., 2017). The magnitude of selection bias is officially represented as follows:

$$E\{Y(1) - Y(0)|D = 1\} = ATET + E\{Y(0)|D = 1 - Y(0)|D = 0\} \qquad [5]$$

By creating comparable counterfactual households for treated households, PSM reduces the bias due to observables. Given the assumption of conditional independence and overlap conditions, ATET is computed as follows:

$$ATET = E[Y(1)|D = 1, p(x)] - E[Y(0)|D = 0, p(x) \qquad [6]$$

In the PSM with multiple treatment method, separate conditional probabilities between those farmers who accessed institutional services and those who did not receive were estimated using logit regressions following Lechner (2002). The nearest neighbour matching algorithm (Caliendo and Kopeinig, 2008) was used. All analysis was done in STATA version 15.1.

3. Results and discussion

3.1.Sample characterization

3.1.1. Socioeconomic characteristics of studied households

Descriptive statistics of explanatory, treatment and outcome variables are presented by country and overall sample in table 1. Average age of the household head within the analysed sample is 47.4 years. However, farmers in Zimbabwe were comparably older as evidenced by an average age of 51.4 years compared to 43.1 years in the Malawian sub-sample. In addition, about 23.4% of the sampled farmers could be classified as youth (15≤X≤35 years of age), with more representation of youths in Malawi (30.4%) compared to 16.6% in Zimbabwean sample. A greater proportion of sampled farmers had attained at least primary education (56.2%). More farmers from Malawi had attained at least primary education (69.8%) compared to 43.3% in the Zimbabwean sub-sample. Also, male farmer representation in the analysed sample is high (78.8%), with even higher proportion of male farmers in Malawi (82.0%) compared to 75.7% in the Zimbabwean sub-sample. Average land size holding in the whole sample, Malawi and Zimbabwe are 2.0, 1.6 and 2.3 hectares respectively. Ownership and use of a bicycle for transport seemed to be a common practice in the studied sample and in Malawi with respective ownership percentages at 51.6 and 66.3%. Ownership of bicycle was relatively low in Zimbabwe with about 37.6% ownership rate. Mean annual household income was within the same range in the whole sample, Zimbabwe and Malawi of USD 607-619. Also, farmers in Zimbabwe travelled slightly more distances to the nearest town (97.8km) compared to 61.3 km in Malawi.

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[Insert Table 1 here]

3.1.2. Access to extension, credit, and CSA technologies adoption

Access to agricultural credit in the whole sample was only 4.5%. Credit access in Zimbabwe and Malawian sub-samples was at 1.8 and 7.3% respectively. Lack of insurance, collateral for farmers, high transaction costs for screening credit applicants possibly explains why formal credit access is low in Malawi and Zimbabwe. Credit access in studied countries is mainly a problem for cereal and food crops as most credit lenders prefer high value enterprises such as tobacco and livestock.

However, access to agricultural extension services was relatively higher compared to credit within the sample (39.3%) and was even higher in Zimbabwe (51.2%) compared to 26.7% in Malawi (Table 1). Access to both credit and extension was at 14.7% within the whole sample, 10 and 19.6% in Zimbabwe and Malawian sub-samples respectively. Access to agricultural extension services have improved in Malawi and Zimbabwe through time. This can be attributed to the shift from earlier extension models (e.g. the train and visit approach) in the 20th century that were mainly linear, top-down and rigid (Hanyani-Mlambo, 2000; Knorr et al., 2007) to more participatory and Information Communication Technology (ICT) based approaches.

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The bottom part of Table 1 shows the description and respective statistics for adoption of CSA technologies considered in this study. Results show that adoption of CA was at 30.3, 30.8 and 29.7% in the whole sample, Zimbabwean and Malawian samples respectively. DTM adoption was relatively higher compared to all the CSA technologies considered with adoption rates in Malawi, Zimbabwe and whole sample at 57.3, 68.7 and 63.2% respectively. Use of intercropping as a CSA practice was low with respective mean adoption rates at 12.8, 4.5 and 8.5% in Malawi, Zimbabwe and the overall sample. Also, adoption of improved legume varieties was at 28.6% in the studied sample and 32.9 and 24.5% in Malawi and Zimbabwe sub-samples respectively. The CSA adoption index was almost similar in the respective countries (1.3). The CSA index communicate that farmers on average adopted at least one CSA practice.

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Linking the three treatment categories with CSA adoption, it can be seen that all the treatment categories significantly explain adoption of CSA practices (Table 2). Presented in Table 2 are Analysis of variance (ANOVA) results of mean differences between adoptions of CSA technologies by the three treatment categories. It can be observed from the results that adoption of CSA technologies is related to access to credit and extension services. Significant p-values for the ANOVA results (equality of group mean) revealed that mean adoption rates by the four treatment clusters ((i) no credit and extension, (ii) credit only, (iii) extension only and (iv) extension and credit) significantly differ. Precisely stated, mean CSA adoption rates significantly differ by the treatment categories which suggests differential effect of the treatment categories on CSA adoption.

[Insert Table 2 here]

Also, in Figure 2 which further relates CSA adoption rates to the four treatment categories, it can be seen that access to credit, and extension correlates with higher adoption of CA, DTM, IL, INTER and the CSA adoption index. A positive correlation can be noticed in the Figure 2 between access to credit, and extension to higher technologies adoption especially, for CA, improved legume, DTM and CSA adoption index. Important to note is the fact that access to both credit and extension correlates with the highest levels of CSA adoption (Figure 2).

[Insert Figure 2 here]

3.1.3. CSA adoption and the links to productivity and income.

Smallholder farmers are assumed to be rational such that they adopt innovative technologies (e.g. CSA) if the expected difference in utility between adoption and non-adoption is positive. In other words, by adopting CSA technologies farmers expect productivity and livelihood outcome gains from their farming enterprises. Here the analysis relates CSA adoption to efficiency (cereal and legume productivity) and income for the farmer. Cereal and legume productivity are measured as harvested cereal (legume) output divided by area put under cereal(legume) in kg/ha. In Figure 3 CSA adoption rates are plotted against logarithms of cereal productivity, legume productivity and total household income. From the plotted figure it is seen that adoption of the various CSA practices considered (CA, DTM, IL, INTER) correlate positively with productivity and household income. Part A, B, C, D & E of the figure respectively relate CA, DTM, INTER, IL and CSA adoption index to household income, cereal and legume productivity. The positive correlation of CSA adoption and productivity and income is more visible in panel (E) of Figure 3 which relates productivity and incomes to the CSA adoption index. However, for intercropping the relationship is not clear and as consistent to other CSA practises.

[Insert Figure 3 Here]

3.2.Determinants of access to credit and access to extension services

The parameter estimates of the multinomial logit model, which is used to predict treatment status are presented in Table 3. The parameters are interpreted as factors that influence access to extension, credit and credit and extension simultaneously. The base category in all cases is zero access to both extension and credit. The results show that access to credit only was chiefly influenced by land size holding owned and household income. Precisely, an increase in land size and income augments chances of accessing credit in the studied sample. Farmers with relatively bigger arable land size holding may have larger budgets for their planned farming activities which increase their need for credit services. Also, land size increases propensity to diversify crops and hence chances of producing high value crops with access to credit. In both Zimbabwe and Malawi, farming budgets relate positively with land put under cultivation, so farmers putting more land under cultivation will require more resource hence the need for credit. Also, farmers with relatively more incomes may seek credit knowing very much that they can easily pay it back even when returns from the farming enterprise doesn't allow them to payback. Results imply that more affluent households and those with relatively larger land size holdings are more likely to get credit from both formal and informal lending credit institutions. This explain the importance of land ownership and affluence as collateral for accessing credit.

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[Insert Table 3 here]

Results show that access to extension services were chiefly explained by land size holding, ownership of a functional bicycle, education and household income. The results imply that access to an additional hectare of land and income enhance farmers' chances of accessing extension services. This could be because farmers with larger tracts of land are more likely to adopt and try new technologies on their farm and are more likely to expand their production activities which may increase their propensity to seek for agricultural extension advice. In Zimbabwe, for instance, farmers with relatively more resources at their disposal (such as income) may have an advantage in accessing extension as they can invite and pay individual extension agents to visit their farming plots. The payment is done in cash[2] or kind[3]. Also, more affluent farmers maybe more likely to meet the transaction costs incurred in receiving extension advice which explains why income is a significant factor on extension access. For instance, in both Zimbabwe and Malawi, farmers at times must visit the local extension agent's offices or homes to seek advice or visit lead/champion farmers to their farms to seek advice. Richer farmers are therefore, more likely to meet the costs for transport and other services required to make successful visits which improves their odds of accessing extension services. In addition, the more educated farmers were more likely to access extension services possibly because they may know and value extension services more than their less educated counterparts which in turn raises their propensity to seek for agricultural advice. Furthermore, the relatively more mobile farmers (with access to functional bicycles) were more likely to access extension services. This simply stress the importance of mobility in accessing key agricultural institutional services like agricultural extension in rural farming communities. Extension agents in Zimbabwe and Malawi are not very mobile due to resource constraints and hence, for farmers to increase their chances of getting extension advice from government for instance, require them to be mobile to at least visit the district or village extension office.

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Further, results showed that access to both extension and credit is positively and significantly influenced by land size holding, primary education, bicycle ownership, income and distance to nearest town. As explained before, results show the importance of larger land size holding, mobility (through access to a

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[2] The farmer can give cash for transport, lunch or as a token of appreciation to the invited extension agent)

[3] The payment can be in goods e.g. basic food stuffs (sugar, cooking oil, salt etc.) or farm produce (vegetables, maize grain etc.)

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bicycle), education, and income in enhancing access to both credit and extension services. Results also show distance to town to positively explain access to extension and credit services. This could be explained by the availability of localised extension and credit services in rural communities in studied countries that no longer limits access to institutional services with further distances from main towns. For instance, government extension officers are found at district and village level in both Zimbabwe and Malawi which makes distance to town less important as a constraint for extension access. However, extension worker to farmer ratios remain high in both countries. Also, formal credit services from banks in towns are strict on lending requirements (e.g. the need for collateral) for smallholder farmers which discourage them from seeking credit services in distant towns but rather from their social networks (e.g. friends, relatives or other community groups). The result also implies that improving localised extension and credit services in rural communities will reduce constraints imposed by transaction costs in accessing both credit and extension.

3.3.Synergistic impacts of access to credit and extension

Table 4 presents the results of the doubly robust IPWRA estimator on the impact of credit, extension and the synergistic impacts of extension and credit. Much interest was on those subjects who received treatment and hence reported are average treatment effect on the treated (ATET) estimates which shows how CSA adoption outcomes changes as a result of treatment in the treated sub-population. In all cases IPWRA estimates are interpreted with reference to the potential outcome mean of the control group (no access to both extension and credit). A positive (negative) ATET estimate will therefore, be interpreted as an increase (decrease) in CSA adoption outcomes from the potential outcome mean *X* that would have occurred if farmers had no access to both extension and credit (i.e. were in the Control group). To assess the robustness of the main results on the impacts of Credit, extension and both on CSA technologies adoption, results from propensity score matching are also presented in table 5. The kernel density distribution plots showing overlap between farmers with access to Credit and Extension services and those without access (Figure 4) revealed that the common support assumption was satisfied. Reported in tables 4 and 5 are average treatment effects on the treated (ATET) sample.

[Insert Figure 4 here]

Results presented in Tables 4, shows that access to extension only positively impacted on: CA adoption by 34.3%, DTM by 9.52%, improved legume by 21.3% and that access to extension improved CSA adoption index by 0.61 CSA practices. Robustness ATET estimates from PSM in Table 5 confirm the results and shows that access to extension improves CA by 15%, IL adoption by 9.1% and that access to extension improved CSA adoption index by 0.22 units.

[Insert Table 4 here]

Further, results in Table 4 show that access to both extension and credit improves CA adoption by 50.2%, Intercropping by 6.2%, Improved legume by 41.5% and CSA adoption index by 1.05 units. PSM results in table 5 also show that access to both extension and credit improve CA adoption by 24.8%, improved legume adoption by 28.8% and CSA adoption index by 0.551 units results all significant at 1%. Both IPWRA and PSM estimates point to consistent superior impacts of simultaneous access to credit and extension services on CA, improved legume adoption and CSA adoption index. ATET estimates for impact of extension only are less than for impact of access to both extension and credit access implying some synergy in impact for access to both extension and credit.

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[Insert Table 5 here]

3.4.Heterogeneities of synergistic impacts of credit and extension access on CSA technologies adoption

The study further analysed the impacts of credit, extension access and simultaneous adoption of credit and extension on adoption of CSA technologies by country, age group status and gender. Results are presented in Tables 6-8.

3.4.1. Regional heterogeneities

Table 6 present IPWRA estimates on impact of credit and extension on CSA technology adoption by studied country. Scrutinising impact of the treatments by studied country reveal that in the Malawian sub-sample, access to credit only improved CA adoption by 10.8% and that access to extension only improved CA adoption, DTM adoption and IL adoption by 41.1, 17.1 and 18% respectively. Also, access to extension improved CSA adoption index by 0.723 units.

On the other hand, in the Zimbabwean sub-sample, access to credit improved legume adoption by 34.8% and access to extension positively improved CA, IL and CSA adoption index by 24.2%, 18.8% and 0.36 units respectively. However, access to extension only reduced intercropping adoption by 3.8%.

[Insert Table 6 here]

The results of the synergistic impacts of credit and extension access on CSA adoption show that in the Malawian sub-sample, simultaneous access to credit and extension services positively and significantly improves: CA adoption by 59.9%, IL adoption by 39.5% and CSA adoption index by 1.23 units. Further, in the Zimbabwean sub-sample, results also show that simultaneous access to credit and extension services significantly improves CA, IL and CSA adoption index by 25.7%, 32.4% and 0.49 units respectively.

Overall results point to the importance of credit in adoption of CA in Malawi and importance of credit in enhancing IL adoption in Zimbabwe and that extension access significantly improves CA, IL adoption and CSA adoption index in both countries. In addition, extension access improves DTM adoption in Malawi but negatively affect intercropping adoption in Zimbabwe. More importantly, results point to enhanced synergistic impacts of simultaneous access to credit and extension on CA, IL and CSA adoption index in both Zimbabwe and Malawi which corroborate to main findings in tables 4 & 5.

3.4.2. Age heterogeneities

The IPWRA estimates presented in Table 7 show the impact of credit and extension services by young and older farmers. Results show that in the young farmers' group, access to credit only improved CA adoption by 17.4% and that access to extension only improved CA adoption by 43%. While, within the old farmer group access to extension services only improved CA, DTM, IL adoption and CSA adoption index by 29.8%, 11.1%, 24.9% and 0.64 units respectively.

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[Insert Table 7 here]

On synergistic impacts of credit and extension, results show that access to both extension and credit expands CA adoption by 70.4% and CSA adoption index by 0.98 units in the youthful farmer group. In the older farmer group access to both credit and extension positively and significantly enhanced CA, INTER, IL and CSA adoption index by 43.9%, 7.3%, 39.1% and 1.0 units respectively. Results show slightly differentiated impact results by farmer youth status with access to credit and extension services having greater evident impacts on CSA technology adoption in the older farmer group than the youthful farmer group.

3.4.3. Gender heterogeneities

The IPWRA estimates by gender of farmer are shown in Table 8. Results show that access to credit only significantly improves CA adoption by 12.7% and IL adoption by 57.9% in the male and female sub-samples respectively. Access to extension services only improves CA, DTM, IL and CSA adoption index in the male sub-sample by 34%, 11.7%, 21.1% and 0.61 units respectively. Also results show negative significant impact of extension only on intercropping in the male sub-sample. On the contrary, in the female sub-sample, access to extension only significantly improves CA, IL and CSA adoption index by 26.1%, 30.6% and 0.60 units respectively.

[Insert Table 8 here]

Results also show that access to both extension and credit in the male sub-sample enhanced adoption of CA, and IL adoption by 55.9 and 42.5% respectively and CSA adoption index by 1.1 units. In the female sub-sample simultaneous adoption of credit and extension did not have significant impact on CSA technology adoption. Results here report differentiated impacts of simultaneous access to credit and extension on CSA technology adoption with pronounced impacts of credit and extension access jointly in the male farmer sub-sample.

3.5.Discussion: impact of credit and extension on CSA technology adoption

Results point to the importance of both extension and credit in improving CSA technology adoption in smallholder farming systems of Zimbabwe and Malawi. Agriculture extension individually proved to be more effective in promoting CSA technology adoption when compared to credit access only. This could possibly be due to constrained access to credit and relatively higher access to extension advice in the studied sample. In Zimbabwe and Malawi, extension advice is so relevant in numerous aspects and in some cases it also helps the farmer in accessing information relevant for them to access credit among other important farming resources. Credit access for cereal and food crops in both Zimbabwe and Malawi is currently a big problem and this could be constraining adoption of CSA technologies. Formal credit lending institutions in both countries often prefer secure property occupancy (i.e. land or property title deeds) as collateral for accessing credit. However, most smallholder farmers in Zimbabwe and Malawi are poor and lack such secure property rights and this at present is a major obstacle for accessing credit through formal channels. Farmers often resort to informal means including savings and credit mobilization to access agricultural credit. The informal credit access channels are mainly based on own farmer social networks and trust rather than collateral as required by formal credit institutions. Some of the common sources for smallholder farmers include own savings, credit associations, relatives and

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friends, merry go rounds[4], and informal money lenders. However, informal channels are not easily available to all farmers and may not offer sufficient credit quantities required by farmers. This explains continued low rates of credit access in Zimbabwe and Malawi.

In previous studies access to extension have been found to improve technologies adoption and livelihood outcomes. For instance, Donkor et al. (2016) found access to extension to impact positively on fertilizer adoption in Ghana, and Wossen et al. (2017) found positive impacts of extension access on improved technology adoption in Nigeria. More so, Ragasa and Mazunda (2018) and Owens et al. (2003) found positive technology access driven impacts of agricultural extension on livelihood outcomes in Malawi and Zimbabwe respectively. Results in previous studies and in the current study both point to the importance of extension in aiding technologies adoption in agriculture. Agricultural extension is important for CSA technology adoption in agriculture as it is one of the central ways of conveying information on new technologies, improved farming practices and better management. This is achieved through reducing information asymmetry often associated with new technologies (Christoplos and Kidd, 2000; Ghimire and Huang, 2015; Makate et al., 2018). Specifically, agricultural extension transfer information of new technologies from the global knowledge base and from researchers to farmers, enabling farmers to clarify their own goals and possibilities (Anderson and Feder, 2004). In addition, extension services access facilitates adoption and spread of CSA technologies by exposing farmers to the technologies and by educating them about best farming management practices (Anderson and Feder, 2007; Wossen et al., 2013), which can eventually lead to improved farm productivity and better livelihood outcomes.

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Most importantly, results reveal enhanced impact of simultaneous access to credit and extension on adoption of CSA technologies in both Zimbabwe and Malawi particularly, on adoption of conservation agriculture, improved legume varieties and on number of CSA technologies adopted by the smallholder farmer. The result suggests important collective effect of accessing both credit and extension on CSA technology adoption. This is in line with other studies that have found extension access to have greater impacts on livelihood outcomes for farmers with access to credit (see for example Wossen et al. (2017)). Also, Hassan and Nhemachena (2008) stressed the importance of extension and credit services in technology transfer and adaptation to climate change. The two institutional services are crucial for farmers (in both Zimbabwe and Malawi) to access required resources for their farming activities including information (production, marketing, transport information etc.), farming inputs (seed, fertilizer, agrochemicals, etc.) among other needs which explains their effectiveness in aiding adoption of CSA. For instance, with access to credit, the farmer is able to access the much needed complementary inputs for CSA such as seed, fertilizers (Swaminathan et al., 2010), and can make meaningful investments on the farm e.g. building water reservoirs for small scale irrigation and buying farm tools and equipment. Simultaneous access to credit and vital information (from extension) will enhance propensities for farmers to adopt CSA technologies even those which require high initial capital (knowledge and finance).

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[4] Merry go round is a practice in which farmers form small groups (based on their social networks) and within those groups they give one of the members at a time (monthly or weekly) a certain amount of money and that is done in a cycle (merry go round fashion) until every member receives their share.

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Further, results point to youth and gender differentiated impacts of simultaneous access to credit and extension on CSA technology adoption. Impacts were found to be comparably inferior for youthful and women farmer groups compared to older and male farmer groups respectively. The inferior impacts of access to extension and credit within the youthful farmer group could partly be explained by youth challenges in both Zimbabwe and Malawi. Youths face several challenges including unemployment (UNESCO, 2011), and despite them being one of the most productive groups (Mangal, 2009), they are often left out in various key policies and programs including in agriculture (FAO et al., 2009). For instance, in Zimbabwe youths lack employment opportunities, and secure land tenure security and this has affected their propensities to access farming resources (including credit) and make meaningful investments in agriculture. Lack of land and or tenure security by youth farmers is also believed to be forcing a number of youths out of agriculture in Zimbabwe, Malawi and other developing regions (Maiga et al., 2017).

Also, women remain disadvantaged in accessing key institutional support services for agricultural development in both Zimbabwe and Malawi. Women challenges in agriculture include but are not limited to lack of access to complementary CSA resources (labour, capital, information, transport, energy) (Murray et al., 2016; Sims et al., 2012; UN-Women et al., 2015) and this could explain inferior impacts of simultaneous access to extension and credit in the female farmer sub-sample. In both Zimbabwe and Malawi, agricultural labour productivity of women is heavily constrained by lack of access to resources including labour saving technologies, credit and basic farm tools. For instance, in Malawi, Murray et al. (2016) found smallholder women farmers to have limited access to basic agricultural equipment, energy, transport among other resources which affects their adaptation to climate variability and change. Such unique women problems coupled with other general challenges affecting smallholder agriculture (in Zimbabwe and Malawi) reduce propensities of women to adopt beneficial climate smart agricultural technologies.

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4. Conclusions and recommendations

In conclusion, simultaneous access to agricultural credit and extension have far greater impacts on CSA technology adoption in smallholder farming systems of Zimbabwe and Malawi. However, impacts are slightly inferior in women and youth farmer groups possibly due to common women and youth farmer challenges in the two countries in accessing key resources for full participation in agriculture (labour, capital, information, energy, transport. Study results calls for prudent policy and institutional strategies aimed at improving access to both extension and credit for improved CSA technology adoption and spread. Further, targeted extension and credit improvement strategies should be gender and age inclusive. Possible, strategies to improve extension access may include: improving number of extension workers per village, improving coordination of extension messages relayed to farmers, making extension systems more gender and age inclusive (i.e. increasing youth and women extension agents' numbers), capacity building of extension institutions and personnel, increased financing for national extension programs among others. Also, making credit easily available for farmers should be a priority. Prohibitive collateral requirements in both countries can be revised to accommodate smallholder farmers in accessing credit. Moreover, government non-governmental organizations and other private players can also in various ways support farmers in accessing credit by expanding and strengthening rural formal and informal

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credit markets (e.g. by strengthening rural collective action such as, community saving groups, cooperatives through offering some training in group dynamics related subjects) and decentralizing formal financial institutions. Most importantly, policy and institutional strategies in improving access to extension and credit services should be cognisant of disadvantaged groups such as the youth and women. Participatory policy and institutional forums (that include women and youth) in designing and developing appropriate agricultural policies are therefore, recommended. Improving access to credit and efficient agricultural extension services will go a long way in minimising CSA scaling challenges in Zimbabwe and Malawi.

Conflict of interest statement

The authors declare no conflict of interests

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Availability of supporting data

Data for this study can be obtained from CIAT Dataverse.

Repository URL: https://dataverse.harvard.edu/dataverse/CIAT

References

Ajayi, M.T., Fatunbi, A.O., Akinbamijo, O.O., 2018. Strategies for Scaling Agricultural Technologies in Africa. Forum for Agricultural Research in Africa (FARA), Accra Ghana

Aker, J.C., 2011. Dial “A” for agriculture: a review of information and communication technologies for agricultural extension in developing countries. Agricultural Economics, 42(6), 631-647 DOI: https://doi.org/10.1111/j.1574-0862.2011.00545.x.

Anderson, J., Feder, G., 2007. Agricultural extension. In: (Eds.),, in: Evenson, R., Pingali, P.L. (Eds.), Handbook of Agricultural Economics, pp. 2343-2378

Anderson, J.R., Feder, G., 2004. Agricultural extension: Good intentions and hard realities. The World Bank Research Observer, 19(1), 41-60 DOI: https://doi.org/10.1093/wbro/lkh013.

Caliendo, M., Kopeinig, S., 2008. Some practical guidance for the implementation of propensity score matching. Journal of economic surveys, 22(1), 31-72 DOI: https://doi.org/10.1111/j.1467-6419.2007.00527.x.

Christoplos, I., Kidd, A., 2000. Guide for monitoring, evaluation and joint analyses of pluralistic extension support. Guide for monitoring, evaluation and joint analyses of pluralistic extension support. DOI: https://www.cabdirect.org/cabdirect/abstract/20036794119.

Donkor, E., Enoch, O.-S., Victor, O., Henry, J., 2016. Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana. NJAS - Wageningen Journal of Life Sciences, 79, 41-49 DOI: https://doi.org/10.1016/j.njas.2016.10.002.

FAO, 2013. Sourcebook on Climate Smart Agriculture, Forestry and Fisheries (Rome, Italy: Food and Agriculture Organization of the United Nations (FAO). Food and Agriculture Organization DOI: http://www.fao.org/climatechange/37491-0c425f2caa2f5e6f3b9162d39c8507fa3.pdf.

FAO, 2018. Climate Smart Agriculture: Building Resilience to Climate Change. Springer International Publishing AG, Cham, Switzerland DOI: DOI 10.1007/978-3-319-61194-5.

Journal Pre-proof

FAO, ILO, UNESCO, 2009. Training and Employment Opportunities to Address Poverty Among Rural Youth: , A Synthesis Report. UNESCO, ILO, FAO, Bangkok, Thailand

Ghimire, R., Huang, W.-C., 2015. Household wealth and adoption of improved maize varieties in Nepal: a double-hurdle approach. Food Security, 7(6), 1321-1335 DOI: https://doi.org/10.1007/s12571-015-0518-x.

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., Lamanna, , C., van Etten, J., Rose, A., Campbell, B., 2018. Climate risk management and rural poverty reduction. Agricultural Systems, In Press DOI: https://doi.org/10.1016/j.agsy.2018.01.019.

Hanyani-Mlambo, B.T., 2000. Re-framing Zimbabwe's public agricultural extension services: Institutional analysis and stakeholders views. Agrekon, 39(4), 665-672 DOI: https://doi.org/10.1080/03031853.2000.9523682.

Hassan, R., Nhemachena, C., 2008. Determinants of climate adaptation strategies of African farmers: Multinomial choice analysis. African Journal of Agricultural and Resource Economics, 2(1), 83-104

Kassie, M., Teklewold, H., Marenya, P., Jaleta, M., Erenstein, O., 2015. Production risks and food security under alternative technology choices in Malawi: Application of a multinomial endogenous switching regression. Journal of Agricultural Economics, 66(3), 640-659 DOI: https://doi.org/10.1111/1477-9552.12099.

Katengeza, S.P., Holden, S.T., Lunduka, R.W., 2019. Adoption of drought tolerant maize varieties under rainfall stress in Malawi. Journal of Agricultural Economics, 70(1), 198-214 DOI: https://doi.org/10.1111/1477-9552.12283.

Knorr, J., Bentaya, M.G., Weikersheim, V.H., 2007. The History of Agricultural Extension in Malawi. Margraf Publishers DOI: https://doi.org/10.1080/1389224X.2014.874090.

Lechner, M., 2002. Program heterogeneity and propensity score matching: an application to the evaluation of active labor market policies. Review of Economic Statistics, 84, 205-220 DOI: https://doi.org/10.1162/003465302317411488

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P.T., Sessa, R., Shula, R., Tibu, A., Torquebiau, E.F., 2014. Climate-smart agriculture for food security. Nature Climate Change, 4(12), 1068-1072 DOI: 10.1038/nclimate2437.

Lunduka, R.W., Mateva, K.I., Magorokosho, C., Manjeru, P., 2017. Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe Climate and Development, 1-12 DOI: DOI:10.1080/17565529.2017.1372269.

Maiga, E., Christiaensen, L., Palacios-Lopez, A., 2017. Is African Youth Exiting Agriculture en Masse?, mimeographed. World Bank, Washington, USA

Makate, C., Makate, M., Mango, N., 2017a. Sustainable agriculture practices and livelihoods in pro-poor smallholder farming systems in southern Africa. African Journal of Science, Technology, Innovation and Development, 9(3), 269-279 DOI: https://doi.org/10.1080/20421338.2017.1322350.

Makate, C., Makate, M., Mango, N., 2018. Farm types and adoption of proven innovative practices in smallholder bean farming in Angonia district of Mozambique. International Journal of Social Economics, 45(1), 140-157 DOI: https://doi.org/10.1108/IJSE-11-2016-0318.

Makate, C., Wang, R., Makate, M., Mango, N., 2016. Crop diversification and livelihoods of smallholder farmers in Zimbabwe: adaptive management for environmental change. SpringerPlus, 5(1), 1-18 DOI: https://doi.org/10.1186/s40064-016-2802-4.

Makate, C., Wang, R., Makate, M., Mango, N., 2017b. Impact of drought tolerant maize adoption on maize productivity, sales and consumption in rural Zimbabwe. Agrekon, 56(1), 67-81 DOI: 10.1080/03031853.2017.1283241.

Journal Pre-proof

Mangal, H., 2009. Best Practices for Youth in Agriculture: , The Barbados, Grenada and Saint Lucia Experience: Final report.

Mango, N., Makate, C., Lulseged, T., Powell, M., Gift, N., 2018. Adoption of Small-Scale Irrigation Farming as a Climate-Smart Agriculture Practice and Its Influence on Household Income in the Chinyanja Triangle, Southern Africa. Land 7(49), 1-19 DOI: doi:10.3390/land7020049.

McCarthy, N., Brubaker, J.R., FAO., 2014. Climate-Smart Agriculture and Resource Tenure in Sub-Saharan Africa: A Conceptual Framework. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Murray, U., Gebremedhin, Z., Brychkova, G., Spillane, C., 2016. Smallholder Farmers and Climate Smart Agriculture Technology and Labor-productivity Constraints amongst Women Smallholders in Malawi. Gender, Technology and Development, 20(2), 117-148 DOI: https://doi.org/10.1177/0971852416640639.

Nkonya, E., Jawoo, K., Edward, K., Timothy, J., 2018. Climate Risk Management through Sustainable Land and Water Management in Sub-Saharan Africa, in: L. Lipper et al. (eds.) (Ed.), Climate Smart Agriculture. Natural Resource Management and Policy DOI: DOI 10.1007/978-3-319-61194-5_19.

Owens, T., Hoddinott, J., Kinsey, B., 2003. The impact of agricultural extension on farm production in resettlement areas of Zimbabwe. Economic Development and Cultural Change, 51(2), 337-357 DOI: https://doi.org/10.1086/346113.

Partey, S.T., Dakorah, A.D., Zougmoré, R.B., Mathieu, O., Mary, N., Nikoi, G.K., Sophia, H., 2018. Gender and climate risk management: evidence of climate information use in Ghana. Climate change DOI: https://doi.org/10.1007/s10584-018-2239-6.

Petrick, M., 2004. Farm investment, credit rationing, and governmentally promoted credit access in Poland: a cross-sectional analysis. Food Policy, 29(3), 275-294 DOI: https://doi.org/10.1016/j.foodpol.2004.05.002.

Ragasa, C., Mazunda, J., 2018. The impact of agricultural extension services in the context of a heavily subsidized input system: The case of Malawi. World Development, 145, 25-47 DOI: https://doi.org/10.1016/j.worlddev.2017.12.004.

Senyolo, M.P., Long, T.B., Blok, V., Omta, O., 2018. How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. Journal of Cleaner Production, 172, 3825-3840 DOI: https://doi.org/10.1016/j.jclepro.2017.06.019.

Shoji, M., Aoyagi, K., 2012. Social Capital Formation and Credit Access: Evidence from Sri Lanka. World Development, 40(12), 2522-2536 DOI: https://doi.org/10.1016/j.worlddev.2012.08.003.

Sims, B.G., Bhatti, A.M., Mkomwa, S., Kienzle, J., 2012. Development of mechanization options for smallholder farmers: Examples of local manufacturing opportunities for sub-Saharan Africa., In International Conference of Agricultural Engineering, Valencia, Spain

Smith, A., Sieglinde, S., John, D., Chiwimbo, G., Regis, C., 2016. Doubled-up legume rotations improve soil fertility and maintain productivity under variable conditions in maize-based cropping systems in Malawi. Agricultural Systems, 145, 139–149 DOI: https://doi.org/10.1016/j.agsy.2016.03.008.

StataCorp, L., 2015. Stata treatment-effects reference manual. College Station: Stata Press

Sumberg, J., Anyidoho, N.A., Chasukwa, M., Chinsinga, B., Leavy, J., Tadele, G., Whitfield, S., Yaro, J., 2014. Young people, agriculture, and employment in rural Africa. Routledge Employment, Politics London

Swaminathan, H., Du Bois, R.S., Findeis, J.L., 2010. Impact of Access to Credit on Labor Allocation Patterns in Malawi. World Development, 38(4), 555-566 DOI: https://doi.org/10.1016/j.worlddev.2009.11.002.

Tambo, J.A., Mockshell, J., 2018. Differential Impacts of Conservation Agriculture Technology Options on Household Income in Sub-Saharan Africa. Ecological Economics, 151, 95-105 DOI: https://doi.org/10.1016/j.ecolecon.2018.05.005.

Journal Pre-proof

Thierfelder, C., Rusinamhodzi, L., Setimela, P., Walker, F., Eash, N.S., 2016. Conservation agriculture and drought-tolerant germplasm: Reaping the benefits of climate-smart agriculture technologies in central Mozambique. Renewable Agriculture and Food Systems, 31(5), 414-428 DOI: https://doi.org/10.1017/S1742170515000332.

Journal Pre-proof

Totin, E., Segnon, A.C., Marc, S., Hippolyte, A., Zougmoré, R.B., Todd, R., Thornton, P.K., 2018. Institutional Perspectives of Climate-Smart Agriculture: A Systematic Literature Review. Sustainability, 10(1990) DOI: doi:10.3390/su10061990.

Ugochukwu, A.I., Phillips, P.W., 2018. Technology Adoption by Agricultural Producers: A Review of the Literature, From Agriscience to Agribusiness. Springer, Cham, pp. 361-377 DOI: https://doi.org/10.1007/978-3-319-67958-7_17.

UN-Women, UNDP, UNEP, World-Bank, 2015. The cost of the gender gap in agricultural productivity in Malawi, Tanzania and Uganda, (Working Paper No. 100234). World Bank., Washington, DC

UNESCO, 2011. World youth report [online]. United Nations Educational Scientific and Cultural Organization (UNESCO) DOI: UNWorldYouthReport.org.

Westermann, O., Förch, W., Thornton, P.K., 2015. Reaching more farmers: innovative approaches to scaling up climate smart agriculture., CCAFS Working Paper no 135. CGIAR Research Program on Climate Change, Agriculture and Food Security CCAFS, Copenhagen, Denmark DOI: URL: https://ccafs.cgiar.org/publications/reaching-more-farmers-innovative-approachesscaling-climate-smart-agriculture#.WSZj_vmGOUk.

Wooldridge, J.M., 2010. Econometric analysis of cross section and panel data. MIT press

World Bank, 2001. World Development 2000/2001: Attacking Poverty. . Oxford University Press, New York.

Wossen, T., Abdoulaye, T., Arega, A., Mekbib, G.H., Shiferaw, F., Adetunji, O., Victor, M., 2017. Impacts of extension access and cooperative membership on technology adoption and household welfare. Journal of Rural Studies, 54, 223-233 DOI: https://doi.org/10.1016/j.jrurstud.2017.06.022.

Wossen, T., Berger, T., Mequaninte, T., Alamirew, B., 2013. Social network effects on the adoption of sustainable natural resource management practices in Ethiopia. International Journal of Sustainable Development & World Ecology, 20(6), 477-483 DOI: https://doi.org/10.1080/13504509.2013.856048.

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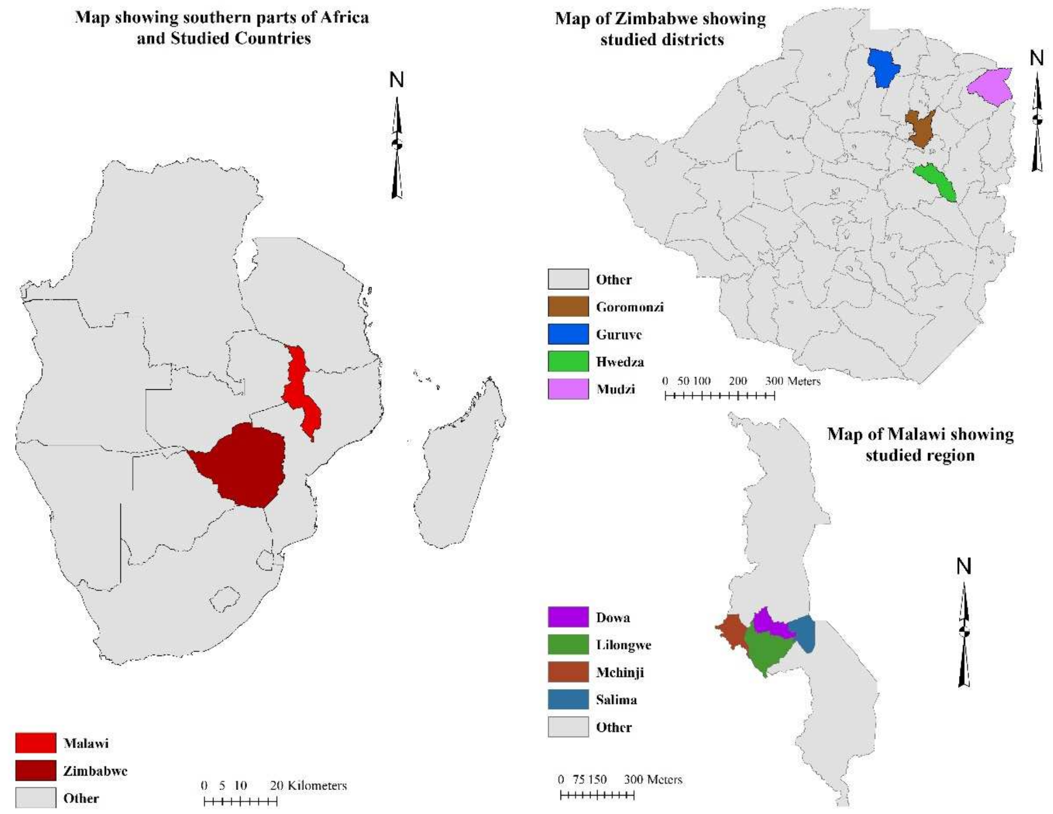

Figure 1: Study area

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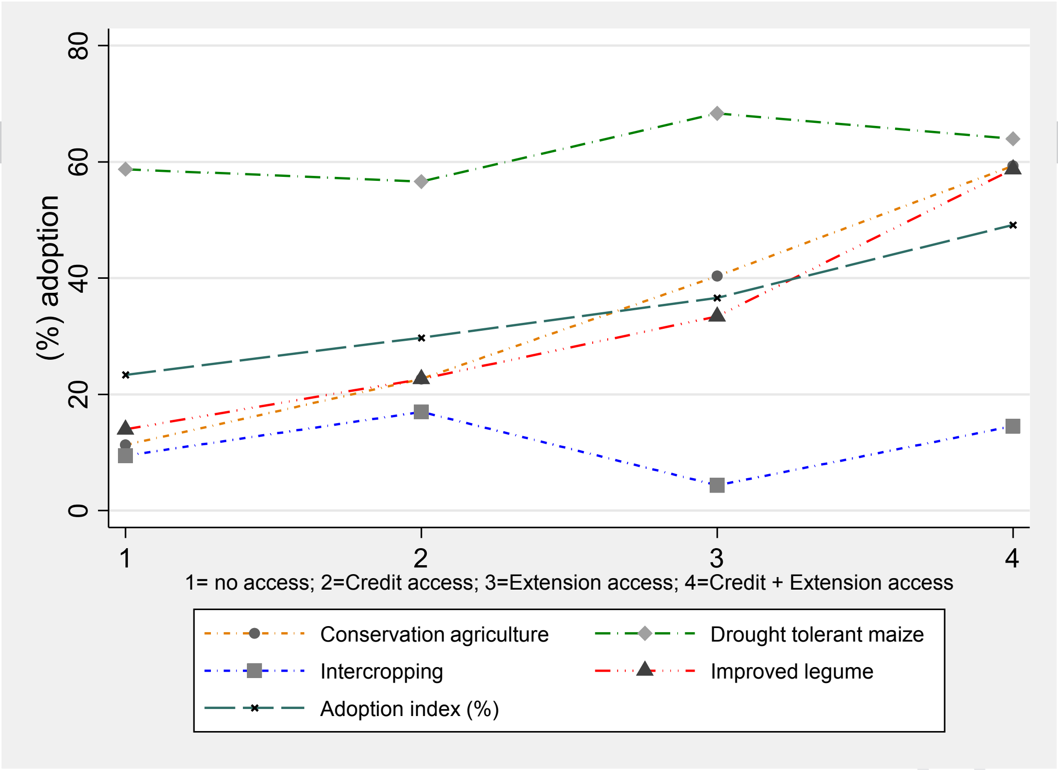

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679 Figure 2: Adoption of CSA technologies by Extension, credit access regimes (Treatment)

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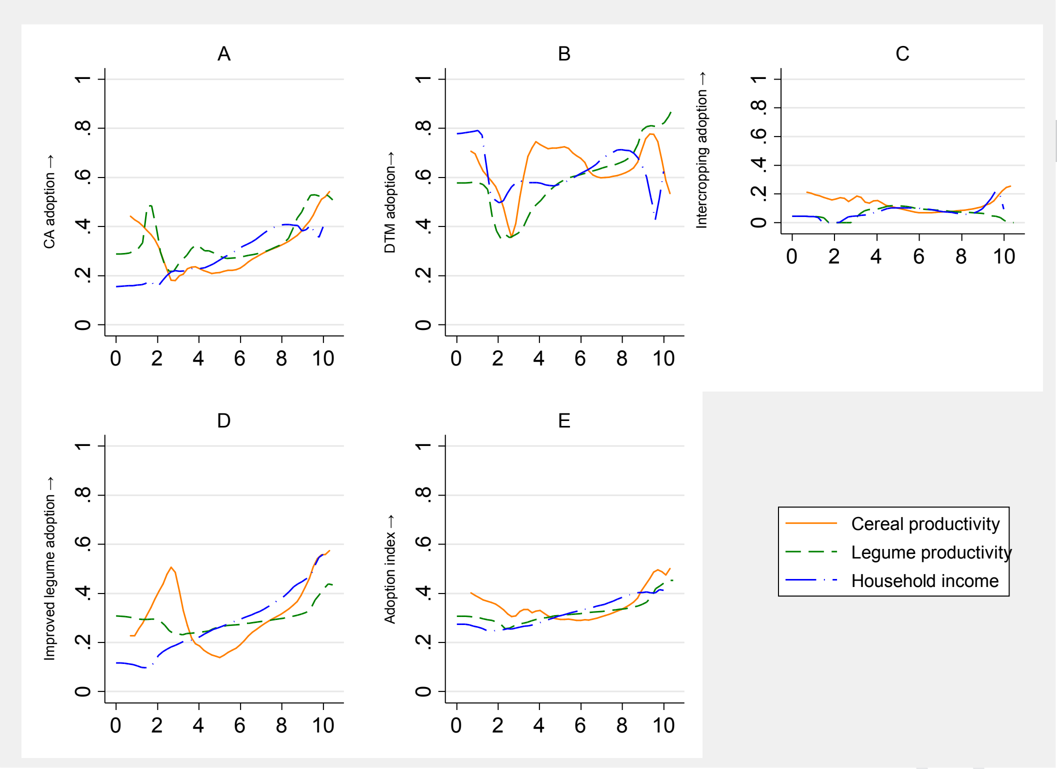

Figure 3: Associations between adoption of CSA technologies and cereal productivity, legume productivity and household income. Cereal, legume productivity and income variables are in logarithm.

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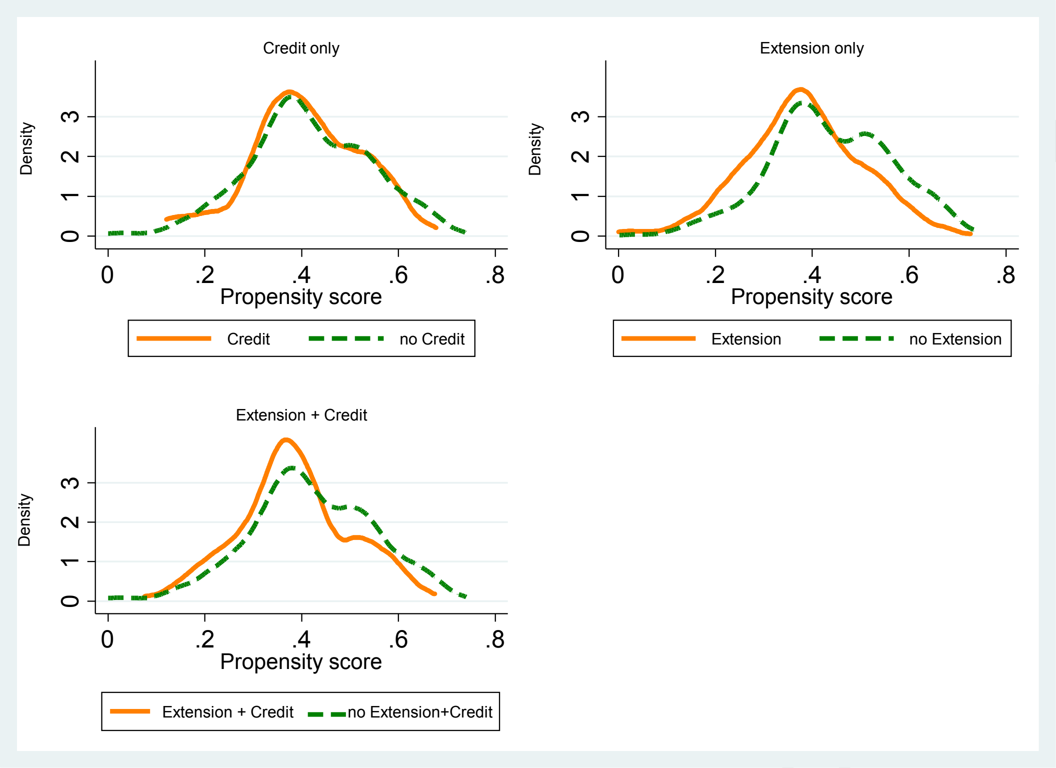

Figure 4: Kernel density distribution showing overlap between farmers with access to Credit and Extension services and those without access.

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Tables

Table 1: Summary statistics of analysed variables by country

VARIABLES	Variable description and measurement	Malawi	Zimbabwe	Overall Sample
		mean	mean	mean
Explanatory variables				
Age	Age of household head in years	43.135	51.420	47.376
Primary education	Binary variable =1 if farmer had attained at least primary education; 0 otherwise	0.698	0.433	0.562
Youth	Binary variable=1 if farmers is in the Youth category 15≤X≤35; 0 otherwise	0.304	0.166	0.234
Male	Binary variable=1 if household head is male; 0 otherwise	0.820	0.757	0.788
Land size	Land size holding owned in hectares	1.570	2.344	1.967
Bicycle	Binary variable =1 if household head owns a bicycle; 0 otherwise	0.663	0.376	0.516
Income	Annual household income per in US$	618.950	607.499	613.083
Distance to town	Distance to the nearest town in Kilometers	61.268	97.796	79.984
Treatment variables				
Credit	Binary variable =1 if household accessed credit through formal or informal institutions; 0 otherwise	0.073	0.018	0.045
Extension	Binary variable =1 if household accessed government or private extension services; 0 otherwise	0.267	0.512	0.393
Extension & Credit	Binary variable =1 if farmer accessed both credit and extension; 0 otherwise	0.196	0.100	0.147
Outcome variables: Adoption of CSA technologies				
Conservation agriculture	Binary variable =1 if farmer adopted conservation agriculture; 0 otherwise	0.297	0.308	0.303
Drought tolerant maize	Binary variable=1 if farmer adopted drought tolerant maize; 0 otherwise	0.573	0.687	0.632
Intercropping	Binary variable if farmer adopted intercropping; 0 otherwise	0.128	0.045	0.085
Improved legume	Binary variable =1 if farmer adopted improved legume; 0 otherwise	0.329	0.245	0.286
CSA technology adoption index	Number of climate smart agriculture technologies adopted by the farmer	1.327	1.285	1.305
N		572	601	1173

Data Source: Data for this study comes from household level surveys carried out by the International Centre for Tropical Agriculture (CIAT) in Zimbabwe and Malawi in 2011/12

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Table 2: Characteristics of smallholder farmers by treatment (credit and extension access clusters)

VARIABLES	No extension or credit		Credit		Extension		Extension + Credit		Overall		ANOVA
	Cluster means	Cluster SD	Cluster means	Cluster SD	Cluster means	Cluster SD	Cluster means	Cluster SD	Cluster means	Cluster SD	p-value
Conservation agriculture	0.113	0.317	0.226	0.423	0.403	0.491	0.593	0.493	0.303	0.460	0.000***
Drought tolerant maize	0.587	0.493	0.566	0.500	0.683	0.466	0.640	0.482	0.632	0.483	0.0151**
Intercropping	0.094	0.293	0.170	0.379	0.043	0.204	0.145	0.353	0.085	0.279	0.0000***
Improved legume	0.140	0.347	0.226	0.423	0.334	0.472	0.587	0.494	0.286	0.452	0.0000***
CSA adoption index	0.934	0.877	1.189	1.057	1.464	0.974	1.965	1.081	1.305	1.021	0.0000***
N	487		53		461		172		1173		

Notes: *** p<0.01, ** p<0.05, * p<0.1, SD = Standard deviation; ANOVA=Analysis of Variance. Data was collected from selected smallholder farmers in Zimbabwe and Malawi.

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Table 3: Parameter estimates of factors influencing access to extension and credit in the studied sample

VARIABLES	Credit only	Extension only	Extension & credit
Land size	0.167*	0.170**	0.188**
	(0.101)	(0.083)	(0.086)
Age household head	-0.006	0.007	-0.006
	(0.012)	(0.005)	(0.007)
Primary education	-0.075	0.290**	0.594***
	(0.318)	(0.146)	(0.192)
Bicycle	0.474	0.432***	0.604***
	(0.312)	(0.148)	(0.201)
Income	0.483**	0.112***	0.315***
	(0.188)	(0.041)	(0.075)
Distance to town	0.001	0.001	0.003**
	(0.003)	(0.001)	(0.001)
Constant	-5.138***	-2.331***	-3.854***
	(1.378)	(0.363)	(0.576)
Region fixed effects	Yes	Yes	Yes
Observations	1,173	1,173	1,173

Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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Table 4: Impact of extension and credit access regimes (treatment) on CSA technology adoption

	IPWRA estimates				
VARIABLES	CA	DTM	INTER	IL	Adoption index
	ATET	ATET	ATET	ATET	ATET
Credit only	0.098	-0.017	0.071	0.032	0.196
	(0.062)	(0.074)	(0.054)	(0.064)	(0.150)
Extension only	0.343***	0.095*	-0.035	0.213***	0.611***
	(0.044)	(0.049)	(0.026)	(0.046)	(0.100)
Extension & Credit	0.502***	0.042	0.062*	0.415***	1.049***
	(0.055)	(0.053)	(0.037)	(0.054)	(0.143)
Potential outcome mean	0.129***	0.583***	0.100***	0.195***	0.992***
	(0.023)	(0.037)	(0.019)	(0.027)	(0.065)
Observations	1,173	1,173	1,173	1,173	1,173

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; CA=Conservation agriculture; DTM=Drought tolerant maize; INTER=Intercropping; IL=Improved legume; ATET=Average treatment effect on the treated; IPWRA=Regression adjustment with Inverse probability weighting

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Table 5: Impact of extension and credit access regimes on CSA technology adoption PSM

	Propensity score matching estimates (NNM)				
VARIABLES	CA	DTM	INTER	IL	Adoption index
	ATET	ATET	ATET	ATET	ATET
Credit only	0.055	-0.082	0.093	0.020	0.085
	(0.077)	(0.080)	(0.062)	(0.096)	(0.164)
Extension only	0.150***	0.044	-0.070	0.091**	0.215**
	(0.035)	(0.035)	(0.018)	(0.031)	(0.069)
Extension + Credit	0.248***	-0.020	0.035	0.288***	0.551***
	(0.060)	(0.057)	(0.031)	(0.065)	(0.134)
N	1173	1173	1173	1173	1173

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; NNM=nearest neighbor matching; PSM=Propensity Score matching; ATET=Average treatment effect on the treated

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Table 6: Impact of credit and extension regimes by country

	IPWRA Estimates					IPWRA Estimates				
	MALAWI					ZIMBABWE				
VARIABLES	CA	DTM	INTER	IL	Adoption index	CA	DTM	INTER	IL	Adoption index
Credit only	0.108*	0.0424	0.0905	-0.0651	0.170	0.209	-0.162	0.0289	0.348**	0.417
	(0.0648)	(0.0868)	(0.0650)	(0.0709)	(0.177)	(0.137)	(0.154)	(0.0898)	(0.153)	(0.284)
Extension only	0.411***	0.171**	-0.0392	0.180**	0.723***	0.242***	-0.0215	-0.0379*	0.188***	0.355***
	(0.0584)	(0.0689)	(0.0324)	(0.0718)	(0.131)	(0.0489)	(0.0535)	(0.0198)	(0.0446)	(0.107)
Extension & Credit	0.599***	0.0839	0.119	0.395***	1.229***	0.257***	-0.0478	-0.0150	0.324***	0.488***
	(0.0731)	(0.0781)	(0.0729)	(0.0796)	(0.221)	(0.0892)	(0.0906)	(0.0339)	(0.0842)	(0.182)
Potential outcome means	0.0827***	0.529***	0.0999***	0.232***	0.949***	0.154***	0.707***	0.0620***	0.106***	1.038***
	(0.0251)	(0.0456)	(0.0245)	(0.0425)	(0.0800)	(0.0333)	(0.0419)	(0.0177)	(0.0244)	(0.0657)
Observations	572	572	572	572	572	601	601	601	601	601

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; CA=Conservation agriculture; DTM=Drought tolerant maize; INTER=Intercropping; IL=Improved legume; IPWRA=Regression adjustment with Inverse probability weighting

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Table 7: Impact of credit and extension regimes by farmer age group

	IPWRA Estimates					IPWRA Estimates				
	Young					Old				
VARIABLES	CA	DTM	INTER	IL	Adoption index	CA	DTM	INTER	IL	Adoption index
Credit only	0.174*	-0.0521	0.106	-0.168	0.0511	0.0890	-0.0520	0.0431	0.0350	0.128
	(0.101)	(0.113)	(0.106)	(0.170)	(0.269)	(0.0764)	(0.0939)	(0.0597)	(0.0793)	(0.176)
Extension only	0.430***	-0.0386	-0.0470	-0.104	0.197	0.298***	0.111**	-0.0193	0.249***	0.644***
	(0.0960)	(0.119)	(0.0860)	(0.123)	(0.235)	(0.0495)	(0.0555)	(0.0243)	(0.0537)	(0.102)
Extension & Credit	0.704***	-0.144	0.0721	0.173	0.982***	0.439***	0.0963	0.0733*	0.391***	1.001***
	(0.150)	(0.122)	(0.0912)	(0.198)	(0.376)	(0.0691)	(0.0618)	(0.0416)	(0.0614)	(0.167)
Potential outcome means	0.0756*	0.702***	0.144***	0.418***	1.349***	0.123***	0.567***	0.0781***	0.177***	0.933***
	(0.0399)	(0.0677)	(0.0508)	(0.128)	(0.150)	(0.0241)	(0.0455)	(0.0177)	(0.0294)	(0.0706)
Observations	274	274	274	274	274	898	898	898	898	898

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; CA=Conservation agriculture; DTM=Drought tolerant maize; INTER=Intercropping; IL=Improved legume; IPWRA=Regression adjustment with Inverse probability weighting

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Table 8: Impact of credit and extension regimes by Gender of farmer

	IPWRA Estimates					IPWRA Estimates				
	MALE					FEMALE				
VARIABLES	CA	DTM	INTER	IL	Adoption index	CA	DTM	INTER	IL	Adoption index
Credit only	0.127*	-0.00361	0.0701	0.00210	0.196	-0.0741	-0.142	-0.0537	0.579**	0.309
	(0.0653)	(0.0788)	(0.0583)	(0.0635)	(0.158)	(0.0460)	(0.312)	(0.0361)	(0.277)	(0.576)
Extension only	0.340***	0.117**	-0.0548*	0.211***	0.607***	0.261*	0.0612	-0.0328	0.306*	0.596***
	(0.0489)	(0.0544)	(0.0281)	(0.0508)	(0.112)	(0.151)	(0.163)	(0.0406)	(0.175)	(0.222)
Extension & Credit	0.559***	0.0389	0.0587	0.425***	1.113***	0.161	-0.241	0.712	0.147	0.778
	(0.0585)	(0.0617)	(0.0442)	(0.0587)	(0.156)	(0.528)	(0.612)	(0.528)	(0.516)	(1.125)
Potential outcome means	0.113***	0.584***	0.110***	0.198***	1.004***	0.0741	0.476***	0.0537	0.0873	0.691***
	(0.0257)	(0.0416)	(0.0211)	(0.0303)	(0.0752)	(0.0460)	(0.131)	(0.0361)	(0.0565)	(0.165)
Observations	923	923	923	923	923	249	249	249	249	249

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; CA=Conservation agriculture; DTM=Drought tolerant maize; INTER=Intercropping; IL=Improved legume; IPWRA=Regression adjustment with Inverse probability weighting

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Highlights

- Credit and extension access enhance adoption of climate-smart agriculture (CSA) in Zimbabwe and Malawi
- Simultaneous access to credit and extension have far greater impacts on CSA adoption than in isolation
  Joint access to credit and extension have less pronounced impacts in youth and female farmer groups
- Education, access to transport services, land size and income improve simultaneous access to extension and credit
- Gender and youth sensitive policy and institutional strategies are recommended to enhance impact of institutional services on CSA adoption

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