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An Empirical Analysis of Expanding Rice Production in Sub-Sahara Africa

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The Impact of Microcredit on Agricultural Technology Adoption and Productivity: Evidence from Randomized Control Trial in Tanzania

Yuko Nakano* and Eustadius F. Magezi†

Abstract

This paper examines the impact of microcredit on the adoption of technology and productivity of rice cultivation in Tanzania. Collaboratively with BRAC, a globally-known microfinance institution, we offered microcredit specifically designed for agriculture to randomly selected farmers. We estimate the intention-to-treat effect (ITT) as well as the local average treatment effect (LATE) of microcredit, by using the eligibility to the program as an instrumental variable (IV). Overall, we find statistically weak or even null evidence that the BRAC program increases the use of chemical fertilizer. Also, credit use does not result in an increase in paddy yield, profit from rice cultivation, or household income for borrowers. Our results from sub-sample analyses suggest that credit does not increase the fertilizer use by those who have better access to irrigation water as they have already applied the amount of fertilizer near to the recommended level. On the other hand, credit increases the fertilizer use by those who have limited access to irrigation water and have previously used little fertilizer. However, possibly due to the poor yield response to fertilizer, the increase in chemical fertilizer use does not result in higher yield for them. We also observed similar phenomenon for the comparison between trained and non-trained borrowers before the intervention.

Keywords: Microcredit, Technology Adoption, Agriculture, Tanzania, Africa

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1. Introduction

Agricultural development is indispensable for poverty reduction and food security in Sub-Saharan Africa (SSA). The slow growth of crop productivity in SSA is in sharp contrast to the experience of the Asia during the Green Revolution, where there has been a rapid increase in paddy yield due to the diffusion of fertilizer-responsive modern varieties (MVs) of rice (David and Otsuka 1994; Evenson and Gollin 2003). One of the reasons for this low productivity growth in SSA is the low adoption rates of modern inputs, such as chemical fertilizer and MVs. Research also points out that in addition to adopting modern inputs, improving agronomic practice is also important to increase paddy yield in SSA (Nakano et al. 2013; Nakano et al. 2016; Otsuka and Larson 2013; Otsuka and Larson 2016).

Lack of access to credit is often identified as one constraint on the adoption of agricultural technology (Crawford et al. 2003; Croppenstedt et al. 2003; Feder et al. 1985; Guirkinger and Boucher 2008; Morris et al. 2007; Moser and Barrett 2006; Zeller 1998). Poor households without sufficient collateral tend to be excluded from formal financial services, due to high transaction costs and imperfect information, which makes formal banks reluctant to offer services to them (Ghatak 1999; Gíne 2011; Stiglitz and Weiss 1981). As a consequence, poor farmers may be unable to invest in new technology or profitable income generating activities (Conning and Udry 2007).

Microfinance has attracted growing attention as a means of overcoming such situations. Microfinance institutions (MFIs), which are semi-formal financial institutions that offer a wide range of services including collateral-free microcredits, microsavings, and microisunrances, have increased in number and outreach. The number of MFIs has continued to increase and the number of clients who have benefitted from microfinance reached roughly 211 million by 2013 (Microcredit Summit Champaign 2015). Microfinance has generated considerable enthusiasm and hope for ensuring sustainable financial inclusion and poverty alleviation, culminating in the

Nobel Prize for Peace, awarded in 2006 to Mohammed Yunus and the Grameen Bank for their contribution to reducing world poverty.

Accordingly, many studies have been conducted to examine the impact of MF, especially microcredit, on the welfare of the poor in developing countries (e.g. Morduch 1999; Pitt and Khander 1998; Roodman and Morduch 2014; Takahashi et al. 2010; see also Benerjee 2013; Karlan and Morduch 2010; Kono and Takahashi 2010; van Rooyen 2012 for review).[1] Also, an increasing number of studies evaluate the impact of microcredit by conducting randomized control trials (RCT) (Angelucci et al. 2015; Attanasio et al. 2015; Ausburg 2015; Banerjee et al. 2015 a; Banerjee et al. 2015 b; Crépon et al. 2015; Karlan and Zinman 2009; 2010; 2011; 2018; Tarozzi et al. 2015) and by quasi-experimental methods (Kaboski and Townsend 2005; 2012). These studies often examine the effect of microcredit on various outcomes such as consumption, new business creation, and business and household income, as well as other human development indicators including education, health, and women's empowerment (see Bauchet et al. 2011 for a review). Most of these studies show that microcredit increases business investments but has a relatively small impact on income or human development measurements, and thus, microcredit is not a silver bullet for poverty reduction.

However, the number of experimental studies that examine the impact of microcredit on the adoption of agricultural technology and productivity is relatively small. This is partly because most microcredit targets small business holders or entrepreneurs as their borrowers. For example, Giné and Yang (2009) and Karlan et al. (2014) examine the impact of the microcredit with and without microinsurance. Ashraf et al. (2009) also examine the impact of a package of export promotion services with and without credit on the production of export crops and income in Kenya. They found that credit increases the participation in the program but does not translate into higher income. These studies do not, however, examine the sole impact of microcredit on

[1] Here we only focus on the study on microcredit rather than microfinance in general. See Bauchet et al. (2011) for a review on the impact microfinance including microinsurance and microsavings.

agricultural productivity. To our knowledge, the only two studies that examine the direct impact of microcredit on agricultural technology by using RCT are Hossain et al. (2018) and Beaman et al. (2014). Hossain et al. (2018) found that access to credit has positive effects on the adoption of MVs of rice as well as paddy yield, yet does not increase household income or expenditure. Beaman et al. (2014) observed that access to credit increases the input use but does not result in higher net revenue from the crop.

This paper contributes to the literature by conducting RCT to examine the impact of microcredit on the technology adoption and productivity of rice cultivation in Tanzania. Unlike previous studies, we examine the impact of microcredit not only on input use but also the adoption of improved agronomic practices, which are important to increase the productivity and profitability of rice cultivation. Collaboratively with BRAC, a globally-known MFI, we provide microcredit, which is specifically designed for agriculture (referred to as the BRAC program hereafter) to randomly selected farmers in two irrigation schemes. Eligible farmers were invited to a credit program for a loan of about 50USD. Fifty percent of the credit was received as a fertilizer voucher, while the remaining 50 percent was received in cash.[2]

We use two-year panel data, which was collected before and after the intervention. We specifically focus on the impact of microcredit on the adoption of technologies such as modern varieties (MVs), chemical fertilizer, and improved agronomic practices as well as the productivity of rice cultivation. While we randomized the invitation to the microcredit program, participation in the program is not random. Thus, we estimate the intention-to-treat effect (ITT) as well as local average treatment effect (LATE) of microcredit by using the eligibility to the program as an instrumental variable (IV).

[2] As we will discuss later, we provided a basic one-day training for the recipient of the credit on rice cultivation. Our analysis, however, suggests that this training was not effective to the extent that it changes our results.

Overall, we find statistically weak or even null evidence that the BRAC program increases the use of chemical fertilizer. Also, credit use does not result in an increase in paddy yield or profit for borrowers. We conduct subsample analyses comparing borrowers in an irrigation scheme with relatively good access to water to those who are not. We also compare borrowers who have been trained and non-trained before the credit intervention. Our results suggest that credit use does not increase fertilizer use by those who have better access to irrigation water as they had already applied the amount of fertilizer near to the recommended level. On the other hand, credit increases fertilizer use by those who have limited access to irrigation water and had used little fertilizer. However, possibly due to the poor yield response to fertilizer, the increased use of chemical fertilizer does not result in higher yield for them. We also observed similar phenomenon comparing trained and non-trained borrowers before the intervention.

The rest of the paper is organized as follows. Section 2 describes the study site, data collection methods, and implementation of the BRAC program. Section 3 discusses methodology for our analysis. In section 4, we discuss the estimation results on the impact of microcredit. Section 5 presents the conclusion and policy implications.

2. Study Site and Data

2.1 Study Site

Three rounds of surveys were conducted in two irrigation schemes, called Ilonga and Chanzuru, located about 15km from Kilosa town, in Kilosa District, Morogoro Region, Tanzania. By 2013, the total developed area of the Ilonga irrigation scheme was 120 hectares, supporting about 600 households, and the Chanzuru irrigation scheme had 400 hectares of developed area with 725 households. There are two cropping seasons in the study area: the main season from November to May and the short rainy season from July to September. During the main season, farmers grow rice in irrigated plots. They also grow other crops such as maize, beans, sunflower, and sesame in upland plots in both the main and short rainy seasons. Since few farmers grow rice in the short rainy season, our analysis focuses only on rice cultivation in the main season.

Despite the proximity to each other, Ilonga has some unique characteristics in comparison to Chanzuru, including the presence of the Ministry of Agriculture Training Institute (MATI), and the Agricultural Research Institute (ARI-Ilonga). Before microcredit intervention, JICA had also conducted training (called TANRICE training) on rice cultivation technologies in Ilonga in 2008 (Nakano et al. 2018). Furthermore, the Ilonga irrigation scheme is located in the upper streams of the river than Chanzuru. Ilonga has three cemented channels, while Chanzuru has only one channel that is not cemented. The Chanzuru irrigation scheme has no drainage system, which makes it difficult for farmers to control the water availability in their plots as well. Thus, farmers in Ilonga have better access to both training and extension services and irrigation water.

2.2 Data

The data collection was conducted in three rounds of surveys, from 2010 to 2012. The baseline survey was conducted from September to November 2010. In this survey, 412 households were randomly selected from the roster of farmers growing rice in both irrigation schemes. The second survey was conducted from August to September 2011, followed by the intervention of the BRAC program from November 2011 to May 2012. Due to the budget constraint, however, we could reach to only 358 households in the second round of our survey.

During the first and second survey, we ask farmers to identify the most important plot (referred to hereafter as the sample plot). In the sample plot, we collected the detailed information about rice cultivation, and compute variables related to technology adoption, production costs, and productivity. In addition to rice cultivation in the sample plot, other household-level variables including basic household characteristics and income related variables were collected. Summary statistics of the variables used in the analysis are shown in Appendix Table 1.

During the intervention, the 412 households who had been interviewed in the first survey were randomly assigned into two groups. The first group consisted of 208 households which were eligible to the credit from BRAC, and the second group consisted of 204 non-eligible households. The randomization was done at the household level in each village. In 2012, all sample households (i.e., eligible, borrower, non-eligible) were revisited again in a follow-up survey that aimed to collect data to assess the impact of the BRAC program. However, 17 households were not accessible, three of which were eligible and 14 were non-eligible. In addition to this, during our data cleaning, we found seven households who identified as borrowers though they were not eligible. Since this is most likely because of enumeration mistakes, we omitted these households from our sample. In addition to this, we omitted one household with an extreme value in important variables. As a result, our sample size in 2012 becomes 387.

In Appendix Table 2, we estimated an attrition probit model, where the dependent variable is a dummy variable which takes one if observation is included in the sample in 2012. The independent variables are eligibility to the program as well as other household characteristics in 2010. We observe that the eligibility to the program has a positive and significant coefficient, suggesting that eligible farmers were less likely to be attrited from our sample. Since sample attrition did not occur randomly, this can potentially cause biases for our estimates. We will take this problem into consideration in our following analyses.

During the follow-up survey in 2012, we asked farmers in the BRAC program similar questions as the previous survey about the plot, where they apply most of the fertilizer received from BRAC. For those who did not join the BRAC program, we asked about the same plots in the first and second rounds of survey. Thus, our data is not plot-level but household-level panel data. Although we collected the data in three rounds of survey, we utilize the data collected in

2010 and 2012. This is because our analysis is mainly based on the cross-sectional variation created by RCT in 2012 and we use the data in 2010 mostly to control for the baseline characteristics.

2.3 Details of the BRAC program

The details on the microcredit given during the intervention are given here as follows. After randomization, a list of eligible households was handed to the administration of the BRAC Kilosa branch, who were in charge of the rest of the activities. The BRAC community organizer visited eligible households and explained the terms and conditions for borrowing from the BRAC program. If eligible farmers agreed, they could participate in the BRAC program. At the end of consultation, four groups of borrowers whose members were jointly responsible for each other’s loan were formed. The group size is relatively large at 15 to 20 people in each, though it is questionable if this group liability was strictly followed or taken seriously by the farmers.

The total amount of the loan to each borrower was 80,000 Tanzanian Shillings (Tsh) which was approximately equal to 50USD. Borrowers were required to borrow both cash and chemical fertilizer. The amount of loan allowed to be received in cash was Tsh 40,000 (approximately 25USD). Borrowers received money before the beginning of the cultivation season, so that they could use it for hiring agricultural labor or purchasing other inputs. The remaining amount (Tsh 40,000) was received as a fertilizer voucher.[3] The voucher was effective at two fertilizer dealers in the village and farmers could exchange the voucher for fertilizer at the market price. Approximately, farmers could obtain 26kg of UREA by using this voucher. It is

[3] In order to minimize the possibility that credit is used for different purposes other than agriculture, we provided half of the credit as a fertilizer voucher. This would have affected the take-up rate of this program. Note, however, that the take up rate of this project is about 39%, which is not low compared to other microcredit programs, which typically provide loans in cash. It should also be noted that we provide relatively small amount of credit in order to avoid overuse of chemical fertilizer by those who have not adopted fertilizer-responsive modern varieties.

important to note that borrowers had little incentive to side sell fertilizer, as they bought it at market price and have to repay the interest, unless non-eligible farmers were willing to pay higher interest to them. It is also notable that the average number of cultivated rice plots per household is 1.3, while that of maize is 0.3. This suggests that the likelihood fertilizer would be diverted to other plots cultivated by the borrower is low.

The duration of the loan was one cultivating season and the interest rate was 25% (They have to repay Tsh 100,000 after harvest). Understanding that farmers receive most of their income after harvesting, they were required to repay 80% of the total payment including the interest after the harvest. This is a special feature of our program customized for agriculture, as usual microcredit program requires frequent repayment soon after the lending starts.[4] The remaining 20% of the total payment was supposed to be repaid in weekly installments during the cultivation period, so that the basic policy of microcredit of frequent repayment to ensure the reimbursement is still maintained. The self-reported repayment rate was 92.5% at the period of our follow-up survey, which was conducted a few months after the harvesting season.

Before giving loan to farmers, BRAC conducted one-day training on the proper use of fertilizer, modern varieties, and basic improved agronomic practices. The training was given only to farmers in borrower groups. Being absent in the training, however, did not risk farmer's eligibility to continue with a program. Although this could give additional benefit to the borrowers, our main results do not change even if we restrict the sample to those who attended this training, suggesting that this training was not effective to the extent that it impacted our results.

[4] Field et al. (2013) and Takahashi et al. (2017) examine the uptake and the impact of microcredit with and without a grace period for credit in non-agricultural settings.

3. Methodology

We estimate the average effects of the participation in the BRAC program on technology adoption, paddy yield, income, and profit from rice cultivation. Let Y_{1i} be the outcome of household i when they participate in the BRAC program, and let Y_{0i} be the outcome of the same household if they do not participate in the BRAC program. We also assume that D_i is a dummy variable that takes one if a household is a borrower and zero if it is not. Then, the average effect of the credit can be defined as $E(Y_{1i}|D_i = 1) – E(Y_{0i}|D_i = 1)$ or $E(Y_{1i} - Y_{0i}|D_i = 1)$. Here, $E(Y_{0i}|D_i = 1)$ is hypothetical and unobservable as the same household cannot be a borrower and non-borrower at the same time. If the program participation is randomly assigned, however, $E(Y_{0i}|D_i = 1)$ would be equal to $E(Y_{0i}|D_i = 0)$ and we can estimate the average impact of the program as

$$ATT = E(Y_{1i}|D_i = 1) - E(Y_{0i}|D_i = 0).$$

The problem, here, is that although the eligibility to the program can be randomly assigned, we cannot force households to take credit. Thus, borrowing or not is endogenously determined by the households. To cope with this selection problem, we first estimate an intention-to-treat (ITT) effect, which can be written as

$$ITT = E(Y_{1i}|Z_i = 1) - E(Y_{0i}|Z_i = 0),$$

where Z_i is a dummy variable that takes one if a household is eligible to the program and zero otherwise. Although actual participation to the program (D_i) is endogenously determined, eligibility to the program is randomly assigned. Thus, we can get unbiased estimates for ITT. ITT, however, captures the impact of being offered the program, rather than being an actual borrower.

To address this issue, we also estimate the Local Average Treatment Effect (LATE). Let D_{1i} and D_{0i} be the values of D_i when $Z_i = 1$ and when $Z_i = 0$, respectively. Obviously, D_i and Z_i are closely associated with each other because only the eligible households could take credit from BRAC. LATE is the average treatment effect on those who joined the BRAC program because of the eligibility to the program, while they did not do so if they were not, and defined by;

$$LATE= E[Y_{1i} - Y_{0i} \mid D_{1i} \neq D_{0i}] .$$

As Imbens and Angrist (1994) show, if Y_{1i}, Y_{0i}, D_{1i}, and D_{0i}, are independent of Z_i and if $D_{1i} \geq D_{0i}$, for all i (monotonicity), LATE can be estimated as coefficient β in a regression model, $Y_i = \alpha + \beta D_i + \varepsilon_i$, by using Z_i as an IV. Following Frison and Pocock (1992) and McKenzie (2012), we also estimate the Analysis of Covariance (ANCOVA) regression for the robustness check, by including the outcome variable at the baseline as the control variable in estimating both ITT and LATE.

4. Results

4.1 Descriptive Analysis

Table 1 shows the descriptive statistics of the adoption of technologies, paddy yield, income and profit from rice cultivation of eligible and non-eligible farmers, and borrowers. New technologies include the use of modern varieties of rice, the application of chemical fertilizer, improved bund construction, plot leveling, and transplanting in rows. Improved bund construction entails piling soil solidly around the plots, while plot leveling involves flattening the ground for better storage and equal distribution of water on paddy fields. Transplanting seedlings in rows allows rice growers to control plant density precisely and remove weeds easily. Income is defined as revenue[5] minus the paid-out costs of hired labor, rental machinery, draft animals, and other purchased inputs. Profit is defined as revenue minus the paid-out costs and imputed costs of self-produced seeds, family labor, and owned machinery and animals,

[5] When farmers do not sell the product, we impute the value of output by using the average price of the product in the village. We also impute the costs of family labor and owned machinery by using the average wage rate and rental price in the village.

evaluated at village market prices. Profit, thus, can be interpreted as the return on land and management practices.

Eligible and non-eligible famers for the BRAC program were randomly selected. Among eligible farmers, there are farmers who decided to take the loan (referred to as borrowers), and those who opted not to borrow despite being eligible (referred to as eligible non-borrowers). Overall, in our sample, among 205 eligible farmers, 80 farmers actually took a loan, and thus, the take-up rate was about 39%. This is relatively high compared to other microcredit related studies, whose take up rate varies from about 10% to 30% (Angelucci et al. 2015; Banerjee et al. 2015a; Banerjee et al. 2015b; Beaman et al. 2014; Crépon et al. 2015; Hussain et al. 2018; Tarozzi et al. 2015).

We conduct *t*-test comparisons between eligible and non-eligible farmers and between borrowers and non-eligible farmers, whose results are shown by asterisks. In addition to this, we conducted a sub-sample analysis to compare borrower and non-eligible farmers in the Ilonga and Chanzuru irrigation schemes as well as borrowers and non-eligible farmers who have been trained and not before the credit intervention.

First, we find that the chemical fertilizer use, the adoption rate of the improved bund, as well as input costs is significantly higher for borrowers than non-eligible farmers for the total sample. The borrowers on average use 78.0 kg of fertilizer per hectare while non-eligible farmers use 53.2 kg. The borrowers do not achieve, however, higher paddy yield or revenue than non-eligible farmers. The paddy yield for the borrowers is 3.2 tons per hectare while that of non-eligible farmers is 3.1 tons per hectare. As a result, there is no statistically significant difference in profit and income between these two groups. It is also notable that the total labor cost is significantly lower for the BRAC borrowers than non-eligible farmers.

We also compare the paddy yield, the adoption of technologies, and profit of borrowers and non-eligible households in the Ilonga and Chauzuru irrigation schemes. In Ilonga, where farmers have relatively good access to irrigation water, even non-eligible households apply chemical fertilizer of 84.2 kg per hectare while non-eligible farmers in Chanzuru apply only 20.8 kg per hectare on average.[6] The non-eligible famers in Ilonga achieve a paddy yield of 3.8 tons per hectare whereas the paddy yield of Chanzuru is 2.4 tons per hectare. This shows that due to favorable conditions in Ilonga, including better access to irrigation water and extension services, farmers in Ilonga apply more chemical fertilizer and achieve higher yield even without any intervention from BRAC. It is also notable that the adoption rate of modern variety is 39-54% in Ilonga, while that in Chanzuru is between 9-11%. This suggests the possibility that the fertilizer response to yield is lower in Chanzuru than in Ilonga as more farmers are using non fertilizer-responsive traditional varieties.

In Ilonga, borrowers apply 94.3 kg of chemical fertilizer, while non-eligible farmers apply 84.2 kg per hectare, a statistically insignificant difference. On the other hand, in the Chanzuru irrigation scheme, borrowers apply 61.7 kg of chemical fertilizer, whereas non-eligible farmers apply 20.8 kg per hectare. The difference between two groups are statistically highly significant. The paddy yield, however, is not statistically different between borrowers and non-eligible farmers either in Ilonga or Chauzuru. Borrowers in Chanzuru achieve higher profits than non-eligible households due mainly to lower labor costs, while there is no significant difference in profit between borrowers and non-eligible households in Ilonga.

Regarding the comparison between borrowers and non-eligible farmers who were trained and non-trained before the intervention, we observe similar tendency between Ilonga and Chanzuru. Namely, even non-eligible farmers who were trained before apply as much as 94.2 kg of chemical fertilizer per hectare, while non-eligible farmers who were not trained apply only 41.7 kg per hectare. This suggests that trained farmers apply more fertilizer even without any credit intervention than those who were not. Trained borrowers do not apply more fertilizer than trained non-eligible farmers even when they use credit. On the other hand, non-trained

[6] The recommended level of fertilizer application is 125-250 kg per hectare.

borrowers apply more chemical fertilizer than non-eligible farmers by about 33 kg per hectare (41.7 kg per hectare vs. 75.0 kg per hectare). This suggests that credit effectively increases the fertilizer application of those who were not trained before and, thus, have used little fertilizer without credit intervention.

We also show the fertilizer use in 2010 and 2011 for all categories of farmers. We do not observe any significant differences between eligible and non-eligible farmers, which suggest that the balancing is successfully done. Another important point is that there is no significant differences between the fertilizer use in 2011 and that in 2012 for non-eligible farmers. This implies that there is little spill-over or diversion of credit from eligible farmers to non-eligible farmers in 2012 at least in the form of chemical fertilizer. If there is any spill over, the fertilizer use for non-eligible farmers would also increase compared to the last year. We do not observe any significant differences between borrowers and non-eligible farmers in total household income or income from other sources for both total and sub-sample analyses.

4.2 Estimation Results

In order to estimate ITT and LATE on the impact of microcredit, we first examine the balance between eligible and non-eligible farmers of the baseline characteristics by conducting *t*-tests between eligible and non-eligible farmers. As shown in Appendix Table 3, we find no statistically significant difference in terms of household characteristics at the baseline between eligible and non-eligible households, except the value of household assets and the adoption rate of leveling, which are significant at 10%. This suggests that randomization was generally successful and we control for baseline household characteristics and the adoption of technologies at baseline, respectively for ITT and LATE estimation in the following analyses, so that we control for the initial differences in these two variables.

We also present the first stage regression results in Appendix Table 4. Here, the dependent variable is being a BRAC borrower and the main independent variables are the dummy variable which takes one if a farmer is eligible for the BRAC program as well as other household characteristics. We find that our instrument of being eligible (denoted as Z during model specification) has a highly significant coefficient, and thus, can be used as IV of being borrowers. We do not find any significant impact from other baseline household characteristics on being a BRAC borrower.

Table 2 reports the estimation results of ITT and LATE with and without the outcome variable at the baseline. We control for basic household characteristics, including total land holdings (ha), value of household assets (USD), number of adult household members, years of schooling of household head, female household head dummy, and age of household head in all the estimation models. For ITT, we report only the coefficient of being eligible farmers, while the coefficient of being BRAC borrowers instrumented by being eligible farmers are reported for LATE. We report the robust standard error without clustering because we only have two villages and use a randomly assigned variable as IV (Cameron and Miller 2015). Since we have a relatively large number of outcome variables, we also conducted multiple hypotheses testing for significant variables, following Romano and Wolf 2005, whose results are indicated by + in the table.[7]

Both ITT-ANCOVA and LATE-ANCOVA estimates show that the participation in the program increases the amount of chemical fertilizer by about 8-22 kg and this is significant at 10%. This significant effect, however, becomes insignificant after we conduct multiple hypotheses testing. The results of ITT and ANCOVA without outcome variables at the baseline also suggest that there is no significant impact of credit on fertilizer use. There is also no significant treatment effect for the adoption of other technologies such as adoption of MVs,

[7] We classify the variables into following family: (1) modern input use (chemical fertilizer use and the adoption of MVs), (2) adoption of improved agronomic practices (the adoption of improved bund, plot leveling, and transplanting in rows), (3) productivity (paddy yield, revenue, income, and profit of rice cultivation per hectare), (4) costs (total input costs, labor costs, machinery and animal costs per hectare, use of credit other than BRAC).

improved bund construction, plot leveling, or transplanting in rows. Also, all the results show that the participation to the program does not increase paddy yield for borrowers. In terms of revenue, costs, and profit of rice cultivation, we observe that participation in the training significantly decreases the total labor cost; this is still significant even after we consider multiple hypotheses testing.[8] In all other variables, we do not observe any significant treatment effect of being BRAC borrowers.

4.3 Attrition bias and bounds test

Since our sample may suffer from attrition problem, we estimate the lower and upper bounds of our treatment effect by following Karlan and Valdivia (2011). Namely, we examined whether these attritors were the most successful farmers, slightly successful farmers (+ 0.25 standard deviation and 0.1 standard division from non-attired households), slightly less successful farmers (-0.1 standard deviation, and -0.25 standard deviation from non-attrited farmers) or the least successful farmers. We also conduct multiple hypotheses testing here, as we did in Table 2. The results are shown in columns (1) to (7) in Table 3 respectively.[9] We observe that although the effect of borrowing is significant for chemical fertilizer use, it becomes insignificant if we

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[8] The reduction of total labor cost is mainly due to the decreased family labor costs for the borrowers. One possible explanation may be that since borrowers could use credit to invest in other economic activities such as off-farm business, they reallocate their labor from rice cultivation to other activities. Since we do not have any data on family labor use for other activities, it is difficult for us to examine this point empirically. Note, however, that as we will discuss later, there is no impact of credit use on income from other sources, suggesting that such labor reallocation, if any, was not large to the extent that it increases income from different sources.

[9] In Table 3, (1) imputes the minimum value of each variable in the nonattrited treatment distribution to attrited in the treatment group and the maximum value of nonattrited control distribution to attrited in the control group. (2) Imputes the mean minus 0.25 s.d. of the nonattrited treatment distribution to attrited in the treatment group and the mean plus 0.25 s.d. of the nonattrited control detrition to attrited in the control group. (3) Replaces 0.25.s.d. in column (2) with 0.1. s.d. (4) The unadjusted results. (5) Imputes the mean plus 0.10 s.d. of the nonattrited treatment distribution to attrited in the treatment group and the mean minus 0.10 s.d. of the nonattrited control distribution to attrited in the control group. (6) Replaces 0.1.s.d. in column (5) with 0.25. s.d. (7) Imputes the maximum value of each variable in the nonattrited treatment distribution to attrited in the treatment group and the minimum value of non-attrited control distribution to attrited in the control group. We assume all eligible households become borrowers as we cannot predict who would be borrowers among attrited households.

conduct multiple hypotheses testing. We observe a negative and significant effect of credit on total labor costs. Generally, we do not observe any significant effect on other outcome variables except for the first and seventh cases. The results are qualitatively the same as our main estimation results, except for the first and seventh case where we assume that the attritors are the least or most successful farmers. Since it is a strong assumption that all the attritors achieve minimum or maximum value of non-attritors, the results show that our estimates are largely robust even after considering the attrition bias.

4.4 Sub-Sample Analyses

Our estimates from the total sample found weak or even null evidence of an increase in chemical fertilizer and did not observe any significant increase in yield or profit. In order to further examine the impact of credit use, we conduct two types of subsample analyses. One compares the treatment effects in the Ilonga and Chanzuru irrigation schemes separately, while the other compares the treatment effects of those who had received rice related training before the intervention and not. Note that, as we discussed earlier, farmers in the Ilonga scheme enjoy better access to irrigation water, and thus, apply more fertilizer than farmers in Chanzuru even without a credit intervention. Also those who were trained prior to the study apply more than those who were not even if they were non-eligible for the credit program.

As Table 4 shows, borrowers in Ilonga did not increase chemical fertilizer while borrowers in Chanzuru did so by 17 to 42 kg per hectare. The results are significant and robust for both ITT and LATE estimation even after conducting multiple hypotheses testing. On the other hand, we do not observe a significant treatment effect for paddy yield or other technology adoption either in Ilonga or Chauzuru. In our comparison between trained and non-trained farmers, non-trained borrowers increase chemical fertilizer while trained borrowers do not. Neither of them, however, achieve higher yield than the control group.

These results suggest that those who have favorable access to irrigation water and extension services apply large amounts of fertilizer even without credit intervention. Thus, they do not increase chemical fertilizer application even when they receive credit. On the other hand, those who have unfavorable access to irrigation water or extension services apply little fertilizer without credit intervention. The borrowers in those unfavorable area or with limited knowledge on the use of fertilizer increase their use of chemical fertilizer. However, they do not enjoy higher yield possibly because of a low yield response to fertilizer due to the unfavorable conditions. We observed negative impact of credit on income from rice cultivation for trained farmers, for which we do not have a clear explanation.

4.5 Impact on Household Income

We find that borrowers in Ilonga as well as farmers trained before the program do not increase the use of chemical fertilizer by joining the credit program. This suggests the possibility that fertilizer or money borrowed is used for other purposes such as cultivation for other crops and non-farm business. In order to examine such a possibility, we examine the impact of credit on total household income, crop income other than from the sample plot, livestock income, and business and wage income. As you can see from Table 5, credit does not increase income any from these sources. Although there is a possibility that the loan was used for different activities, it was not effective in increasing income from these activities.[10]

[10] Our complementary study suggests that borrowers increase chemical fertilizer use for maize plots and earned higher income from maize in Chanzuru. This increase, however, was not enough to increase total crop income or household income significantly. See Magezi and Nakano (2019) for more detailed analyses on the impact of BRAC program on different sources of income and expenditure.

5. Conclusion

We analyze the impact of microcredit on technology adoption and productivity of rice cultivation by conducting RCT in Tanzania. Using eligibility for the BRAC credit program as an IV, we examine the impact of being a borrower on the adoption of technology and productivity of rice cultivation. Overall, we found weak or even null evidence of an increase in chemical fertilizer and did not observe any significant increase in yield, profit or household income. The insignificant impact of credit on fertilizer use or yield is consistent with the findings of Njeru et al. (2016), who found that credit use did not increase chemical fertilizer or paddy yield in Kenya. Admittedly, however, the statistical power of our analyses is not as high as many other microcredit impact evaluations. Thus, the results should be interpreted with care.

We conduct a sub-sample analyses and compare borrowers and non-borrowers in irrigation schemes with and without good access to irrigation water. We also compare borrowers and non-borrowers who were trained before the intervention and those who were not. Our results show that those who were in the irrigation scheme with good access to water have applied a relatively high amount of chemical fertilizer, which is near to the recommended level, even without credit use. Thus, even after they receive credit, they did not increase the use of chemical fertilizer. Also, those who were trained before the credit intervention apply a relatively large amount of chemical fertilizer and do not increase it even if they join credit program. On the other hand, farmers with relatively unfavourable access to irrigation water or non-trained farmers significantly increase the chemical fertilizer use by using credit. The increased fertilizer use, however, did not results in the increase for yield or profit for these farmers. Although the reason for this is not conclusive, low yield response to fertilizer due to the unfavorable conditions or limited knowledge may be a possible reason, given that the adoption rate of fertilizer responsive MVs is low in these areas. If this is the case, our results support the argument of Kijima and

Otsuka (2010), who emphasize the importance of the extension services prior to the input market development.

Credit also did not increase total household income or income from other sources, such as other crop income, livestock income, and business income. This is consistent with previous experimental studies who found no or little positive impact of agricultural microcredit or microcredit in general on the welfare of the households (Angelucci et al. 2015; Attanasio et al. 2015; Ausburg 2015; Beaman 2014: Crépon et al. 2015; Hossain et al. 2018; Tarozzi et al. 2015). Our results cast doubt on the positive impact of microcredit, even after considering the fungibility, under the circumstances without reclusive economic activities. Combining these results, our study suggests that facilitating access to credit without considering other constraints may not be effective to increase the agriculture productivity as well as the welfare of small-scale farmers.

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Table 1: Paddy yield, technology adoption, factor payments and household income for non-eligible and eligible households and credit borrower

Variable	Total sample			Ilonga		Chanzuru		Trained		Non-trained	
	Non-eligible	Eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower
Use of chemical fertilizer (kg/ha): 2012	53.2	61.3	78.0***	84.2	94.3	20.8	61.7***	94.2	82.1	41.7	75.0***
Use of chemical fertilizer (kg/ha): 2011	50.7	54.1	63.2	86.3	108.7	16.1	20.0	94.7	116.0	40.9	43.0
Use of chemical fertilizer (kg/ha): 2010	44.4	41.0	43.5	74.5	77.7	13.0	9.4	89.2	93.6	30.3	23.0
Modern variety (%): 2012	24.7	23.3	32.7	39.5	54.4	9.3	11.1	43.9	52.3	20.1	23.0
Adoption of improved bund (%): 2012	6.0	7.8	12.5*	7.5	10.0	4.5	15.0**	6.1	13.6	7.0	12.7
Adoption of leveling (%): 2012	38.5	39.0	40.0	33.3	32.5	43.8	47.5	30.3	31.8	43.4	43.6
Adoption of transplanting in row (%): 2012	13.2	13.2	15.0	24.7	25.0	1.1	5.0	27.3	31.8	9.3	7.3
Yield (t/ha): 2012	3.1	3.0	3.2	3.8	3.5	2.4	2.8	4.0	3.3	2.9	3.0
Revenue (USD/ha): 2012	1326.7	1267.6	1330.8	1596.9	1430.1	1044.4	1231.6	1643.1	1373.1	1260.4	1293.2
Income (USD/ha): 2012	896.5	833.1	855.2	1071.6	911.1	713.7	799.2	1163.2	790.2	838.5	876.8
Profit (USD/ha): 2012	401.6	403.8	516.5	625.5	562.7	167.5	470.4**	713.6	460.7	338.6	526.4
Total input costs (USD/ha): 2012	89.0	97.3	118.9**	126.8	156.1**	49.5	81.8***	125.0	159.2	79.1	102.9
Total labor costs (USD/ha): 2012	775.2	705.4*	622.0***	763.1	628.9**	787.8	615.1***	708.2	660.6	791.4	603.3***
Total machinery and animal costs (USD/ha): 2012	61.0	61.2	73.3	81.5	82.4	39.6	64.3	96.3	92.7	51.3	60.6
Use of credit other than BRAC Program (USD): 2012	15.7	18.3	12.2	27.5	18.2	3.4	6.2	22.3	9.1	16.0	13.1

Table 1: Paddy yield, technology adoption, factor payments and household income for non-eligible and eligible households and credit borrower cont.

	Total sample			Ilonga		Chanzuru		Trained		Non-trained	
	Non-eligible	Eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower	Non-eligible	Borrower
Total household income (USD): 2012	888.7	837.3	888.2	790.9	783.1	990.9	993.4	1405.9	1076.4	789.8	830.4
Total crop income (USD): 2012	546.9	549.9	641.6	606.6	604.3	484.6	678.9	681.1	761.1	530.4	598.0
Total livestock income(USD): 2012	34.8	24.2	29.5	37.7	18.1	31.8	41.0	58.9	23.2	32.6	33.6
Business and wage labor income (USD): 2012	307.0	263.2	217.0	146.6	160.7	474.6	273.4	665.9	292.1	226.8	198.8
Observations	182	205	80	93	40	89	40	33	22	129	55

Source: Author.

*** denotes significant at 1%, ** significant at 5%, and * significant at 10% in *t*-test comparison between eligible and non-eligible households and between borrower and non-eligible households.

Table 2: Estimated results on the impact of being a BRAC borrower in 2012

	(1)	(2)	(3)	(4)
		ITT		LATE
VARIABLES	ITT	(ANCOVA)	LATE	(ANCOVA)
Chemical fertilizer use (kg/ha)	8.07	8.77*	20.68	22.47*
	(5.246)	(4.881)	(13.113)	(12.163)
The adoption of modern variety (%)	-0.58	-0.78	-1.49	-2.01
	(3.911)	(3.651)	(9.922)	(9.266)
Adoption of improved bund (%)	2.81	2.94	7.19	7.51
	(2.542)	(2.555)	(6.403)	(6.424)
Levelled plot (%)	-0.14	-1.09	-0.35	-2.80
	(5.006)	(4.990)	(12.675)	(12.664)
Plot transplanted in rows (%)	0.88	0.94	2.26	2.41
	(3.318)	(3.236)	(8.399)	(8.182)
Yield (ton/ha)	-0.15	-0.15	-0.38	-0.40
	(0.175)	(0.168)	(0.445)	(0.428)
Revenue (USD/ha)	-66.98	-67.34	-171.60	-172.54
	(73.290)	(70.468)	(187.054)	(179.406)
Income (USD/ha)	-73.68	-71.04	-188.77	-181.67
	(68.891)	(66.906)	(175.710)	(169.668)
Profit (USD/ha)	-2.25	0.91	-5.77	2.32
	(71.968)	(71.588)	(182.264)	(180.263)

Total input costs (USD/ha)	6.89	6.59	17.66	16.87
	(9.370)	(8.997)	(23.581)	(22.588)
Total labor costs (USD/ha)	-73.56**	-75.19**	-188.45**	-191.91**
	(31.488)+	(31.277)+	(79.474)+	(78.730)+
Total machinery and animal costs (USD/ha)	1.94	3.09	4.96	7.86
	(7.159)	(6.985)	(18.096)	(17.516)
Use of credit other than BRAC Program (USD)	2.31	2.15	5.93	5.51
	(7.191)	(7.120)	(18.239)	(18.001)

Source: Author.

***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parentheses. + p<0.1 in multiple hypotheses testing. We control for household characteristics (total land holdings (ha), value of household asset (USD), number of adult household members, years of schooling of household head, female household head dummy, and age of household head) in all the estimation models. Sample size is 387.

Table 3: Bounds for the IV estimates of the impact of being a BRAC borrower (ANCOVA)

	Lower bounds			Unadjusted	Upper bounds		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Min	0.25 s.d.	0.1 s.d.		0.1 s.d.	0.25 s.d.	Max
Chemical fertilizer (kg/ha)	-27.07*	22.84**	25.53**	23.56**	29.12***	31.81***	46.96***
	(15.20)	(11.11)	(11.12)	(12.004)	(11.19)	(11.27)	(12.31)
Modern variety	-20.77**	-1.44	0.38	-1.99	2.81	4.64	9.81
	(9.49)	(8.26)	(8.23)	(8.972)	(8.22)	(8.24)	(8.36)
Improved bund (%)	-19.59**	4.75	5.86	4.63	7.33	8.44	11.08*
	(8.19)	(5.91)	(5.90)	(6.523)	(5.89)	(5.90)	(6.09)
Plot leveling (%)	-19.94	-5.49	-3.24	-0.56	7.33	2.01	10.82
	(12.23)	(11.66)	(11.63)	(12.726)	(5.89)	(11.65)	(11.91)
Transplanting in row (%):	-25.96***	-4.01	-2.45	-4.15	-0.38	1.17	4.87
	(8.91)	(7.32)	(7.31)	(7.940)	(7.32)	(7.35)	(7.54)
Yield (t/ha)	-2.66***	-0.60	-0.52	-0.56	-0.40	-0.32	0.57
	(0.61)	(0.39)	(0.39)	(0.429)	(0.39)	(0.39)	(0.45)
Revenue (USD/ha)	-1,191.15***	-262.03	-226.38	-227.05	-178.85	-143.21	222.60
	(266.19)	(165.12)	(164.75)	(180.241)	(164.76)	(165.15)	(186.79)
Income (USD/ha)	-1,069.80***	-267.40*	-234.82	-240.00	-191.38	-158.79	280.11
	(236.93)	(157.63)	(157.35)	(173.085)	(157.40)	(157.78)	(187.51)
Profit (USD/ha)	-935.36***	-45.89	-11.56	-27.49	34.21	68.53	563.01***
	(253.65)	(165.10)	(164.93)	(186.909)	(165.16)	(165.67)	(201.92)

Total input costs (USD/ha)	-156.69***	20.32	24.66	30.56	30.46	34.80	73.92***
	(44.75)	(22.04)	(22.02)	(22.843)	(22.04)	(22.10)	(26.05)
Total labor costs (USD/ha)	-571.88***	-211.15***	-197.26***	-180.07**	-178.75**	-164.86**	37.09
	(109.44)++	(71.58)++	(71.35)++	(79.598)+	(71.23)+	(71.27)+	(83.55)
	-49.66**	6.68	9.94	8.30	14.30	17.56	35.45**
Total machinery and animal costs (USD/ha)	(20.33)	(15.81)	(15.78)	(17.424)	(15.79)	(15.83)	(16.69)
Use of credit other than BRAC Program (USD)	-170.60***	1.16	4.38	4.99	8.67	11.89	22.20
	(41.79)	(16.91)	(16.90)	(17.055)	(16.93)	(16.99)	(18.14)

Source: Author.

***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parentheses. ++ p<0.05, + p<0.1 in multiple hypotheses testing. We control for household characteristics (total land holdings (ha), value of household asset (USD), number of adult household members, years of schooling of household head, female household head dummy, and age of household head) in all the estimation models. Outcome variables at baseline are also controlled. Sample size is 412.

Table 4: ANCOVA estimates on the impact of being a BRAC borrower in 2012 (Sub-sample analysis)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ilonga		Chanzuru		Trained		Non-trained	
VARIABLES	ITT	LATE	ITT	LATE	ITT	LATE	ITT	LATE
Use of chemical fertilizer (kg/ha)	3.86	9.65	16.56***	42.20***	-10.92	-18.24	14.03**	37.64***
	(8.096)	(19.797)	(5.626)++	(13.158)+++	(13.682)	(21.018)	(5.573)++	(14.136)++
Modern variety (%)	-4.01	-10.06	1.25	3.18	4.80	8.26	-2.06	-5.55
	(6.252)	(15.615)	(4.004)	(9.957)	(11.010)	(17.439)	(4.016)	(10.720)
Adoption of improved bund (%)	1.20	2.97	3.90	9.79	3.96	6.72	2.76	7.44
	(3.499)	(8.412)	(3.558)	(8.616)	(5.883)	(9.083)	(3.121)	(8.232)
Adoption of leveling (%)	0.31	0.79	0.32	0.82	9.82	16.80	-5.03	-13.60
	(6.933)	(17.000)	(7.250)	(18.251)	(10.896)	(17.636)	(6.037)	(16.153)
Adoption of transplanting in row (%)	-2.02	-5.09	2.38	6.11	4.22	7.08	1.40	3.76
	(6.291)	(15.487)	(1.810)	(4.513)	(10.434)	(16.191)	(3.419)	(9.073)
Observations	194	194	193	193	71	71	278	278

Table 4: ANCOVA estimates on the impact of being BRAC borrower in 2012 (Sub-sample analysis) cont.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ilonga		Chanzuru		Trained		Non-trained	
VARIABLES	ITT	LATE	ITT	LATE	ITT	LATE	ITT	LATE
Yield (ton/ha)	-0.41	-1.04	0.06	0.15	-0.76	-1.27*	-0.12	-0.31
	(0.274)	(0.677)	(0.188)	(0.466)	(0.494)	(0.761)	(0.181)	(0.484)
Revenue (USD/ha)	-178.79	-447.33	28.09	71.57	-319.24	-530.13*	-52.50	-141.73
	(113.446)	(279.252)	(81.261)	(201.018)	(194.027)	(297.883)+	(78.334)	(209.483)
Income (USD/ha)	-174.34	-440.51	5.22	13.27	-408.79**	-686.10**	-33.43	-90.47
	(109.718)	(272.478)	(76.995)	(191.133)	(179.713)++	(282.801)++	(73.696)	(196.585)
Profit (USD/ha)	-126.60	-325.75	109.86	278.37	-268.60	-457.88	43.92	118.34
	(112.748)	(285.305)	(88.887)	(215.390)	(180.412)	(283.671)	(81.882)	(215.436)
Total input costs (USD/ha)	8.96	22.51	8.50	21.50	34.15	57.39	2.82	7.52
	(16.512)	(40.355)	(7.704)	(18.608)	(34.302)	(54.077)	(8.963)	(23.340)
Total labor costs (USD/ha)	-62.24	-158.52	-77.21	-196.23*	-91.93	-158.36	-91.37**	-245.47***
	(43.140)	(107.424)	(47.288)	(116.443)	(73.318)	(118.249)	(36.135)++	(95.237)++
Total machinery and animal costs (USD/ha)	-5.73	-13.92	9.53	24.24	-0.67	-1.18	2.92	7.86
	(10.329)	(24.590)	(9.587)	(23.826)	(21.517)	(34.884)	(7.224)	(19.096)
Use of credit other than BRAC Program (USD)	-0.18	-0.45	7.85	19.95	-2.14	-3.66	0.03	0.09
	(12.525)	(30.708)	(5.534)	(14.126)	(11.944)	(18.878)	(8.920)	(23.683)
Observations	194	194	193	193	71	71	278	278

Source: Author.

***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parentheses. +++ p<0.01, ++ p<0.05, + p<0.1 in multiple hypotheses testing. We control for household characteristics (total land holdings (ha), value of household asset (USD), number of adult household members, years of schooling of household head, female household head dummy, and age of household head in all the estimation models.) Outcome variables at baseline are also controlled.

Table 5: ANCOVA estimates on the impact of the BRAC credit program on household income

	Total Sample		Ilonga		Chanzuru		Trained		Non-Trained	
	LATE	ANCOVA	LATE	ANCOVA	LATE	ANCOVA	LATE	ANCOVA	LATE	ANCOVA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Total household income (USD)	7.35	-18.94	374.43	332.44	-504.41	-513.20	-678.55	-653.27	279.75	271.00
	(334.549)	(333.139)	(446.176)	(444.451)	(480.192)	(478.769)	(699.096)	(712.574)	(378.571)	(374.233)
Total crop income (USD)	-34.61	-88.45	-89.14	-137.50	-28.79	-92.81	53.59	-19.23	-86.54	-117.93
	(132.919)	(124.861)	(197.373)	(183.677)	(169.426)	(156.734)	(226.155)	(213.550)	(154.035)	(146.257)
Total livestock income(USD)	-22.32	-20.70	-50.52	-48.14	-3.28	-1.78	-55.70	-55.16	-6.85	-7.16
	(21.938)	(21.838)	(37.010)	(36.792)	(28.791)	(28.756)	(35.392)	(34.547)	(28.434)	(28.086)
Business and wage labor income (USD)	64.29	62.64	514.09	494.28	-472.33	-471.60	-676.43	-553.49	373.14	377.49
	(292.410)	(289.917)	(395.245)	(393.042)	(415.351)	(414.842)	(631.563)	(590.268)	(332.343)	(329.332)

Source: Author.

***p<0.01, **p<0.05, *p<0.1. Robust standard errors in parentheses. We control for household characteristics (total land holdings (ha), value of household asset (USD), number of adult household members, years of schooling of household head, female household head dummy, and age of household head in all the estimation models.) Outcome variables at baseline are also controlled. Sample size is 387.

Appendix Table 1: Summary Statistics

VARIABLES	Mean	S.D.	Min	Max
Number of adult household members: 2010	2.76	1.35	1.00	11.00
Total land holdings (ha): 2010	0.37	0.88	0.00	12.55
Value of household assets (USD): 2010	361.00	570.90	10.00	7577.00
Ilonga village: 2010	0.50	0.50	0.00	1.00
Age of household head: 2010	47.81	14.68	20.00	87.00
Female household head (dummy): 2010	0.21	0.41	0.00	1.00
Years of schooling of household head: 2010	5.91	2.90	0.00	16.00
Use of chemical fertilizer (kg/ha): 2012	57.51	60.06	0.00	247.50
Use of chemical fertilizer (kg/ha): 2010	42.60	61.16	0.00	370.60
Use of chemical fertilizer (kg/ha): 2011	52.53	64.20	0.00	370.60
Adoption of improved bund (%): 2012	6.98	25.51	0.00	100.00
Adoption of leveling (%): 2012	38.76	48.78	0.00	100.00
Adoption of transplanting in row (%): 2012	13.18	33.87	0.00	100.00
Modern variety: 2012	23.98	40.44	0.00	100.00
Yield (t/ha): 2012	3.05	1.85	0.00	10.63
Revenue (USD/ha): 2012	1295.00	769.80	0.00	4723.00
Income (USD/ha): 2012	863.00	700.80	-985.10	3743.00
Profit (USD/ha): 2012	402.70	740.00	-1442.00	3615.00
Total input costs (USD/ha): 2012	93.38	99.66	0.00	777.20
Total labor costs (USD/ha): 2012	738.20	307.80	0.00	2153.00
Total machinery and animal costs (USD/ha): 2012	61.08	73.62	0.00	305.30
Use of credit other than BRAC Program (USD): 2012	17.09	68.31	0.00	666.70
Total household income (USD): 2012	861.50	1314.00	-337.20	11386.00
Total crop income (USD): 2012	548.50	531.40	-337.20	3414.00
Total livestock income (USD): 2012	29.20	87.55	0.00	848.00
Business and wage labor income (USD): 2012	283.80	1160.00	-84.00	10533.00

Source: Author.

Sample size is 387.

Appendix Table 2: Attrition probit in 2012

VARIABLES	Non-attired in 2012
Eligible	1.030***
	(0.231)
Ilonga village: 2010	-0.072
	(0.208)
Total land holdings (ha): 2010	-0.111
	(0.094)
Value of household asset (thousand USD) :2010	0.044
	(0.147)
Number of adult HH members: 2010	-0.021
	(0.070)
Years of schooling of HH head: 2010	-0.025
	(0.030)
Female household head (dummy): 2010	-0.240
	(0.262)
Age of HH head: 2010	0.005
	(0.009)
Constant	1.337***
	(0.465)
Observations	412

Source: Author.

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

Appendix Table 3: Balancing test between eligible and non-eligible households

	Non-eligible	Eligible
Household Characteristics		
Total land holdings (ha): 2010	0.33	0.40
Value of household asset (USD): 2010	412.63	315.19*
Number of adult household members: 2010	2.83	2.70
Years of schooling of household head: 2010	5.96	5.86
Female household head (dummy): 2010	0.21	0.20
Age of household head: 2010	48.70	47.01
Yield & Technological adoption		
Yield (t/ha): 2010	2.21	2.20
Use of chemical fertilizer (kg/ha): 2010	44.39	41.00
Modern variety: 2010	18.16	18.67
Adoption of improved bund (%): 2010	8.24	5.85
Adoption of leveling (%): 2010	64.84	72.68*
Adoption of transplanting in row (%): 2010	20.33	18.54
Factor Payment		
Revenue (USD/ha): 2010	637.91	630.44
Total input costs (USD/ha): 2010	53.38	52.35
Total labor costs (USD/ha): 2010	748.59	752.91
Total machinery and animal costs (USD/ha): 2010	25.72	20.81
Income (USD/ha): 2010	417.26	411.15
Profit (USD/ha): 2010	-180.49	-191.43
Use of credit other than BRAC Program (USD): 2010	9.27	18.67
Observations	182	205

Source: Author.

*** denotes significant at 1%, ** significant at 5%, and * significant at 10% in *t*-test comparison between eligible and non-eligible households.

Appendix Table 4: Results of first stage regression on being a BRAC borrower

	(1)
VARIABLES	BRAC borrower (dummy): 2012
Eligible for BRAC program (dummy): 2012	0.390***
	(0.035)
Ilonga village: 2010	0.002
	(0.036)
Total land holdings (ha): 2010	0.007
	(0.026)
Value of household asset (1000 USD)	0.034
	(0.027)
Number of adult household members: 2010	-0.007
	(0.012)
Years of schooling of household head: 2010	-0.001
	(0.007)
Female household head (dummy): 2010	-0.030
	(0.046)
Age of household head: 2010	-0.001
	(0.001)
Constant	0.058
	(0.087)
Observations	387
Adjusted R-squared	0.220

Source: Author.

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

Abstract(in Japanese)

要約

本研究はマイクロクレジット（小規模無担保融資）が稲作技術の採用および生産性に与える影響をタンザニアで行われたランダム化比較実験のデータを用いて検証する。世界的なマイクロクレジット機関である BRAC と共同で農業向けのマイクロクレジットをランダムに選択された農家に提供し、intention-to-treatment effect（ITT）および local average treatment effect（LATE）の推計を行った。その結果、マイクロクレジットは化学肥料投入量、単位面積当たりの収量および収益に統計的に有意な影響を与えないことが分かった。さらに、比較的よく整備された灌漑地区とそうでない灌漑地区を比べた結果、比較的よく整備された灌漑施設では、もともとある程度肥料投入量が多く、農家はクレジットを用いても施肥量を増やさないことが明らかになった。また、灌漑の整備が十分でない地区では、近代品種の普及が進んでおらず、肥料反応性が低いため、クレジットによって施肥量は増えるが、それが生産性の大幅な向上にはつながっていないことが示された。実験以前に農業研修を受けたことがある農家とそうでない農家の比較においても、同様の結果が確認された。

キーワード：マイクロクレジット、技術普及、農業、タンザニア、アフリカ

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