Case 3:

The Determinants of Technology Adoption: The Case of the Rice Sector in Tanzania

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Abstract

Using an extensive household-level data set collected in Tanzania, this paper investigates the determinants of technology adoption in rice cultivation by focusing on the role of credit. We find that credit enhances fertilizer use and the adoption of labor-intensive agronomic practices such as transplanting in rows, for which monitoring of hired labor is easy. We also find that new technologies are adopted more widely in irrigated areas and small-scale farmers are not at a disadvantage. Based on these findings, we argue that with appropriate policies including credit, a rice Green Revolution can improve the productivity of small-scale farmers in Tanzania.

Keywords: technology adoption, Green Revolution, Sub-Saharan Africa, Tanzania

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1. Introduction

Agriculture development is important for poverty reduction and food security in Sub-Saharan Africa (SSA) (World Bank 2008). Among major cereals grown in the region, the importance of rice is now increasing rapidly (Balasubramanian et al. 2007). Total milled rice production in SSA increased from 2 million tons in 1961 to 16 million tons in 2009. At the same time, milled rice imports into SSA increased from 0.5 million tons in 1961 to 10 million tons in 2009 due to insufficient domestic production to meet the growing demand (Otsuka and Kijima 2010; Seck et al. 2010). So far, the increase in rice production is mainly due to the expansion of cultivated areas, while the paddy yield in African countries has grown slowly from around 1.5 to 2.5 tons per hectare over 50 years (FAO 2012).[1] Since the population continues to grow rapidly in SSA, and arable land per agricultural population has started to decline, improving productivity is regarded as a key to boosting domestic rice production and to ensuring food security.

One possible strategy for achieving productivity improvement is to seek a rice Green Revolution in SSA (Spencer 1994; Otsuka and Kalirajan 2005; Otsuka 2006; World Bank 2008). The Asian Green Revolution can be characterized as an increase in paddy yield through the diffusion of high-yielding modern varieties (MVs) together with an increase in chemical fertilizer application and the adoption of better crop and water management practices, such as bund construction and leveling of plots, along with transplanting in rows (Evenson and Gollin 2003). Emerging cases from the Sahel in West Africa show that this style of cultivation achieves yields of 3 to 5 tons per hectare, which is comparable to yields in Asian countries (Nakano et al. 2011). This implies that the potential for a rice Green Revolution is high in SSA. Therefore, it is important to investigate the current status of these technologies in SSA and the determinants of their adoption. However, most existing studies are case studies based on data from areas with particular production and socioeconomic conditions; thus, they do not reveal how a rice Green Revolution can be realized beyond their case study areas (Diagne 2006; Sakurai 2006; Kijima et al. 2010; Kajisa and Payongayong 2010).

In order to draw lessons on how to realize a Green Revolution in SSA, this paper investigates the strategies for rice productivity improvement

1. Note that this figure is based on FAO statistics, which include northern African countries. Paddy yields in northern African countries are much higher in general than those in SSA countries.

in Tanzania, the largest rice producing country in East Africa, by using an extensive household-level data set collected in 2009. The situation of rice production in Tanzania is largely similar to Africa as a whole: the paddy yield is stagnant while arable land per agricultural population is declining due to rapid population growth (FAO 2012; United Republic of Tanzania 2009). Therefore, increasing the yield is critical for further increasing production in the country. Our survey is the first effort to collect detailed information on rice farming households in the major rice-growing regions of the country. This paper gives a nationally representative picture of Tanzania's rice sector, beyond the snapshots of particular places provided by existing case studies (Meertens et al. 1999; Ngailo et al. 2007). To the authors' knowledge, this is the first such attempt not only in Tanzania but also among the East African countries.

Using this unique data set, we examine the determinants of the adoption of MVs, chemical fertilizer, and improved agronomic practices, including construction of bunds, leveling of plots, and transplanting in rows, which we regard as the key components of the Asian Green Revolution. We start with a description of the current status of farming practices and the adoption of these technologies, because little is known yet about rice farming practices in the country. We then examine the circumstances under which new technologies become more likely to be adopted, by particularly focusing on the role of credit in technology adoption. This aspect is crucially important, because emerging empirical studies point to the lack of credit access as being a key constraint for the adoption of new agricultural technologies (Feder et al. 1985; Carter 1989; Gine and Klonner 2005; Moser and Barrett 2006; Miyata and Sawada 2007; Foster and Rosenzweig 2010). Since we use a single-year cross-sectional data set, our analyses basically rely on reduced-form and instrumental variable (IV) approaches to avoid statistical problems due to self-selection and reverse causality in the adoption of modern technologies and practices. Through these analyses, we believe that this paper contributes to a better understanding of the current status of rice farming in Tanzania and possible strategies for future productivity improvement.

The rest of the paper is organized as follows. Section 2 explains the data set. Section 3 explains our hypotheses, followed by the descriptive analyses in Section 4. Sections 5 and 6 present the results of the statistical analyses on, respectively, the determinants of access to credit and technology adoption. The paper ends with the conclusions in Section 7.

2. The data

In Tanzania, rice is cultivated in three agro-ecological zones, namely, the Eastern Zone, Southern Highland Zone, and Lake Zone. In order to obtain a general picture of rice cultivation in the whole country, we covered all three zones. We chose one representative region from each zone: the Morogoro region from the Eastern Zone, the Mbeya region from the Southern Highland Zone, and the Shinyanga region from the Lake Zone (Figure 1). The sample regions are the major producers of rice, and they produce nearly 40% of the rice grown in the country. We can regard our survey as being nationally representative in terms of rice production. In each region, we have selected two major rice-growing districts: Kilombero and Mvomero in the Morogoro region; Kyela and Mbarali in the Mbeya region; and Shinyanga Rural and Kahama in the Shinyanga region.

In our sample area, most of the rice is grown under irrigated or rain-fed lowland conditions and upland rice cultivation is rarely observed. Therefore, we chose the sample villages by stratified random sampling on the basis of the number of rice-growing villages under irrigated and rain-fed conditions. For this purpose, we relied on the 2002-03 agricultural census in each region. In total, we selected 76 villages in six districts as our sample villages. In each village, we randomly sampled 10 households, and generated a total sample of 760 households. The survey was conducted from September 2009 to January 2010. We collected two types of data: village-level data and household-level data. The former was collected by a group interview with village key informants, whereas the latter was collected by an individual interview. During the individual interviews, farmers were asked to identify their most important rice plot and asked in detail about their practices of rice cultivation on that plot, which we call a sample plot hereafter.[2] Figure 1 shows the location and irrigation status of our sample plots. For our analyses, we dropped 64 households that did not grow rice either because they did not have plots suitable for rice cultivation or their plots did not receive enough rainfall or irrigation water in 2009. We also dropped outliers and some observations that had missing values in the key variables, and our effective sample became 672.

2. Our data show a higher proportion of irrigated plots in the sample plots than in the other plots. The average paddy yield for the sample plots is 2.2 t/ha while that for the other plots is 1.8 t/ha. The adoption rate of MVs is also statistically higher for the sample plots than the other plots. Thus, we have to be careful in interpreting the results, as the data are not representative of all the plots.

3. Hypotheses

The Asian-style rice Green Revolution can be characterized by the adoption of a set of new technologies. The set of new technologies can be classified into two components: modern inputs and improved practices. Modern inputs include fertilizer-responsive high-yield MVs as well as chemical fertilizer, while improved practices include bund construction and leveling of plots for better water management, and transplanting in rows for better crop management. Henceforth, we use the term "the adoption of new technologies" when we refer to the progress of all these components; otherwise, we use the name of the respective components.

In our analyses, we first investigate what factors underlie the adoption of these technologies. Relying on the past empirical literature, we particularly focus on the role of credit (Feder et al. 1985; Carter 1989; Moser and Barrett 2006; Foster and Rosenzweig 2010). We argue, however, that the importance of credit can differ for different technologies and practices. In order to adopt MVs, farmers have to buy seed when they switch varieties, but usually they self-produce it several times until the seed performance declines significantly. Hence, credit may have a limited impact on the adoption of MVs. On the other hand, farmers need cash on hand to purchase chemical fertilizer to the extent that the credit market is malfunctioning.[3] We expect that those who can access credit or those who can self-finance can adopt fertilizer.

Improved practices, including bund construction, plot leveling, and transplanting in rows, are all labor intensive. Of these practices, it is easy for farmers to monitor if transplanting in rows is done properly. In this case, access to credit would have a positive impact on the adoption of transplanting in rows as farmers can rely on hired agricultural labor. On the other hand, it is difficult to monitor hired labor to check whether they properly expend the expected effort for bund construction and leveling of plots. For these practices, farmers are not inclined to rely on hired labor (Otsuka 2007), and thus credit may not have a strong impact.

4. Descriptive analyses

This section aims to examine the current status of rice cultivation in Tanzania and the possible constraints on the adoption of modern

3. Seeds are a more expensive input than fertilizer as the average cost of purchased seed is 20 USD, and that of purchased chemical fertilizer is 80 USD / ha for those who purchased inputs.

technologies. Table 1 summarizes the basic statistics of rice cultivation in the sample regions in Tanzania. In each region, we classify the sample plots into rain-fed or irrigated. The share of irrigated plots in the entire sample is 22.6% (152 of 672 observations). The overall average yield is 1.8 t/ha under rain-fed conditions and 3.7 t/ha under irrigated conditions, resulting in 2.2 t/ha as the overall average.[4] Focusing only on the top 25% of high-yield farmers, they achieve 5.9 t/ha in irrigated areas and 3.7 t/ha even under rain-fed conditions. These facts imply a high potential for both irrigated and rain-fed rice cultivation in Tanzania even though the overall average is not high, especially in the rain-fed areas. A critical research issue is how to realize the potential yield.

To gain insight into the emergence of a rice Green Revolution in Tanzania, we first explore the application of modern inputs by irrigation status and region. The share of MVs is merely 7.1% in rain-fed areas and 28.7% in irrigated areas on average. However, in the irrigated area in Morogoro, the share of MVs is 87.5%. This is consistent with the experience of Asia, where farmers tend to adopt MVs in more favorable areas (David and Otsuka 1994). In Mbeya region, which is famous for its aromatic rice, few farmers adopt MVs even in irrigated areas presumably because of their preference for local aromatic varieties over MVs.

In irrigated areas farmers apply a moderate amount of fertilizer (32.2 kg per ha), partly because irrigation water and chemical fertilizer are complements. However, in general, chemical fertilizer application does not reach the level recommended by agronomists (125-250 kg of urea per ha). Turning now to the improved practices, all practices are more widely adopted in irrigated areas than in rain-fed areas. Among them, transplanting in rows, which is a common practice in Asia for easier weeding and harvesting, is still not popular in Tanzania, and only 28.9% of farmers adopt transplanting in rows even in irrigated areas.

Next, we examine the possible constraints on the adoption of modern technologies. First of all, we explore the role of credit in financing the cost of cultivation. In rice farming, unless farmers have sufficient funds on hand, one way to finance paid-out costs is to borrow money from formal or informal sources. In Tanzania, a formal source available in rural areas is a micro-finance organization called a Savings and Credit

4. In the household interviews, we asked the farmers to report their harvest in terms of the number of bags they use to store the paddy rice, and then convert it into kilograms. To compute the yield, the total harvest is divided by the size of plot reported in the interview.

Cooperative Society (SACCOS).[5] Many informal sources also exist, such as traders, rice millers, and moneylenders, as well as family, relatives, and friends. The other way to handle the paid-out cost in farming is to postpone the payment of fees or wages until the time of harvesting. We can regard this, too, as a kind of credit arrangement that relies on an informal agreement between resource sellers and buyers.

It is worth exploring what types of farmers use which kinds of credit arrangements and what type of farmers cannot use any kind of credit. To shed light on this subject, Table 2 shows village- and household-level characteristics by credit status. During the interviews, we asked farmers whether they used credit for rice cultivation in the sample plot or for any other purpose, including rice cultivation in other plots. If they answered that they did not use credit at all, we also asked the reason why they did not use credit. Based on this information, we classified the credit status of farmers into four categories: (1) farmers using credit or making payment after harvesting rice in the sample plot (credit user for rice cultivation in sample plot), (2) farmers using credit for any other purpose except for rice in the sample plot (credit user for other purposes), (3) farmers who do not use credit because they do not need it (credit non-needy), and (4) farmers do not use credit although they need it (involuntary non-credit user).

A discernible difference in terms of access to credit is observed between credit users and non-users. The credit users have better access to SACCOS than non-users. The share of households in a village that has at least one SACCOS is 35.1% for credit users for rice cultivation in sample plots and 51.4% for credit users for other purposes, while it is 21.3% for involuntary non-credit users. The existence of private moneylenders and other credit organizations in the village for credit users for rice cultivation in sample plots (51.4%) is almost the same as that for involuntary non-credit users (54.0%). This may be because farmers do not use credit from private moneylenders for agricultural purposes due to high interest rates. The distance from the district capital is 68.7 km on average for credit users for rice cultivation while it is 53.8 km for involuntary non-credit users. This implies that credit users do not necessarily live in a village that is near the district capital with better access to the market. The share of irrigated plots is higher for credit users in sample plots (51.4%) than it is for those who are in the other

5. Savings and Credit Cooperative Societies (SACCOS) are rural governmental or non-governmental organizations that provide micro-finance at the village or ward level. Some of them function as mutual savings and credit societies for rural people.

categories. As discussed with reference to Table 1, farmers in irrigated areas use more inputs and adopt more labor-intensive practices, resulting in higher demand for credit in irrigated areas. Any types of farmers who use credit and who do not need credit show higher asset value than involuntary non-credit users (0.7 million Tanzanian shillings), which suggests that wealthy farmers have better access to credit or can self-finance expenditures.

How does the credit constraint affect the adoption of technologies? Table 3 compares the adoption of modern inputs and improved practices by credit and irrigation status. Because of the fungibility of credit, here we classify farmers into three categories: credit users, including credit for both rice and non-rice purposes; those who do not use credit because they do not need it (credit non-needy); and those who do not use credit although they need it (involuntary non-credit users). The table also shows the results of *t* tests, comparing between the involuntary non-credit users and either of the other two categories. First of all, under rain-fed conditions, there is little difference in the adoption of technologies among credit users, credit non-needy households, and involuntary non-credit users, except that credit users adopt bund construction slightly more often than involuntary non-credit users. Moreover, regardless of the credit status, adoption of new technology is low. The returns to adoption are lower under rain-fed conditions than in irrigated areas because modern inputs are complementary to irrigation water, and some improved practices such as transplanting in rows are difficult to apply when there is no water control.

Turning now to irrigated areas, a clear difference among the three categories is observed for some technologies. We observe that those who use credit apply more chemical fertilizer than the other categories of farmers. Credit users in irrigated areas apply 47.8 kg of fertilizer per hectare whereas involuntary non-users apply 27.2 kg. Note also that the adoption rate of MVs is not higher for credit users than it is for involuntary credit non-users. Between credit users and involuntary non-users, the adoption of bund construction is slightly higher for credit users in irrigated areas. We do not observe a large difference in the levels of adoption of plot leveling (79.4 and 73.4) and transplanting in rows (29.4 and 28.7).

We also show the paid-out costs of rice cultivation in the lower part of Table 3. Although the difference is not statistically significant, total paid-out costs of agricultural labor are higher for credit users than for involuntary non-credit users. Total paid-out costs to hire labor are 241.5

USD per hectare for credit users in irrigated areas and 122.8 USD in rain-fed areas, while they are 213.0 USD in irrigated areas and 101.9 USD in rain-fed areas for involuntary non-credit users. Among these costs, the paid-out costs of hiring labor for leveling are very small (0.2-4.4 USD per hectare) and there is no large difference among credit users and non-users. On the other hand, the paid-out cost of transplanting is significantly higher for credit users (59.0 USD per hectare) than for involuntary non-credit users (42.6 USD). These results suggest that farmers are inclined to hire more agricultural labor to do transplanting, for which monitoring of hired labor is relatively easy, than to level plots. In fact, our data show that the share of hired labor in the total number of hours spent for leveling is 26%, while it is 54% for transplanting. Farmers could be able to hire more agricultural labor to adopt transplanting in rows by using credit. Note, however, that hired labor is not used for plot leveling not because it does not require labor input. In our field interviews, most farmers claimed a lack of labor or traction power to level their plots.

5. The determinants of credit use

(a) Methodology and variable construction

This section statistically examines the determinants of credit status, by applying a multinominal logit model. The credit status variable takes 1 if farmers use credit for any purpose, and 2 if they do not use credit because they do not need it. The base category is that of farmers who do not use credit although they need it (involuntary non-credit users). We include district dummies in model (1) and village dummies in model (2).

The village-level explanatory variables consist of the existence of SACCOS in the village (dummy) and the existence of private moneylenders and other credit organizations in the village (dummy) to capture the supply-side factors of credit. We also include the distance to the nearest extension office (km) to control access to rice-related training. We control the distance from the district capital (km), the existence of a seed market in the village (dummy),[6] and access to a fertilizer market in the village (dummy) in order to capture market access to the various inputs. We also include the average male agricultural wage rate in the

6. During the village-level interviews, farmers were asked about the number of fertilizer dealers and rice seed dealers accessible from the village. We take access to a seed market as 1 if the answer is more than or equal to 1.

village measured in terms of kg of paddy, which may have a positive impact on credit use because the costs of rice cultivation increase when the agricultural wage rate is higher.

To capture plot characteristics, we include a dummy variable, which takes 1 if the plot is irrigated, and the size of the sample plot (ha). We also include the size of other lowland plots (ha) and the size of upland plots (ha) to capture the land endowment of households, the value of household assets (in million Tanzanian shillings), and the number of cows and bulls owned by the household to capture the influence of physical asset endowment. To capture the impact of human capital endowment, we use the number of adult household members older than 15, the age of the household head, the average years of schooling of adult household members, a dummy for a female-headed household, and experience in rice production in the last five years.

(b) Regression results

The regression results of the determinants of credit status are presented in Table 4. Model (1) shows that the existence of SACCOS apparently increases credit use. Note that, although the credit may not be used directly for the sample rice plots, due to the fungibility of credit, it could still have an impact on rice farming of sample plots. The dummy variable, which takes 1 if the plot is irrigated, has a positive and significant coefficient for being credit non-needy. Due to the high productivity of rice cultivation in previous years, farmers may not need to rely on credit to finance the expenditure. The size of the plots owned in upland areas and household assets have positive and significant coefficients for being credit non-needy, which is consistent with our intuition that wealthy farmers do not need credit. The age of household head significantly decreases the probability of being credit non-needy. The experience in rice production in the last five years significantly increases the probability of being credit non-needy, suggesting that experienced farmers can self finance the expenditure.

6. Determinants of technology adoption

(a) Methodology and variable construction

This section investigates the determinants of the adoption of technologies. The dependent variables are the adoption of MVs (dummy variable takes 1 if adopted), chemical fertilizer use (kg/ha), and the adoption of bund construction, leveling of plots, and transplanting in rows (dummy variable takes 1 if adopted). Similar to the previous section, we first estimate reduced-form regressions for each technology with the same exogenous variables as the credit status model, including district and village dummies in models (1) and (2), respectively. We apply the Tobit estimation method to estimate the chemical fertilizer model since many observations are censored at zero. For the other models, we apply probit or OLS estimation methods.[7]

In model (3), we include the variables of being a credit user and that of being credit non-needy and estimate the model using the same estimation method as the reduced form regression. Since farmers decide if they use credit or not by themselves, these variables can be endogenously determined. In order to circumvent the possible endogeneity biases, we also estimate models using an instrumental variable (IV) method. Although both being a credit user and being credit non-needy may be endogenous variables, our models suffer a weak instrument problem when we treat both variables as endogenous in a single equation. Thus, we instrument the variable of being a credit user by using the existence of SACCOS in the village and the existence of private moneylenders and other credit organizations in the village as instrumental variables in model (4).[8] In this model, we compare credit users with both voluntary and involuntary non-credit users. In model (5), we include the variable of being an involuntary credit user and instrument it by using the same instrumental variables as model (4).[9,10]

7. Since many farmers have not yet adopted these technologies, the probit model suffers the problem of perfect prediction by village dummy variables, resulting in too few remaining observations for the analysis. In order to avoid this problem, we estimate the linear probability model by applying the OLS method for village fixed effect models. For the adoption of MVs, we apply OLS to both district and village fixed effect models for the same reason.

8. In our field interviews, we did not find strong evidence that the establishment of a SACCOS is strongly associated with rice cultivation potential. Rather, the aim of SACCOS is to meet multiple kinds of demands for credit. In fact, our data show that SACCOS are the source of 33.7% of total loans and 50.0% of agricultural loans, including loans for non-rice purposes. We also tried an over-identification test, which partially justifies the validity of SACCOS and other variables as instrumental variables for credit use as we discuss below.

9. We also estimate the just-identified model by using only the existence of SACCOS in the village as an instrumental variable both for models (4) and (5). We also estimate models (4) and (5) by using the limited information maximum likelihood method. Both results are largely the same as the reported results.

10. Although the results are not shown, both the existence of SACCOS and the existence of private moneylenders and other credit organizations have negative and significant coefficients on being an involuntary credit non-user when we estimate the first stage regression with the same exogenous variables as the credit-status model.

We compare the involuntary non-credit user, who can be considered as most seriously credit constrained, with the other two categories of farmers including credit users and credit non-needy farmers in model (5). We would interpret credit as having a positive impact on the adoption of technologies when we observe a negative coefficient of being an involuntary credit non-user in model (5).

Table 5 shows the regression results for the adoption of MVs. Since the endogeneity test does not reject the null hypotheses that the variable of being a credit user is exogenous, we mainly rely on the OLS model shown in column (3) for our interpretation. Note, however, that the first-stage *F* test is highly significant, and the over-identifying test does not reject its null hypothesis, indicating that our IV models are validly estimated in models (4) and (5).

The existence of SACCOS does not have a positive and significant coefficient in model (1). Furthermore, the variable of being a credit user does not have a significant coefficient in model (3). The results of the IV models are also consistent with this result and find no significant impact of being a credit user or being an involuntary non-credit user on the adoption of MVs. Given that SACCOS are significant in the credit use function, these results suggest that there is no serious credit constraint to the adoption of MVs. All the models indicate that farmers in villages with a seed market are likely to switch to MVs. Furthermore, we observe a negative and significant coefficient of the distance from the district capital. Although farmers can reproduce a seed after they adopt it, it seems that access to the seed market matters for the adoption of MVs. Another possible explanation of the negative coefficient of the distance from the district capital is proximity to information or training. Our data indicate that farmers living in a village near to the district capital attend rice-related training more often. This may be one of the reasons why farmers near to the district capital adopt MVs more often. Note, however, that the distance to the nearest extension office has no significant impact on the adoption of MVs, making the impact of training ambiguous.

As expected from the descriptive analysis, we find that MVs are used more commonly in irrigated plots in all the models from (1) to (5). This is consistent with the experience of Asian countries, where farmers in irrigated areas adopt MVs more quickly than farmers in rain-fed areas (David and Otsuka 1994). It is important to note that the size of the plots has a negative coefficient in all the models from (1) to (5), although it is not significant in some of the models. This result suggests that not only large-scale farmers but also small-scale farmers are adopting MVs, which are scale-neutral. Furthermore, the household assets variable does not have significant impact on the adoption of MVs. This suggests that wealth is not a serious constraint to adopting MVs. The sizes of the plots owned in both lowland and upland areas consistently have no positive impact on the adoption of MVs. These results suggest that wealthy and large-scale farmers have no advantage in the adoption of MVs.

Table 6 presents the estimation results of the determinants of chemical fertilizer use. The diagnostic tests presented in the lower part of the table indicate that credit use and being an involuntary non-credit user are endogenous variables (endogeneity test) but they are significantly predicted by the identifying instrumental variables (first-stage *F* test) that have no strong evidence of correlation with the error term (over-identification test), providing confidence in the validity of the model specification. Hence we rely mainly on models (4) and (5) for our interpretation. A key finding on chemical fertilizer use is that the existence of SACCOS in model (1) has a positive and significant coefficient. Furthermore, the coefficient of being a credit user in model (4) is positive and significant, while that of being an involuntary non-credit user is negative and significant in model (5). These results suggest that credit users apply more chemical fertilizer than credit non-users. In all the models, the distance to the district capital has a negative and significant coefficient, which may imply that the relative price of fertilizer is an important determinant of fertilizer application. In fact, our data show that the relative price of urea measured in kilograms of paddy is 1.8 in villages within 50 km of the district capital and 2.3 in villages farther than 50 km from the district capital, and the difference is statistically significant. Another possible interpretation of this negative coefficient is better access to information or training in villages near to the district capital, as we discussed earlier. The size of the plot has a negative and significant coefficient in all five models. Furthermore, the sizes of the plots in lowland areas and in upland areas, and household assets, have no significant and positive impact on fertilizer application. These results suggest that small-scale farmers are not in a disadvantageous position even to purchase fertilizer.

Table 7 shows the results of the adoption of bund construction. Since the endogeneity test does not reject the null hypothesis that the variable is exogenous in both models (4) and (5), we mainly rely on the OLS model shown in column (3) for our interpretation. Note, however, that both the first-stage *F* test and the over-identifying test justify the use of the IV models shown in columns (4) and (5). In model (1), SACCOS do not have a positive and significant coefficient, and being a credit user has no positive and significant coefficient in model (3). The IV models are also consistent with this result and find no significant coefficient of being a credit user or being an involuntary non-credit user in models (4) and (5). Hence, bund construction is not more widely adopted among credit users than credit non-users. The distance from the district capital has negative and significant coefficients in all the models, suggesting that access to information or training can be an important determinant of the adoption of bund construction. Under any model, the dummy of irrigated plots has a positive and highly significant coefficient because most irrigated plots have a bund for water control.

Table 8 summarizes the results of the adoption of plot leveling. The endogeneity test rejects the null hypothesis that the variable of being a credit user is exogenous. Thus, we mainly rely on the IV models shown in columns (4) and (5) for our interpretation. Note also that the first-stage *F* test rejects the null hypothesis of a weak instrument and the over-identifying test does not reject its null hypothesis in both models (4) and (5), suggesting that the IV models are validly estimated. The coefficient of the existence of SACCOS is insignificant in model (1). Being a credit user also is not significant in model (4). On the other hand, being an involuntary credit non-user has a negative impact on the adoption of plot leveling, and the coefficient is significant at 10% in model (5). Since plot leveling is a labor-intensive technology, farmers who have credit access or can self-finance costs may be able to hire more agricultural labor than involuntary non-credit users. Note, however, that the coefficients of being a credit user or being an involuntary non-credit user are smaller and less statistically significant for the adoption of plot leveling than for transplanting in rows, as we will discuss later. This may be because farmers are less inclined to use hired labor to adopt plot leveling as they are for transplanting in rows due to the high monitoring cost. The dummy of being an irrigated plot has a positive and significant coefficient in all the models from (1) to (5). Farmers may have a higher incentive to level a plot in order to utilize irrigation water effectively.

The size of the plot has a negative and significant coefficient in all the models because it is easier to level a small plot than a large plot. This is also consistent with our observation that farmers cannot rely on hired labor to level plots since the adoption of this technology requires great care. The dummy variable of being a female-headed household consistently has a negative and significant coefficient in models (2) and

(4), suggesting that a lack of family labor is a constraint on adopting plot leveling. Five years of rice production experience significantly increases the adoption of plot leveling in all the models from (1) to (5). This may be because experienced farmers understand the importance of good water management.

Table 9 summarizes the results of the adoption of transplanting in rows. Endogeneity tests reject the null hypotheses that the variables of being a credit user and being an involuntary non-credit user are exogenous in models (4) and (5). The first-stage F tests reject the null hypothesis of a weak instrument and over-identifying tests do not reject the null hypothesis. Therefore, we rely mainly on the IV models shown in columns (4) and (5) for our interpretation. Model (1) indicates that the existence of SACCOS has a positive and significant impact on the adoption of transplanting in rows. Furthermore, being a credit user in model (4) has a positive and significant coefficient, while being an involuntary credit non-user has a negative and significant coefficient, indicating that credit access is important for the adoption of transplanting in rows. Since transplanting in rows is a labor-intensive practice and it is easy to monitor whether it is implemented properly, farmers are inclined to hire labor to adopt this technology. This may be why credit users are adopting transplanting in rows more frequently than credit non-users. Distance to the district capital has a negative and significant coefficient in models (1) to (4), suggesting that access to information or training can be an important determinant of the adoption of transplanting in rows. Being an irrigated plot has a positive and significant coefficient in all the models from (1) to (5). This may be because water control is very important for the adoption of transplanting in rows. Plot size has a negative and significant coefficient in models (1) to (5), which suggests that farmers may not be able to hire as much labor as they want, presumably due to the high labor price at peak season caused by an imperfect labor market.

7. Conclusions

Using extensive data collected in Tanzania, our paper sought to understand the current practice of rice cultivation and to identify the factors underlying the adoption of new rice cultivation technologies such as MVs, chemical fertilizer, and improved agronomic practices. Overall, it was found that the adoption of these technologies is not high, but is gradually emerging.

Statistical analyses of our extensive data set reveal that credit users are applying more chemical fertilizer, which requires cash for purchase, than credit non-users. Meanwhile, the adoption rate of MVs, which can be self-produced to some extent, is not higher for credit users than credit non-users. In terms of improved practices, credit users adopt transplanting in rows more frequently than credit non-users. A possible reason for this is that this practice can be monitored relatively easily even when farmers use hired labor, and credit access allows labor-constrained farmers to rely on hired labor. On the other hand, we observe smaller difference between credit users and credit non-users in the adoption of bund construction and plot leveling than in that of transplanting in rows. Unlike transplanting in rows, farmers do not tend to rely on agricultural labor to adopt these technologies, which are difficult to monitor. In short, improvement in credit access may selectively enhance technology adoption. However, we should be careful in interpreting these results. Since both bund construction and plot leveling are long-term investments, observing the limited impact of credit access in this particular year does not necessarily mean that credit has no impact on the adoption of these technologies. Furthermore, since we cannot deny the possibility that SACCOS are established in favorable areas, we need to carefully interpret the causal relationship between credit use and the adoption of technologies. Further investigation of this issue is needed before we can conclude that credit access can enhance technology adoption in an area where there is currently no credit access as it does in an area with credit access.

Our results also indicate the new technologies are more widely adopted in irrigated areas than in rain-fed areas. Nakano and Kajisa (2012) and Tokuda and Nakano (2013) suggest that the adoption of MVs effectively enhances paddy yield and the profitability of rice cultivation only when they are grown in an irrigated area with proper water management and fertilizer application. There is some possibility that irrigation is installed in favorable areas, and thus we cannot rigorously examine the causal impact of irrigation on the adoption of new technologies in this paper. However, our results suggest that irrigation is a prerequisite for the adoption of new technologies because the adoption rate of these technologies is low in rain-fed areas.

The distance from the district capital is also indicated as being important for the adoption of MVs and chemical fertilizer, as well as some labor-intensive technologies such as bund construction and transplanting in rows. For the adoption of modern inputs, market access and low prices due to proximity to the market may be important determinants of adoption. Our data also show that farmers near to the district capital attend rice-related training more often. This could be one possible reason why farmers near to the district capital adopt these new technologies. However, we do not observe a significant impact of the distance from an extension office, which we consider to be a proxy for attendance at rice-related training. Since the distance from the district capital can capture many other possible effects, more careful examination is needed before we conclude that access to information or training on the adoption of these technologies has a positive impact.

It is also important to note that plot size in general has a negative impact on the adoption of new technologies. Furthermore, we do not observe any strong positive impact of household assets or the size of plots owned in lowland or upland areas on the adoption of new technologies. This suggests that small-scale and poor farmers are not disadvantaged in technology adoption. Therefore, our results suggest that with appropriate policies, including enhancing access to credit, a rice Green Revolution can contribute to improving the productivity of small-scale farmers in Tanzania.

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Table 1. Yield and modern inputs and practices for rice cultivation by region and irrigation status

	Morogoro		Mbeya		Shinyanga		Average	
	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated
Paddy yield (t/ha)	2.0	3.8	1.6	3.5	1.7	4.6	1.8	3.7
Paddy yield of top 25% (t/ha)							3.7	5.9
Modern inputs use								
Share of modern variety (%)	17.8	87.5	0.0	2.1	1.9	13.1	7.1	28.7
Chemical fertilizer use (kg/ha)	11.7	40.4	10.7	31.7	0.9	0.0	6.7	32.2
Improved practices								
Share of bunded plots (%)	8.2	84.8	16.3	89.6	95.3	100.0	49.0	88.8
Share of leveled plots (%)	22.0	69.6	38.5	78.1	87.6	100.0	54.8	77.0
Share of straight row transplanting plots	4.4	47.8	3.8	22.9	6.4	0.0	5.2	28.9
Observations	182	46	104	96	234	10	520	152

Table 2. Characteristics of villages and households by credit status

	Credit user		Credit non-user	
	Credit user for rice cultivation in sample plot	Credit user for other purposes	Credit non-needy	Involuntary non-credit user
Existence of SACCOS (%)	35.1	51.4	28.9	21.3
Existence of private moneylender and other credit organization (%)	51.4	63.9	62.7	54.0
Distance to the district capital (km)	68.7	43.9	43.6	53.8
Share of irrigated plots (%)	51.4	20.8	28.9	19.6
Household assets (million Tsh)	1.1	0.8	1.0	0.7
Observations	37	72	83	480

Table 3. Modern inputs and improved practices for rice cultivation by credit and irrigation status

	Rain-fed			Irrigated		
	Credit use for any purpose	Credit non-needy	Involuntary non-credit user	Credit use for any purpose	Credit non-needy	Involuntary non-credit user
Modern inputs						
Share of modern variety (%)	4.1*	3.4*	8.2	15.2**	27.3	33.9
Chemical fertilizer use (kg/ha)	7.2	3.1	7.1	47.8*	29.9	27.2
Improved practices						
Share of bunded plots (%)	56.0*	49.2	47.7	94.1*	95.8*	85.1
Share of leveled plots (%)	58.7	55.9	53.9	79.4	87.5*	73.4
Share of straight row transplanting plots	4.0	5.1	5.4	29.4	29.2	28.7
Hired labor and rental capital cost						
Labor cost per hectare in USD1)	122.8	88.1	101.9	241.5	255.6	213.0
Paid-out cost of labor use for plot leveling per hectare in USD	2.2	0.2	1.0	4.4	2.1	3.0
Paid-out cost of labor use for transplanting per hectare in USD	12.8	7.5	8.6	59.0**	64.3**	42.6
Paid-out cost of rental machinery or animals for land preparation per hectare in USD	28.6	28.8	29.1	76.7***	19.1	31.4
Paid-out cost of rental machinery or animals for plot leveling per hectare in USD	0	1.2	.89	5.0	2.3	1.6
Observations	75	59	386	34	24	94

Note: *** denotes significant at 1%, ** significant at 5%, and * significant at 10% in *t* test comparing between involuntary non-credit users and either of the other two categories.
[1)] The exchange rate used is 1 USD = 1,320.3 Tanzanian shillings.

Table 4. The determinants of credit status (multinominal logit estimation)

	[1]		[2]	
	District FE		Village FE	
	Credit user	Credit non-needy		
Existence of SACCOS in the village	0.961***	0.396		
	[0.000]	[0.183]		
Private moneylender and other credit organization in the village	0.174	0.558*		
	[0.505]	[0.052]		
Distance to the nearest extension office (km)	-0.006	-0.027		
	[0.800]	[0.362]		
Existence of seed market	0.502	-0.443		
	[0.216]	[0.364]		
Access to fertilizer market	0.221	-0.035		
	[0.499]	[0.921]		
Male agricultural wage rate in kg of paddy	0.018	-0.016		
	[0.419]	[0.631]		
Distance to the district capital (km)	-0.001	-0.005		
	[0.798]	[0.324]		
= 1 if plot is irrigated	-0.294	0.850**	-0.574	1.688***
	[0.502]	[0.029]	[0.325]	[0.009]
Size of the plot (ha)	0.105	0.055	-0.023	-0.008
	[0.185]	[0.600]	[0.826]	[0.956]
The size of plots owned in a lowland area except the sample plot (ha)	-0.019	-0.150*	-0.006	-0.142
	[0.731]	[0.099]	[0.928]	[0.202]
The size of plots owned in an upland area (ha)	0.064	0.168**	0.111	0.283***
	[0.392]	[0.010]	[0.198]	[0.002]
Household assets (million Tsh)	0.044	0.197*	0.122	0.454**
	[0.696]	[0.087]	[0.400]	[0.015]
Number of cows and bulls owned	-0.003	-0.009	-0.008	-0.010
	[0.795]	[0.531]	[0.593]	[0.518]
Number of adults (age ≥ 15)	0.076	0.020	0.064	0.011
	[0.288]	[0.820]	[0.471]	[0.906]
The age of hh head	-0.019*	-0.043***	-0.021	-0.044***
	[0.087]	[0.001]	[0.100]	[0.005]
Average years of schooling of adult hh members	0.054	-0.140*	-0.024	-0.158*
	[0.429]	[0.058]	[0.768]	[0.055]
=1 if female hh head	0.715**	-0.252	0.368	-0.436
	[0.049]	[0.583]	[0.405]	[0.414]
Experience in rice production in last 5 years	0.040	0.197**	0.078	0.201*
	[0.589]	[0.026]	[0.373]	[0.061]
Constant	-2.669***	-1.408	0.324	0.242
	[0.004]	[0.213]	[0.766]	[0.869]
Observations	672	672	672	672

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. The determinants of the adoption of MVs

	(1) District FE OLS	(2) Village FE OLS	(3) District FE OLS	(4) District FE IV (2SLS)	(5) District FE IV (2SLS)
Credit use for any purpose			0.006	-0.078	
			[0.851]	[0.682]	
Credit non-needy			-0.022		
			[0.509]		
Involuntary non-credit user					0.108
					[0.466]
Village characteristics					
SACCOS	-0.008				
	[0.744]				
Private moneylender and other credit organization in the village	-0.023				
	[0.322]				
Distance to the nearest extension office (km)	-0.002		-0.002	-0.002	-0.002
	[0.251]		[0.282]	[0.273]	[0.219]
Existence of seed market	0.179***		0.172***	0.182***	0.181***
	[0.000]		[0.000]	[0.000]	[0.000]
Access to fertilizer market	0.031		0.033	0.037	0.037
	[0.299]		[0.260]	[0.222]	[0.216]
Male agricultural wage rate in kg of paddy	0.001		0.001	0.002	0.002
	[0.620]		[0.575]	[0.491]	[0.470]
Distance to the district capital (km)	-0.001***		-0.001***	-0.001***	-0.001***
	[0.002]		[0.002]	[0.002]	[0.002]
Household characteristics					
= 1 if plot is irrigated	0.441***	0.195***	0.444***	0.438***	0.448***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.015*	-0.007	-0.016*	-0.014	-0.014
	[0.063]	[0.384]	[0.063]	[0.102]	[0.116]
The size of plots owned in a lowland area except the sample plot (ha)	0.003	0.002	0.003	0.003	0.002
	[0.608]	[0.621]	[0.610]	[0.560]	[0.750]
The size of plots owned in an upland area (ha)	-0.008	-0.007	-0.007	-0.008	-0.006
	[0.203]	[0.248]	[0.258]	[0.211]	[0.398]
Household assets (million Tsh)	-0.009	-0.007	-0.008	-0.009	-0.007
	[0.415]	[0.515]	[0.446]	[0.414]	[0.562]
Number of cows and bulls owned	-0.000	-0.001	-0.000	-0.000	-0.000
	[0.731]	[0.505]	[0.699]	[0.696]	[0.649]
Number of adults (age ≥ 15)	0.008	0.010	0.008	0.008	0.009
	[0.239]	[0.100]	[0.261]	[0.226]	[0.205]
The age of hh head	-0.001	-0.001	-0.001	-0.001	-0.001
	[0.336]	[0.303]	[0.331]	[0.315]	[0.243]
Average years of schooling of adult hh members	-0.002	0.003	-0.002	-0.001	-0.003
	[0.761]	[0.591]	[0.692]	[0.814]	[0.656]
= 1 if female hh head	-0.050	0.006	-0.052	-0.043	-0.042
	[0.161]	[0.841]	[0.143]	[0.289]	[0.259]
Experience in rice production in last 5 years	0.004	0.002	0.004	0.004	0.006
	[0.602]	[0.692]	[0.593]	[0.599]	[0.452]
Constant	0.372***	0.387***	0.355***	0.351***	0.270**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.046]
Observations	672	672	672	672	672
R-squared	0.426	0.613	0.426		
First-stage *F*				7.596	8.521
				[0.001]	[0.000]
Endogeneity test (Durbin statistics)				0.214	0.496
				[0.644]	[0.481]
Over-identifying test (Sargan statistics)				0.988	0.570
				[0.330]	[0.450]

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6. The determinants of chemical fertilizer use (kg/ha)

	(1) District FE Tobit	(2) Village FE Tobit	(3) District FE Tobit	(4) District FE IV (2SLS)	(5) District FE IV (2SLS)
Credit use for any purpose			22.527	101.364***	
			[0.473]	[0.006]	
Credit non-needy			16.474		
			[0.650]		
Involuntary credit non-user					-81.585***
					[0.004]
Village characteristics					
SACCOS	63.406**				
	[0.021]				
Private moneylender and other credit organization in the village	-7.203				
	[0.791]				
Distance to the nearest extension office (km)	0.348		-0.621	0.166	0.405
	[0.903]		[0.834]	[0.639]	[0.277]
Existence of seed market	-1.438		16.695	-5.879	-0.525
	[0.969]		[0.648]	[0.468]	[0.942]
Access to fertilizer market	23.591		35.467	1.656	3.255
	[0.537]		[0.321]	[0.778]	[0.570]
Male agricultural wage rate in kg of paddy	1.308		1.430	-0.824*	-0.686
	[0.539]		[0.509]	[0.060]	[0.105]
Distance to the district capital (km)	-1.594***		-1.459***	-0.227***	-0.204***
	[0.000]		[0.000]	[0.000]	[0.001]
Household characteristics					
= 1 if plot is irrigated	22.214	12.810	28.302	10.831	2.380
	[0.488]	[0.644]	[0.381]	[0.120]	[0.735]
Size of the plot (ha)	-38.047**	-27.409**	-40.360**	-4.253**	-4.094**
	[0.015]	[0.031]	[0.011]	[0.012]	[0.014]
The size of plots owned in a lowland area except the sample plot (ha)	-5.963	-0.252	-8.487	-0.999	0.011
	[0.431]	[0.963]	[0.272]	[0.326]	[0.991]
The size of plots owned in an upland area (ha)	-5.900	-1.392	-11.021	-0.173	-1.808
	[0.612]	[0.873]	[0.376]	[0.884]	[0.158]
Household assets (million Tsh)	7.311	11.650	6.559	0.499	-1.242
	[0.469]	[0.155]	[0.525]	[0.815]	[0.574]
Number of cows and bulls owned	1.141	0.211	0.900	0.176	0.225
	[0.429]	[0.892]	[0.546]	[0.381]	[0.265]
Number of adults (age ≥ 15)	-10.472	-1.289	-11.530	-2.210	-2.090
	[0.243]	[0.857]	[0.209]	[0.105]	[0.121]
The age of hh head	0.191	-1.577*	0.349	0.125	0.388
	[0.847]	[0.068]	[0.730]	[0.527]	[0.109]
Average years of schooling of adult hh members	16.058**	12.532**	16.079**	0.809	2.092*
	[0.025]	[0.038]	[0.026]	[0.498]	[0.074]
= 1 if female hh head	19.391	8.736	26.036	-1.377	2.591
	[0.573]	[0.749]	[0.453]	[0.861]	[0.720]
Experience in rice production in last 5 years	-4.882	-4.081	-3.099	-0.858	-2.263
	[0.490]	[0.493]	[0.664]	[0.507]	[0.113]
Constant	-90.240	-43.971	-111.301	41.734***	103.242***
	[0.306]	[0.541]	[0.183]	[0.007]	[0.000]
Observations	672	672	672	672	672
First-stage *F*				7.596	8.521
				[0.001]	[0.000]
Endogeneity test (Durbin statistics)				12.973	14.417
				[0.000]	[0.000]
Over-identifying test (Sargan statistics)				0.7411	0.335
				[0.3893]	[0.855]

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. The determinants of adoption of bund construction

	(1) District FE Probit	(2) Village FE OLS	(3) District FE Probit	(4) District FE IV (2SLS)	(5) District FE IV (2SLS)
Credit use for any purpose			-0.102	0.021	
			[0.644]	[0.918]	
Credit non-needy			0.126		
			[0.594]		
Involuntary credit non-user					-0.032
					[0.838]
Village characteristics					
SACCOS	-0.024				
	[0.898]				
Private moneylender and other credit organization in the village	0.156				
	[0.376]				
Distance to the nearest extension office (km)	-0.010		-0.011	-0.001	-0.001
	[0.525]		[0.511]	[0.729]	[0.785]
Existence of seed market	0.555**		0.569**	0.129***	0.129***
	[0.031]		[0.022]	[0.003]	[0.001]
Access to fertilizer market	-0.224		-0.246	-0.048	-0.048
	[0.315]		[0.265]	[0.133]	[0.125]
Male agricultural wage rate in kg of paddy	0.024		0.024	0.002	0.002
	[0.155]		[0.164]	[0.300]	[0.288]
Distance to the district capital (km)	-0.008***		-0.008***	-0.001***	-0.001***
	[0.006]		[0.006]	[0.002]	[0.003]
Household characteristics					
= 1 if plot is irrigated	2.025***	0.386***	2.003***	0.562***	0.560***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.085	-0.006	-0.086	-0.011	-0.012
	[0.187]	[0.494]	[0.174]	[0.212]	[0.197]
The size of plots owned in a lowland area except the sample plot (ha)	0.007	0.002	0.006	0.001	0.002
	[0.856]	[0.699]	[0.882]	[0.825]	[0.783]
The size of plots owned in an upland area (ha)	-0.071	-0.009	-0.072	-0.005	-0.005
	[0.209]	[0.173]	[0.198]	[0.461]	[0.443]
Household assets (million Tsh)	-0.058	-0.009	-0.061	-0.011	-0.012
	[0.493]	[0.455]	[0.471]	[0.342]	[0.332]
Number of cows and bulls owned	0.008	0.000	0.008	0.000	0.000
	[0.499]	[0.702]	[0.501]	[0.813]	[0.799]
Number of adults (age ≥ 15)	0.055	0.007	0.060	0.008	0.008
	[0.291]	[0.307]	[0.248]	[0.249]	[0.251]
The age of hh head	-0.006	-0.000	-0.006	-0.001	-0.001
	[0.408]	[0.649]	[0.416]	[0.308]	[0.467]
Average years of schooling of adult hh members	-0.024	-0.005	-0.020	-0.005	-0.004
	[0.584]	[0.423]	[0.646]	[0.453]	[0.478]
= 1 if female hh head	-0.354	-0.036	-0.337	-0.039	-0.040
	[0.163]	[0.337]	[0.182]	[0.359]	[0.313]
Experience in rice production in last 5 years	-0.003	-0.002	-0.004	-0.000	-0.001
	[0.952]	[0.816]	[0.941]	[0.958]	[0.899]
Constant	-0.783	0.047	-0.668	0.245***	0.268*
	[0.189]	[0.667]	[0.243]	[0.003]	[0.058]
Observations	672	672	672	672	672
R-squared		0.752			
First-stage *F*				7.596	8.521
				[0.001]	[0.000]
Endogeneity test (Durbin statistics)				12.973	0.051
				[0.000]	[0.822]
Over-identifying test (Sargan statistics)				0.7411	0.599
				[0.3893]	[0.807]

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8. The determinants of the adoption of plot leveling

	(1) District FE Probit	(2) Village FE OLS	(3) District FE Probit	(4) District FE IV (2SLS)	(5) District FE IV (2SLS)
Credit use for any purpose			-0.060	0.513	
			[0.718]	[0.102]	
Credit non-needy			-0.042		
			[0.820]		
Involuntary credit non-user					-0.484*
					[0.052]
Village characteristics					
SACCOS	0.223				
	[0.111]				
Private moneylender and other credit organization in the village	0.218				
	[0.102]				
Distance to the nearest extension office (km)	-0.006		-0.009	-0.002	-0.000
	[0.568]		[0.382]	[0.541]	[0.923]
Existence of seed market	0.088		0.184	0.014	0.036
	[0.663]		[0.350]	[0.840]	[0.573]
Access to fertilizer market	-0.171		-0.190	-0.089*	-0.083*
	[0.319]		[0.263]	[0.071]	[0.096]
Male agricultural wage rate in kg of paddy	0.004		0.005	-0.000	0.000
	[0.768]		[0.681]	[0.904]	[0.994]
Distance to the district capital (km)	0.001		0.001	0.000	0.000
	[0.760]		[0.750]	[0.954]	[0.763]
Household characteristics					
= 1 if plot is irrigated	1.161***	0.359***	1.138***	0.387***	0.340***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.087*	-0.030**	-0.087*	-0.030**	-0.030**
	[0.064]	[0.031]	[0.063]	[0.037]	[0.038]
The size of plots owned in a lowland area except the sample plot (ha)	-0.046	-0.010	-0.049*	-0.012	-0.006
	[0.113]	[0.249]	[0.089]	[0.168]	[0.525]
The size of plots owned in an upland area (ha)	-0.021	-0.010	-0.028	-0.006	-0.015
	[0.568]	[0.310]	[0.443]	[0.561]	[0.170]
Household assets (million Tsh)	0.109*	0.031*	0.108*	0.025	0.015
	[0.092]	[0.078]	[0.098]	[0.158]	[0.435]
Number of cows and bulls owned	0.012	0.003	0.013*	0.002	0.002
	[0.106]	[0.108]	[0.088]	[0.217]	[0.173]
Number of adults (age ≥ 15)	-0.048	-0.017	-0.048	-0.016	-0.016
	[0.207]	[0.125]	[0.203]	[0.171]	[0.177]
The age of hh head	-0.001	0.000	-0.002	0.000	0.002
	[0.810]	[0.825]	[0.650]	[0.998]	[0.415]
Average years of schooling of adult hh members	-0.005	0.001	-0.002	-0.006	0.001
	[0.880]	[0.876]	[0.948]	[0.535]	[0.948]
= 1 if female hh head	-0.242	-0.093*	-0.213	-0.112*	-0.098
	[0.220]	[0.096]	[0.274]	[0.092]	[0.120]
Experience in rice production in last 5 years	0.076**	0.018*	0.085**	0.021*	0.012
	[0.042]	[0.089]	[0.022]	[0.055]	[0.322]
Constant	-1.075**	0.171	-0.857*	0.226*	0.590***
	[0.021]	[0.295]	[0.055]	[0.083]	[0.010]
Observations	672	672	672	672	672
R-squared		0.428			
First-stage *F*				7.596	8.521
				[0.001]	[0.000]
Endogeneity test (Durbin statistics)				3.458	5.297
				[0.063]	[0.021]
Over-identifying test (Sargan statistics)				1.782	0.400
				[0.182]	[0.527]

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9. The determinants of the adoption of transplanting in rows

	(1) District FE Probit	(2) Village FE OLS	(3) District FE Probit	(4) District FE IV (2SLS)	(5) District FE IV (2SLS)
Credit use for any purpose			-0.111	0.715***	
			[0.621]	[0.009]	
Credit non-needy			0.038		
			[0.874]		
Involuntary credit non-user					-0.526***
					[0.009]
Village characteristics					
SACCOS	0.462***				
	[0.009]				
Private moneylender and other credit organization in the village	0.032				
	[0.860]				
Distance to the nearest extension office (km)	0.001		-0.001	0.001	0.002
	[0.932]		[0.933]	[0.765]	[0.390]
Existence of seed market	0.446*		0.565**	0.039	0.080
	[0.056]		[0.011]	[0.513]	[0.115]
Access to fertilizer market	-0.054		0.000	-0.021	-0.008
	[0.804]		[0.999]	[0.631]	[0.842]
Male agricultural wage rate in kg of paddy	-0.001		0.005	-0.004	-0.003
	[0.971]		[0.731]	[0.234]	[0.360]
Distance to the district capital (km)	-0.006**		-0.006**	-0.001*	-0.001
	[0.035]		[0.039]	[0.056]	[0.102]
Household characteristics					
= 1 if plot is irrigated	0.888***	0.203***	0.881***	0.241***	0.184***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.462***	-0.018**	-0.465***	-0.038***	-0.036***
	[0.001]	[0.039]	[0.001]	[0.002]	[0.002]
The size of plots owned in a lowland area except the sample plot (ha)	0.082**	0.010*	0.073**	0.007	0.014*
	[0.026]	[0.073]	[0.044]	[0.336]	[0.065]
The size of plots owned in an upland area (ha)	0.057	-0.002	0.038	0.003	-0.007
	[0.224]	[0.735]	[0.435]	[0.692]	[0.422]
Household assets (million Tsh)	-0.002	-0.003	-0.005	-0.005	-0.016
	[0.982]	[0.781]	[0.947]	[0.759]	[0.301]
Number of cows and bulls owned	0.001	-0.001	0.001	0.000	0.001
	[0.895]	[0.580]	[0.857]	[0.764]	[0.597]
Number of adults (age ≥ 15)	-0.099	-0.004	-0.099	-0.015	-0.014
	[0.104]	[0.527]	[0.100]	[0.129]	[0.143]
The age of hh head	0.012*	0.000	0.013*	0.003**	0.004***
	[0.084]	[0.789]	[0.068]	[0.048]	[0.009]
Average years of schooling of adult hh members	0.082*	0.009	0.086*	0.005	0.014*
	[0.085]	[0.122]	[0.069]	[0.556]	[0.090]
= 1 if female hh head	-0.104	-0.005	-0.001	-0.058	-0.026
	[0.702]	[0.887]	[0.996]	[0.318]	[0.611]
Experience in rice production in last 5 years	0.027	0.005	0.044	0.005	-0.004
	[0.585]	[0.456]	[0.381]	[0.590]	[0.711]
Constant	-1.892***	0.135	-1.984***	0.006	0.403**
	[0.003]	[0.201]	[0.001]	[0.960]	[0.028]
Observations	672	672	672	672	672
R-squared		0.398			
First-stage F				7.596	8.521
				[0.001]	[0.000]
Endogeneity test (Durbin statistics)				12.925	11.522
				[0.000]	[0.001]
Over-identifying test (Sargan statistics)				0.031	0.674
				[0.861]	[0.412]

p-values in brackets.
*** $p < 0.01$, ** $p < 0.05$,* $p < 0.1$.

Figure 1. The regions covered by the survey and the location of surveyed plots by irrigation status in Tanzania