The Impact of Access to Credit and Training on Technology Adoption: A Case of the Rice Sector in Tanzania

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1. Introduction

The consumption of rice is increasing, and the imbalance between domestic production and consumption has been growing in sub-Saharan Africa (SSA) (Otsuka and Estudillo, 2008; Otsuka and Kijima, 2010). The total milled rice production in SSA increased from 2 million tons in 1961 to 16 million tons in 2009 (FAO, 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 inadequate domestic production to meet the growing demand. Unlike in Asia, rice is a cash crop consumed mostly in urban areas (Balasubramanian et al. 2007). Therefore, in urban markets, African domestic producers must compete with imports from Asian producers such as Thailand and Vietnam. Making rice as a profitable commodity for local farmers through the improvement of its productivity is regarded as a key to boosting domestic rice production.

One possible strategy for achieving productivity improvement is to seek an Asian-style rice Green Revolution in SSA (Otsuka, 2006; Otsuka and Kalirajan, 2005). 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 technologies. Emerging cases from the Sahel in West Africa show that this style of cultivation achieves yield of 3 to 5 tons per hectare, which is comparable with the yield of Asian countries (Nakano et al, 2011). This implies that the potential for an Asian-style rice Green Revolution is high in SSA. However, most existing studies are descriptive case studies based on data from the area under particular production and socioeconomic conditions; thus, they do not reveal under what conditions and how this can be realized.

The purpose of this paper is to answer these questions, using an extensive household-level data set collected in Tanzania in 2009. 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 the nationally representative picture of its rice sector, beyond the snapshots at particular places provided by existing case studies. To the authors' knowledge, this is the first attempt not only in Tanzania but also among the East African countries. Through our analyses with this data set, we believe that the paper makes two major contributions. First, we identify the factors underlying productivity improvement or a yield increase. Through this analysis, we intend to understand whether an Asian-style Green Revolution contributes to productivity improvement in Tanzania. We particularly focus on the effects of modern seed and other inputs and modern practices that we regard as the features of the Asian Green Revolution. Second, we examine under what circumstances yield-enhancing factors become more likely to be adopted. Based on the existing literature on technology adoption, we explicitly examine the role of credit and knowledge (or training) in adoption (Feder et al., 1985). The limitation of our analysis is that we rely on a single-year cross-section data set. In other words, our analyses basically use reduced-form regression analyses, instead of estimating structural forms, to avoid statistical problems due to self-selection and reverse causality in the adoption of modern technologies and practices. To overcome this limitation, we try to interpret reduced-form regression analyses with great care.

The rest of the paper is organized as follows. Section 2 explains the data set. Section 3 explains our analytical approach, followed by the descriptive analyses in Section 4. Sections 5, 6, and 7, respectively, present the results of the statistical analyses on the determinants of access to credit and training, those of technological adoption, and the impact of modern technologies on yield. The paper ends with the conclusions in Section 8.

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, Morogogoro region from the Eastern Zone, Mbeya region from the Southern Highland Zone, and 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. Hence, we may be able to regard our survey as 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 from Mbeya; 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 agricultural census in 2002/03 in each region. In total, we selected 76 villages in 6 districts as our sample villages. Figure 1 shows the irrigation status of our survey areas. 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 levels of data: village-level data and household-level data. The former was collected by a group interview with village key informants, while the latter was collected by an individual interview. 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 our effective sample became 634.

3. Our approach

The Asian-style rice Green Revolution can be characterized by the adoption of the set of modern technologies. The set of modern technologies can be classified into two components:

modern inputs and improved practices. Henceforth, we use the term "the adoption of modern technologies" when we refer to the progress of all the components; otherwise, we use the name of each component. Using this classification, the Asian-style rice Green Revolution can be summarized as the progress of the following features in farming (the letters (C) and (K) placed at the end of each feature will be explained later).

- Adoption of modern inputs
    - Adoption of a fertilizer-responsive high-yielding modern varieties (MVs) (K)
    - An increase in chemical fertilizer application (C) (K)
- Adoption of improved practices
    - Construction of a bund for better water management (C) (K)
    - Land leveling for better water management (C) (K)
    - Adoption of an improved crop management such as transplanting in rows (C) (K)

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 and training (Feder et al., 1985). We argue, however, that the importance of these two factors can differ for different technologies and practices. If the adoption of technologies or practices does not require a large amount of cash expenditure, knowledge given by training is sufficient for enhancing adoption. This includes the adoption of a modern variety, to which the letter (K), as in knowledge, is placed beside them. Regarding a modern variety, farmers have to buy certified seed in the market when they switch varieties, but usually they self-produce it several times until the performance of seeds declines significantly. Hence, we expect that cash does not seriously constrain its use. On the other hand, farmers need cash on hand for purchasing chemical fertilizer and hiring labor or a tractor for constructing a bund, doing land leveling, and transplanting seedlings in rows to the extent that the credit market is mal-functioning. We expect that those who can access credit or those who can self-finance can adopt these technologies, to which the letter (C) is placed beside the list. After identifying the determinants of technological adoption, we further examine how these technologies contribute to productivity improvement or a yield increase.

4. Descriptive analyses

4.1 Constraints to the adoption of modern technologies

This section aims to examine the current status of the rice cultivation in Tanzania and constraints of the adoption of modern technologies. Table 1 summarizes the basic statistics of rice cultivation in sample region in Tanzania. In each region, we classify the sample into households cultivating rice at the sample plot under rain-fed or irrigated conditions. The share of irrigated household in the entire sample is 20.0% (127 of 634 observations). The overall average yield is 1.8 t/ha under rain-fed condition and 3.6 t/ha under irrigated condition, resulting in 2.2 t/ha as the overall average. If you focus only on the top 25 % of high yield farmers, they achieve 5.8 t/ha in irrigated area and even under rain-fed condition they achieved 3.7 t/ha. These facts imply the high potential of both irrigated and rain-fed rice cultivation in Tanzania even though the overall average is not high especially in the rain-fed area.

To have some idea on the progress of Asian style Green Revolution, we first explore application of modern inputs by irrigation status and region. The share of MV is merely 7.0 % in rain-fed area and 33.5% in irrigated area on average. However, in the irrigated area in Morogoro, the share of modern variety is 87.5%. This is consistent with the experience of Asia, where farmers tend to adopt MV in more favorable area (David and Otsuka,1994). In Mbeya region, which is famous for their aromatic rice, few farmers adopt MVs even in the irrigated area presumably because of their preference of local aromatic varieties over MVs.

In general, the chemical fertilizer application does not reach to the level recommended by agronomist (125-250 kg of Urea per ha). In irrigated area, nevertheless, farmers apply moderate level of fertilizer partly because irrigation water and chemical fertilizer are complements. Meanwhile, the application of herbicide is higher in rain-fed area than in irrigated area because weed problem is more serious under intermittent aerobic condition in the rain-fed areas.

Turning now to the improved practices, all practices are more widely adopted in irrigated areas. Moreover, in irrigated areas, bund construction is almost fully adopted. Meanwhile, transplanting in rows, which is a common practice in Asia for easier weeding and harvesting, is still not so popular in Tanzania.

Next, we examine the constraints to the adoption of modern technologies. First of all, as the most important possible constraint, 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 the paid-out cost is to borrow money from formal or informal sources. In Tanzania, a formal source available in rural areas is a micro-finance organization called the Savings and Credit Cooperative Societies (SACCOs).[2] Many informal sources also exist, such as traders, rice millers, and money lenders as well as family, relatives, and friends. The other way of handling the paid-out cost in farming is to postpone the payment of fees or wages until the time of harvesting. We can regard this also as a kind of credit arrangement that relies on an informal agreement between the resource owner and the user.

It is worth exploring what type of farmers use which kind 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. We have classified credit status into five categories: (1) farmers making payment after harvesting, (2) farmers using credit for rice in the sample plot, (3) farmers using credit for any purpose except for rice in the sample plot, (4) farmers who claim no need of credit, and (5) farmers do not use credit while they need

[2] 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.

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A discernible feature can be observed according to the category of the payment after harvesting. Based on summary statistics, we can claim that, when few credit suppliers exist such as SACCOs (27.3%), farmers seem to try to circumvent this problem by relying on this informal arrangement. Such an arrangement can emerge when the farmers' average yield in the past is relatively high (2.5 t/ha). This suggests that credit arrangements emerge under the circumstance of a high outcome. The table also indicates that irrigation contributes to achieving this circumstance as we observe a higher percentage of irrigation (63.6%) in this category than in the others. Although less obvious, we can find similar features among the other credit users (i.e., category (2) and (3)), except the point that SACCOs are much more available there. The farmers classified as credit non-needy (category (4)) also show a slightly higher yield, and higher percentage of irrigation than the farmers who need but do not use credit, which could contribute to their self-financing of the paid-out cost. Any types of farmers who use credit and those who do not use because they do not need it show higher asset values than those who do not use credit while they need it. In summary, farmers' credit status seems to be determined by the availability of a credit supplier (particularly SACCOs), past production record as an indicator of credibility, and asset endowment.

How does the credit constraint affect the adoption of technologies? Table 3 compares the adoption of modern inputs and improved practices by farmers by credit and irrigation status. First of all, under rain-fed conditions, the credit constraint does not seem to matter for technology adoption. Regardless of the credit use, the adoption is low. This is understandable because the returns to adoption are limited under rain-fed conditions. On the other hand, a clear difference among the three groups is observed for some technologies in irrigated areas. We observe that those who use credit apply more chemical fertilizer and adopt transplanting in rows more often than those who do not have any access to credit when they need it. Those who did not need any credit construct bunds and level their plots more often than those who needed credit but could not obtain it. This is consistent with our expectation: credit access matters for inputs or practices that require cash on hand (i.e., chemical fertilizer use, constructing bund, land leveling, and transplanting in rows). Note also that credit use does not seem to matter for the adoption of MVs, which is also consistent to our expectation.

Now we turn to our attention to the role of training. We treat farmers as trained if they attended any rice-related training organized by any organization such as the government, an aid agency, and an NGO in the last 5 years. Table 4 compares farmers with training and those without it by irrigation status. A salient feature is that the adoption of a modern variety and straight row transplanting are highly associated with rice training in both rain-fed and irrigated plots. Since these technologies and practices are relatively new to the country, their knowledge seems to matter significantly for adoption. However, we do not observe a large difference in the amount of fertilizer between trained farmers and those who are not trained. This may be because even if farmers are trained, they cannot apply fertilizer because of other factors such as a lack of cash on hand when they apply fertilizer. Another possible reason is that farmers do not to rely on training for knowledge about chemical inputs as they usually get such information from local dealers or rice millers. In this regard, for chemical inputs, the distance or access to markets may be more important than being exposed to training. Meanwhile, although knowledge on other activities such as bund construction, leveling, and ordinary transplanting is important for their appropriate use, these basic practices seem to be known already as a part of their traditional farming practices. By interpreting these results together with the role of credit, it seems possible to accelerate the adoption of modern varieties in both rain-fed and irrigated areas solely by providing a training program without relying on the improvement of access to credit. In irrigated areas, the adoption of straight row transplanting can be enhanced by the provision of a training program as well as improving credit access.

4.2 The role of modern technologies for productivity improvement

In Table 5, we classify our sample into three yield groups (bottom, middle, and top) and show the association of yield with the use of modern inputs and practices by irrigation status. First, the data on modern inputs show that the levels of application are higher in irrigated areas. Furthermore, regardless of irrigation status, we observe a positive association between modern inputs and yield. Regarding improved practices, we cannot identify a clear contribution of bund construction, leveling, transplanting, and straight row transplanting to a yield increase. However, farmers in the bottom yield group tend to adopt these technologies less often. These results suggest that modern inputs and improved practices contribute to enhancing paddy yield.

5. The determinants of credit use and attendance at training

5.1. Methodology and variable construction

This section statistically examines the determinants of credit use and attendance at rice-related training. We apply OLS for both models and include no dummy in model (1), district dummies in model (2), and village dummies in model (3). The credit use variable takes 1 if farmers use credit for any purposes or payment after harvest for the sample rice plot. The dependent variable for the training model is the dummy variable, which becomes 1 if the farmers have attended any rice-related training in the last 5 years.

The village-level explanatory variables for both models consist of the existence of SACCOs in a village (dummy) and the existence of private money lenders in a residential village (dummy) to capture the supply-side factors of the credit. We also include the existence of an extension office within 5km from the residential village (dummy) to control the access to the rice-related training. We control the distance from the district capital (km), the existence of seed market (dummy), access to fertilizer market (dummy), and average male agricultural wage rate in kg of paddy in order to capture the market access to the various inputs.

To capture plot characteristics, we include the 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 land endowment of households, the value of household assets (million Tanzanian shillings) and the number of cows and bulls owned by the household to capture the influence of the physical asset endowment. To capture the impact of human capital endowment, we use the number of adult members older than 15, the age of the household head, the average years of schooling of adult household members, the dummy for a female-headed household, and experience in rice production in the last 5 years. We also include the number of children under age 15. This variable can capture the impact of the availability of cash as a household with more children may need cash for children's education and health and hence may have less cash available for agricultural inputs.

5.2. Regression results

The regression results of the determinants of credit use are presented in Table 6. Models (1) and (2) show that the existence of SACCOs apparently increases the credit use. Note that, although the credit is not used directly for the sample rice plot, due to the fungibility of credit, it could still have an impact on the rice farming of the sample plot. The female household headed household use more credit presumably because they rely more on hired labor to grow rice.

Table 7 summarizes the regression results of attendance at rice-related training. The existence of extension office within 5km from the residential village significantly increases the attendance of the training, which is consistent to our intuitions. The existence of SACCOs has a positive and significant coefficient only in district fixed effect model. The distance to the district capital has negative and significant coefficient in models (1) and (2). This may be because farmers living near district capital enjoy higher paddy price, which gives them strong incentive to attend at rice-related training. Somewhat controversial is that the access to the fertilizer market has negative impact on the attendance of the training, to which we do not have clear explanations.

The farmers with irrigated plots attend training more often. This may be because the returns from adopting new technologies are higher in irrigated areas. Experience with rice production in the last 5 years has a positive and significant coefficient for attendance at rice-related training in all models, which may suggest that more experienced farmers recognize the importance of the new technologies. The size of the plot owned in the lowland area except sample plot has positive and significant coefficient. This suggests that those farmers with larger plots in the lowland area suitable for rice cultivation have more incentive to attend rice-related trainings.

6. Determinants of technology adoption

6.1. Methodology and variable construction

This section investigates the determinants of the adoption of technologies. The dependent variables are the adoption of modern varieties (dummy variable which takes 1 if adopted), chemical fertilizer use (kg/ha), the adoption of bund construction, the adoption of leveling, and the adoption of transplanting in rows. Similar to the previous section, we estimate the reduced-form regressions with no dummy, district dummies, and village dummies by each technology, the results of which are indicated in models (1) to (3) respectively. We include the same exogenous variables as the models of credit use and the attendance at rice-related training.

6.2. Regression results

Table 8 shows the regression results for the adoption of modern varieties. Models (1) and (2) indicate that the existence of extension office has positive and significant coefficient while the existence of SACCOs does not have positive and significant coefficient. This suggests that there is no serious credit constraint for the adoption of modern varieties and training can increases the adoption. Models (1) and (2) indicate that farmers in villages located far from the district capital without a seed market are less likely to switch to modern varieties. This may be because farmers need to purchase seed when they switch to new varieties, although they can reproduce the seed after adoption.

As expected from the descriptive analysis, we find that modern varieties are used more commonly in irrigated plots in all the models from (1) to (3). This is consistent with the experience of Asian countries, where farmers in irrigated areas adopt modern varieties more quickly than farmers in rain-fed areas (David and Otsuka, 1994). The size of the plots has negative and significant variables, which implies that the farmers with large plots do not adopt modern varieties. This may be because in larger plots, it is difficult to control water which is important for the adoption of MVs. The household asset has a negative and significant coefficient in models (1) and (2). This is contrary to our intuitions that less wealthy farmers are more risk-averse and hence face difficulties to adopt new technologies. However, this may suggest that wealth is not a serious constraint to adopt MVs which is scale-neutral (David and Otsuka, 1994).

Table 9 summarizes the determinants of chemical fertilizer use. Since the observations are censored at zero, we apply Tobit models. A key result for chemical fertilizer use is that the existence of the SACCOs in models (1) and (2) has a positive and significant coefficient. Considering that SACCOs has positive impact on credit use, this result suggests that the credit access may matter for chemical fertilizer use. However, we have to be careful to interpret the results since SACCOs may be established in the area with better conditions such as better access to market etc. Since our data is cross-sectional and we do not have good IV to predict the credit use, this is the limitation of our analyses. In models (1) and (2), distance to the district capital has a negative and significant coefficient, which may implies that access to market and the relative price of fertilizer are the important determinants of fertilizer application.

The irrigation dummy has positive and significant coefficient in model (1), and although it is not significant, it also has positive coefficient in models (2) and (3). This implies that farmers apply more fertilizer in irrigated area. This may be because irrigation water and fertilizer are complementary inputs. Note also that fertilizer-responsive modern varieties are adopted more in irrigated areas, which may results in the increase in the fertilizer application in irrigated plots. The average years of schooling of adult household members has a positive and significant coefficient in all the models, which implies the importance of human capital especially to adopt such an expensive and risky technology as fertilizer application.

Table 10 shows the results on the adoption of bund construction. On contrary to our expectation, we find weak evidence of credit constraint. In model (1), SACCOs has positive and significant coefficient while the existence of other private money lender has negative and significant coefficient. In fact, the interest rate of those private money lenders is quite high, and farmers may not use the credit from those sources to adopt bund construction. Another possible explanation may be that since the construction of bund is a long-term investment, the credit access for this year may not affect the adoption of the bund construction.

The distance from the district capital has negative and significant coefficients in models (1) and (2). Since farmers in the villages near district capital enjoy higher price of paddy, the farmers in these area may have higher incentive to adopt these labor-intensive technologies. Under any model, the dummy of irrigated plots has a positive and highly significant coefficient, suggesting that the returns to these improved practices become higher under irrigated conditions.

Table 11 summarizes the results of the adoption of the leveling. Similar tendency as the adoption of bunding is observed. The coefficient of the existence of the SACCOs has a positive and significant coefficient while the existence of private money lender has negative coefficient in model (1). However, when we control district dummy, this relationship is not observed. Farmers adopt leveling of the plots more often in irrigated plots. This may be because farmers in irrigated area construct bund more often than those in rain-fed area to capture irrigated water, and it is easier to level the bunded plots than non-bunded plots. The size of the plots has negative and significant coefficient in all the models. Technically, it is more difficult to level a lager plot than a small plot. Furthermore, Hayami and Otsuka (1993) argue that because of difficulty in monitoring hired workers in spatially dispersed and ecologically diverse agricultural environments, labor market are imperfect. Hired workers are employed only for simple tasks such as weeding and harvesting, but not for care-intensive tasks such as fertilizer application and water management. Since leveling requires much care, farmers may not be able to rely on hired labor completely, and it may hinder the adoption of this technology in a large plot.

Table 12 summarizes the results of the adoption of transplanting in rows. Models (1) and (2) indicate that the existence of SACCOs has positive and significant impact on the adoption of transplanting in rows. Since the transplanting in rows is a labor-intensive practice and farmers may need to hire labor, the credit access may matter for the adoption of the transplanting in rows. Consistently, plot size has a negative and significant coefficient in models (1) and (2), which may indicate that farmers may not be able to hire enough labor to adopt this labor-intensive technology presumably due to high labor at the peak season or lack of credit.

Models (1) and (2) indicate that the access to seed market has a positive and significant coefficient. This may suggest that the returns to the adoption of transplanting in rows may be higher when farmers are growing MVs. Models (1) to (3) indicate that farmers transplant seedlings in rows more often in irrigated areas. Under the rain-fed condition, it may be difficult for the farmers to transplant seedlings in rows because the water control is important to plant seedlings at the right timing.

7. Determinants of paddy yield

7.1. Methodology and variable construction

This section investigates the extent to which Asian-style Green Revolution technologies contribute to a yield increase in Tanzania by means of regression analyses. The dependent variable is paddy yield per hectare (t/ha). We estimate the two types of regression functions: the reduced-form models and structural-form models. In the reduced-form models, the explanatory variables are the same as the technology adoption models. In structural-form models, the explanatory variables consist of the adoption of technologies such as modern inputs and improved practices. Modern inputs include the adoption of modern varieties (dummy) and the amount of chemical fertilizer applied per hectare (kg/ha). The adoption of improved practices is captured by three dummy variables: plots with bunds, plots with leveling, and transplanting seedlings in rows. However, note that the adoption of technologies is the choice of farmers or is endogenous. For the cross-section data, the use of the instrumental variable (IV) method is one approach for solving endogenous biases. Since it is difficult to endogenize many variables and since bunding and leveling are long-term investments, we treat the adoption of modern varieties, chemical fertilizer use, and the adoption of transplanting in rows as endogenous variables, and the adoption of bunding and leveling as exogenous variables (at least in the short run). In structural models, we control the distance from the district capital to capture the differences in the input and output prices. We also include the irrigated plot dummy. Other inputs such as size of the plots, number of cows and bulls owned are also included. We also control the quality of labor input by including the age of household head, average years of schooling of adult household members, female household dummy, and experience in rice production in last 5 years.

7.2. Regression results

Table 13 shows the regression results of the reduced-form yield functions. Models (1) to (3) include no dummy, district dummies, and village dummies respectively. The existence of the SACCOs and the extension office within 5km from the residential village has positive and significant impact on yield. This suggests that the access to the credit and training increase paddy yields probably through the increase in the input and technological use as we discussed in the last section. According to models (1) to (3), irrigation increases paddy yields by 0.8t/ha to 1.5 t/ha. In all models, the size of the plots has negative and significant coefficient on paddy yields. Considering that the size of the plots negatively affect the adoption of some technologies such as MVs, leveling of plots and transplanting seedlings in rows, inactive labor and land market may hider the adoption of those labor intensive technologies and thus have negative impact on the yield. Somewhat controversial is the positive coefficient of the distance from the district capital, to which we do not have good explanations.

Table 14 summarizes the results of the instrumental variable (IV) estimation of yield function. Since the models which include district and village dummies do not satisfy either under-identification or over-identification restrictions, we only show the results of models which include no dummy. Model (1) is OLS estimation while (2) and (3) show the results of IV estimation. Model (2) use two stage least square method (2SLS) while model (3) use limited information maximum likelihood method (LIML). Since our IV models suffer from the problem of weak IV, we show the results of LIML estimation in model (3) for the sake of comparison, although it suffers from the low R-squared. Note models (2) and (3) satisfy the various conditions for the IV to be valid as shown in the lower part of the table.

First, the modern technologies significantly increase the yield. For example, based on the OLS and 2SLS estimations, the adoption of MVs increases the yield significantly by 0.7-1.3t/ha. The results also show that 1 kg of fertilizer increases yield by 6-30 kg, and yield is higher in leveled plots, as we expected. The irrigation dummy has a positive and highly significant coefficient, indicating the importance of water management. Second, plot size has a negative and significant coefficient. This may be because farmers cannot adopt labor-intensive technologies to large plots due to imperfect labor and land rental market.

8. Conclusions

Our paper intended to understand the current practice of rice cultivation and to identify the constraints of the adoption of modern technologies by using extensive data collected in Tanzania. Overall, it was found that the potential of expanding rice production in the country is high. Farmers are achieving high yield especially when they are applying modern inputs and technologies. Since these technologies are adopted more quickly in irrigated areas, the long term strategy to expand rice production in the country may be to expand irrigated area and to develop locally suitable MVs.

Statistical analyses of our extensive data set reveal that, in order to achieve high-input and high-output farming, being credit unconstrained may be important for the adoption of technologies that require cash for purchase or for implementation, which is chemical fertilizer in our case. Meanwhile, the provision of training alone can enhance the adoption of technologies that do not require cash very often. For example, the adoption of modern varieties requires cash for the first purchase but many farmers can rely on self-produced seed for a while. In terms of improved practices, we find a positive impact of credit on the adoption of transplanting in rows. This may be because this practice is relatively labor-intensive and require cash to hire labor. Although our data implies the importance of the access to credit and raining, we have to be careful to interpret the results. Since SACCOs and extension office may be established in a place with better conditions such as better access to market, our results cannot completely exclude this kind of placement bias. This is the limitation of the cross-section analysis of this paper. Further investigation on this issue is needed with more specific survey design.

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Table 1: Yield and modern inputs, practices, and power sources 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)	2.1	3.8	1.5	3.3	1.7	4.6	1.8	3.6
Paddy yield (t/ha) of top 25%							3.7	5.8
Cultivated area in the sample plot (ha)	1.0	0.6	0.7	1.1	1.5	1.0	1.2	0.9
Modern input use								
Share of modern variety (%)	18.3	87.5	0.0	1.4	1.7	13.1	7.0	33.5
Chemical fertilizer use (kg/ha)	12.4	40.4	6.1	30.9	0.9	0.0	5.8	31.9
Herbicide use (l/ha)	1.3	0.5	1.3	0.4	0.0	0.0	0.7	0.4
Improved practices								
Share of bunded plot (%)	8.7	84.8	14.9	88.7	95.3	100.0	49.9	88.2
Share of leveled plot (%)	22.1	69.6	38.6	83.1	87.2	100.0	55.4	79.5
Share of transplanting plot (%)	16.9	93.5	12.9	94.4	46.2	70.0	29.6	92.1
Share of straight row transplanting plot (%)	4.7	47.8	4.0	22.5	6.4	0.0	5.3	29.9
Observations	172	46	101	71	234	10	507	127

Table 2: Characteristics of villages and households by credit status

Variable	Credit user: Payment after harvesting	Credit user: Credit use for rice	Credit user: Credit use for any (exp. Rice in the sample plot)	Non user: Credit non-needy	Non user: Credit needy
Distance to the district capital (km)	64.2	73.2	45.2	43.2	53.0
Existence of SACCOS (%)	27.3	45.5	51.2	32.5	23.9
Existence of private money lender (%)	63.6	54.5	60.7	41.3	44.4
Average of the past 5-year yield (t/ha)	2.5	3.2	2.5	2.4	2.1
Share of irrigated plot (%)	63.6	40.9	22.6	26.3	16.6
Household asset (million Tsh)	0.8	1.0	0.8	0.9	0.7
Number of cows and bulls owned	9.7	2.9	7.3	5.2	5.9
Observations	11	22	84	80	439

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

	Rain-fed			Irrigated		
Variable	Credit use for any purposes	Credit non-needy	Credit needy but do not use	Credit use for any purposes	Credit non-needy	Credit needy but do not use
Modern inputs						
Share of modern variety (%)	3.8	1.7	8.7	19.3	31.2	40.6
Chemical fertilizer use (kg/ha)	3.6	3.2	7.0	58.2	22.4	22.8
Improved practice						
Share of bunded plot (%)	53.7	48.3	48.0	87.9	95.2	86.3
Share of leveled plot (%)	57.3	53.4	54.2	78.8	90.5	76.7
Share of transplanting plot	25.6	25.9	29.9	97.0	90.5	90.4
Share of straight row transplanting plot	4.9	5.2	5.3	39.4	23.8	27.4
Observations	82	58	358	33	21	73

Table 4. Modern inputs and practices for rice cultivation by rice training and irrigation status

	Rain-fed		Irrigated	
	No training	Training	No training	Training
Modern Inputs				
Share of modern variety (%)	5.3	15.5	28.3	45.3
Chemical fertilizer use (kg/ha)	5.7	6.7	30.8	34.5
Improved Practice				
Share of bunded plot (%)	50.7	45.8	87.5	89.7
Share of leveled plot (%)	55.9	53.0	78.4	82.1
Share of transplanting plot	30.4	25.3	89.8	97.4
Share of straight row transplanting plot	4.7	8.4	22.7	46.2
Observations	424	83	88	39

Table 5. Modern inputs and improved practices for rice cultivation by irrigation status and yield group

	Rain-fed			Irrigated		
	Bottom yield group	Middle yield group	Top Yield group	Bottom yield group	Middle yield group	Top Yield group
Paddy yield (t/ha)	0.6	1.6	3.3	2.1	3.5	5.5
Cultivated area in the sample plot (ha)	1.5	1.1	0.9	1.0	0.8	0.7
Modern input use						
Share of modern variety (%)	3.0	5.8	12.8	24.8	38.1	37.9
Chemical fertilizer use (kg/ha)	2.8	7.1	8.3	13.3	26.1	60.0
Improved Practice						
Share of bunded plot (%)	52.4	46.4	50.3	88.4	87.0	89.5
Share of leveled plot (%)	52.4	58.2	56.4	69.8	87.0	81.6
Share of transplanting plot	19.9	29.4	41.1	88.4	97.8	89.5
Share of straight row transplanting plot	2.1	4.6	9.8	18.6	39.1	31.6
Observations	191	153	163	43	46	38

Table6. The Determinant of Credit Use

VARIABLES	(1) No dummy	(2) Districts FE	(3) Village FE
Village characteristics			
SACCOs	0.133***	0.110***	
	[0.000]	[0.001]	
Private money lender	0.013	0.009	
	[0.362]	[0.545]	
Existence of extension office within 5km	0.025	-0.005	
	[0.523]	[0.907]	
Existence of seed market	-0.029	0.044	
	[0.490]	[0.401]	
Access to fertilizer market	0.035	0.061	
	[0.349]	[0.148]	
Male agricultural wage rate in kg of paddy	-0.000	0.001	
	[0.991]	[0.783]	
Distance to the district capital (km)	0.000	0.000	
	[0.510]	[0.901]	
Household characteristics			
=1 if plot is irrigated	0.062	-0.026	-0.025
	[0.121]	[0.607]	[0.695]
Size of the plot (ha)	0.012	0.005	-0.016
	[0.312]	[0.714]	[0.228]
The size of the plots owned in the lowland area except the sample plot (ha)	0.007	0.010	0.011
	[0.354]	[0.211]	[0.153]
The size of the plots owned in the upland area (ha)	0.002	-0.002	-0.000
	[0.819]	[0.845]	[0.989]
Household asset (million Tsh)	0.002	-0.002	-0.003
	[0.929]	[0.906]	[0.879]
Number of cows and bulls owned	-0.000	-0.000	-0.000
	[0.970]	[0.772]	[0.782]
Number of adult (age>=15)	0.005	0.004	0.002
	[0.642]	[0.672]	[0.835]
Number of children (age<15)	0.011	0.012	0.015*
	[0.193]	[0.167]	[0.077]
The age of hh head	-0.002	-0.001	-0.001
	[0.198]	[0.333]	[0.431]
Average years of schooling of adult hh members	0.009	0.014	0.007
	[0.299]	[0.121]	[0.426]
=1 if female hh head	0.103**	0.120**	0.086*
	[0.046]	[0.020]	[0.099]
Experience in rice production in 5 years	-0.002	-0.001	-0.001
	[0.818]	[0.947]	[0.947]
Constant	0.030	-0.004	0.380**
	[0.789]	[0.972]	[0.013]
Observations	634	634	634
R-squared	0.063	0.092	0.250

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table7. Determinants of the Attendance at Rice-Related Training

	(1) No dummy	(2) District FE	(3) Village FE
Village characteristics			
SACCOs	0.045	0.069**	
	[0.170]	[0.036]	
Private money lender	-0.001	-0.006	
	[0.942]	[0.706]	
Existence of extension office within 5km	0.084**	0.075*	
	[0.031]	[0.084]	
Existence of seed market	0.049	0.028	
	[0.242]	[0.591]	
Access to fertilizer market	-0.082**	-0.076*	
	[0.027]	[0.077]	
Male agricultural wage rate in kg of paddy	0.003	0.002	
	[0.231]	[0.579]	
Distance to the district capital (km)	-0.001**	-0.001*	
	[0.016]	[0.069]	
Household characteristics			
=1 if plot is irrigated	0.136***	0.225***	0.145**
	[0.001]	[0.000]	[0.018]
Size of the plot (ha)	0.008	0.012	0.012
	[0.510]	[0.320]	[0.340]
The size of the plots owned in the lowland area except the sample plot (ha)	0.014*	0.014*	0.019**
	[0.081]	[0.083]	[0.010]
The size of the plots owned in the upland area (ha)	-0.002	0.004	0.015
	[0.844]	[0.695]	[0.109]
Household asset (million Tsh)	-0.015	-0.012	-0.018
	[0.381]	[0.493]	[0.279]
Number of cows and bulls owned	-0.001	-0.001	-0.001
	[0.369]	[0.624]	[0.591]
Number of adult (age>=15)	0.006	0.007	-0.010
	[0.530]	[0.478]	[0.303]
Number of children (age<15)	-0.010	-0.008	-0.005
	[0.261]	[0.336]	[0.531]
The age of hh head	-0.001	-0.002	-0.001
	[0.330]	[0.188]	[0.385]
Average years of schooling of adult hh members	0.010	0.005	0.009
	[0.234]	[0.556]	[0.313]
=1 if female hh head	0.069	0.061	0.023
	[0.180]	[0.238]	[0.645]
Experience in rice production in 5 years	0.033***	0.030***	0.031***
	[0.001]	[0.002]	[0.001]
Constant	0.020	0.131	0.508***
	[0.860]	[0.307]	[0.001]
Observations	634	634	634
R-squared	0.093	0.114	0.335

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 8.The Determinants of the Adaption of Modern Variety (OLS Estimation)

	(1)	(2)	(3)
	No dummy	District FE	Village FE
Village characteristics			
SACCOs	-0.070***	-0.014	
	[0.005]	[0.530]	
Private money lender	-0.008	-0.007	
	[0.493]	[0.534]	
Existence of extension office within 5km	0.133***	0.056*	
	[0.000]	[0.060]	
Existence of seed market	0.287***	0.167***	
	[0.000]	[0.000]	
Access to fertilizer market	-0.062**	0.018	
	[0.031]	[0.541]	
Male agricultural wage rate in kg of paddy	0.010***	0.002	
	[0.000]	[0.321]	
Distance to the district capital (km)	-0.000	-0.001**	
	[0.413]	[0.013]	
Household characteristics			
=1 if plot is irrigated	0.253***	0.457***	0.215***
	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.026***	-0.018**	-0.009
	[0.007]	[0.041]	[0.303]
The size of the plots owned in the lowland area except the sample plot (ha) sample plot (ha)	0.007	0.006	0.004
	[0.223]	[0.289]	[0.444]
The size of the plots owned in the upland area (ha)	-0.017**	-0.008	-0.006
	[0.022]	[0.246]	[0.301]
Household asset (million Tsh)	-0.028**	-0.021*	-0.009
	[0.040]	[0.086]	[0.396]
Number of cows and bulls owned	-0.001	0.000	-0.000
	[0.546]	[0.943]	[0.848]
Number of adult (age>=15)	0.002	0.007	0.009
	[0.778]	[0.344]	[0.177]
Number of children (age<15)	0.005	0.003	-0.003
	[0.477]	[0.571]	[0.630]
The age of hh head	0.000	-0.000	-0.001
	[0.666]	[0.764]	[0.485]
Average years of schooling of adult hh members	0.008	0.000	0.006
	[0.225]	[0.967]	[0.268]
=1 if female hh head	-0.036	-0.045	0.011
	[0.365]	[0.207]	[0.743]
Experience in rice production in 5 years	0.006	-0.001	-0.001
	[0.401]	[0.928]	[0.863]
Constant	-0.146*	0.279***	0.381***
	[0.092]	[0.002]	[0.000]
Observations	634	634	634
R-squared	0.302	0.455	0.631

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1.
Numbers in brackets are p-value.

Table 9.Determinants of Chemical Fertilizer Use (kg/ha) (Tobit Estimation)

	(1)	(2)	(3)
	No dummy	District FE	Village FE
Village characteristics			
SACCOs	52.818**	75.960***	
	[0.027]	[0.006]	
Private money lender	17.996	-19.771	
	[0.445]	[0.489]	
Existence of extension office within 5km	17.303	-32.167	
	[0.599]	[0.355]	
Existence of seed market	14.202	-4.517	
	[0.632]	[0.899]	
Access to fertilizer market	18.055	15.233	
	[0.549]	[0.680]	
Male agricultural wage rate in kg of paddy	2.247	-0.020	
	[0.274]	[0.993]	
Distance to the district capital (km)	-0.675*	-1.435***	
	[0.091]	[0.001]	
Household characteristics			
=1 if plot is irrigated	103.261***	50.044	42.943
	[0.000]	[0.107]	[0.108]
Size of the plot (ha)	-20.221	-32.531**	-16.575
	[0.157]	[0.033]	[0.214]
The size of the plots owned in the lowland area except the sample plot (ha)	-8.941	-7.792	-0.637
	[0.270]	[0.317]	[0.904]
The size of the plots owned in the upland area (ha)	-17.027	-0.881	1.109
	[0.224]	[0.931]	[0.878]
Household asset (million Tsh)	18.159	14.369	11.379
	[0.101]	[0.161]	[0.118]
Number of cows and bulls owned	-1.760	1.309	0.931
	[0.322]	[0.363]	[0.579]
Number of adult (age>=15)	-17.721*	-10.916	-1.636
	[0.055]	[0.213]	[0.805]
Number of children (age<15)	-2.679	5.159	1.748
	[0.723]	[0.484]	[0.775]
The age of hh head	0.538	0.797	-0.935
	[0.617]	[0.431]	[0.267]
Average years of schooling of adult hh members	19.932***	21.504***	17.151***
	[0.008]	[0.004]	[0.005]
=1 if female hh head	-0.098	17.497	2.820
	[0.998]	[0.610]	[0.914]
Experience in rice production in 5 years	1.629	-2.716	-3.953
	[0.831]	[0.708]	[0.496]
Constant	-332.527***	-126.587	-103.495
	[0.001]	[0.195]	[0.141]
Observations	634	634	634

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 10. The Determinants of the Adoption of Bunding (OLS Estimation)

	(1) No dummy	(2) District FE	(3) Village FE
Village characteristics			
SACCOs	0.075**	0.009	
	[0.025]	[0.724]	
Private money lender	-0.063***	-0.016	
	[0.000]	[0.163]	
Existence of extension office within 5km	0.155***	0.014	
	[0.000]	[0.669]	
Existence of seed market	0.050	0.130***	
	[0.254]	[0.001]	
Access to fertilizer market	-0.284***	-0.050	
	[0.000]	[0.121]	
Male agricultural wage rate in kg of paddy	-0.003	0.002	
	[0.262]	[0.284]	
Distance to the district capital (km)	-0.001***	-0.001***	
	[0.004]	[0.006]	
Household characteristics			
=1 if plot is irrigated	0.521***	0.582***	0.403***
	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.006	-0.012	-0.005
	[0.639]	[0.205]	[0.617]
The size of the plots owned in the lowland area except the sample plot (ha)	-0.009	0.000	-0.000
	[0.250]	[0.974]	[0.993]
The size of the plots owned in the upland area (ha)	0.043***	-0.002	-0.007
	[0.000]	[0.789]	[0.293]
Household asset (million Tsh)	-0.002	-0.015	-0.011
	[0.898]	[0.242]	[0.410]
Number of cows and bulls owned	0.008***	0.001	0.001
	[0.000]	[0.657]	[0.534]
Number of adult (age>=15)	0.027***	0.009	0.008
	[0.008]	[0.203]	[0.254]
Number of children (age<15)	0.015*	-0.007	-0.009
	[0.090]	[0.285]	[0.139]
The age of hh head	-0.002	-0.001	-0.000
	[0.284]	[0.573]	[0.684]
Average years of schooling of adult hh members	-0.027***	-0.005	-0.006
	[0.003]	[0.430]	[0.371]
=1 if female hh head	-0.037	-0.055	-0.053
	[0.489]	[0.154]	[0.165]
Experience in rice production in 5 years	-0.019*	0.000	-0.001
	[0.061]	[0.960]	[0.927]
Constant	0.710***	0.243**	0.064
	[0.000]	[0.011]	[0.568]
Observations	634	634	634
R-squared	0.382	0.685	0.752

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 11. The Determinants of the Adoption of Leveling (OLS Estimation)

	(1)	(2)	(3)
	No dummy	District FE	Village FE
Village characteristics			
SACCOs	0.089**	0.039	
	[0.018]	[0.255]	
Private money lender	-0.034*	0.000	
	[0.050]	[0.998]	
Existence of extension office within 5km	0.021	-0.047	
	[0.646]	[0.298]	
Existence of seed market	-0.020	0.057	
	[0.677]	[0.302]	
Access to fertilizer market	-0.191***	-0.053	
	[0.000]	[0.234]	
Male agricultural wage rate in kg of paddy	-0.007**	-0.000	
	[0.039]	[0.911]	
Distance to the district capital (km)	-0.001**	-0.000	
	[0.037]	[0.545]	
Household characteristics			
=1 if plot is irrigated	0.328***	0.387***	0.359***
	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.024*	-0.026**	-0.033**
	[0.094]	[0.049]	[0.022]
The size of the plots owned in the lowland area except the sample plot (ha)	-0.019**	-0.012	-0.011
	[0.038]	[0.157]	[0.208]
The size of the plots owned in the upland area (ha)	0.031***	-0.002	-0.005
	[0.004]	[0.858]	[0.638]
Household asset (million Tsh)	0.038*	0.029	0.035*
	[0.065]	[0.121]	[0.073]
Number of cows and bulls owned	0.007***	0.002	0.003*
	[0.000]	[0.192]	[0.065]
Number of adult (age>=15)	0.006	-0.010	-0.017
	[0.627]	[0.351]	[0.116]
Number of children (age<15)	0.009	-0.006	-0.008
	[0.344]	[0.490]	[0.403]
The age of hh head	-0.002	-0.001	-0.001
	[0.236]	[0.344]	[0.720]
Average years of schooling of adult hh members	-0.018*	-0.003	-0.000
	[0.078]	[0.742]	[0.970]
=1 if female hh head	-0.037	-0.060	-0.092
	[0.538]	[0.267]	[0.106]
Experience in rice production in 5 years	0.004	0.020*	0.017
	[0.752]	[0.060]	[0.138]
Constant	0.840***	0.372***	0.253
	[0.000]	[0.006]	[0.130]
Observations	634	634	634
R-squared	0.210	0.370	0.438

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 12. The Determinants of the Adoption of Transplanting in Rows (OLS estimation)

	(1)	(2)	(3)
	No dummy	District FE	Village FE
Village characteristics			
SACCOs	0.070***	0.069***	
	[0.003]	[0.005]	
Private money lender	0.008	0.009	
	[0.488]	[0.406]	
Existence of extension office within 5km	-0.020	-0.064**	
	[0.490]	[0.044]	
Existence of seed market	0.108***	0.104***	
	[0.001]	[0.007]	
Access to fertilizer market	-0.031	0.016	
	[0.264]	[0.603]	
Male agricultural wage rate in kg of paddy	0.000	-0.002	
	[0.867]	[0.420]	
Distance to the district capital (km)	-0.001	-0.001***	
	[0.102]	[0.005]	
Household characteristics			
=1 if plot is irrigated	0.227***	0.222***	0.216***
	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.022**	-0.025***	-0.014
	[0.014]	[0.007]	[0.129]
	0.008	0.009	0.010*
The size of the plots owned in the lowland area except the sample plot (ha)	[0.154]	[0.133]	[0.064]
The size of the plots owned in the upland area (ha)	0.006	0.005	-0.000
	[0.352]	[0.488]	[0.976]
Household asset (million Tsh)	-0.015	-0.016	-0.013
	[0.242]	[0.221]	[0.286]
Number of cows and bulls owned	0.000	0.000	-0.001
	[0.818]	[0.999]	[0.509]
Number of adult (age>=15)	-0.006	-0.005	-0.001
	[0.410]	[0.521]	[0.834]
Number of children (age<15)	-0.002	-0.004	-0.005
	[0.706]	[0.548]	[0.407]
The age of hh head	0.001	0.001	-0.000
	[0.389]	[0.304]	[0.740]
Average years of schooling of adult hh members	0.009	0.011*	0.008
	[0.184]	[0.096]	[0.167]
=1 if female hh head	-0.004	0.007	-0.013
	[0.920]	[0.864]	[0.710]
Experience in rice production in 5 years	0.008	0.007	0.006
	[0.260]	[0.319]	[0.377]
Constant	-0.010	0.101	0.166
	[0.907]	[0.287]	[0.117]
Observations	634	634	634
R-squared	0.165	0.185	0.415

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 13. The Determinants of Paddy Yield (t/ha)

	(1) No dummy	(2) District FE	(3) Village FE
Village Characteristics			
SACCOs	0.187*	0.189*	
	[0.099]	[0.097]	
Private money lender	0.070	0.101*	
	[0.180]	[0.057]	
Existence of extension office within 5km	0.443***	0.364**	
	[0.001]	[0.015]	
=1 if female hh head	-0.254	-0.206	
	[0.161]	[0.250]	
Experience in rice production in 5 years	0.051	0.042	
	[0.136]	[0.221]	
Existence of seed market	0.189	-0.033	
	[0.200]	[0.856]	
Access to fertilizer market	-0.031	0.062	
	[0.814]	[0.676]	
Male agricultural wage rate in kg of paddy	0.017*	0.004	
	[0.086]	[0.725]	
Distance to the district capital (km)	0.007***	0.004**	
	[0.000]	[0.035]	
Household characteristics			
=1 if plot is irrigated	1.556***	1.523***	0.826***
	[0.000]	[0.000]	[0.000]
Size of the plot (ha)	-0.182***	-0.178***	-0.161***
	[0.000]	[0.000]	[0.000]
The size of the plots owned in the lowland area	-0.020	-0.031	-0.023
lowland area except the sample plot (ha)	[0.451]	[0.257]	[0.391]
The size of the plots owned in the upland area (ha)	-0.005	-0.005	-0.020
	[0.882]	[0.881]	[0.543]
Household asset (million Tsh)	0.026	0.028	0.020
	[0.672]	[0.647]	[0.741]
Number of cows and bulls owned	0.016***	0.016***	0.015***
	[0.002]	[0.003]	[0.007]
Number of adult (age>=15)	-0.052	-0.039	-0.049
	[0.136]	[0.259]	[0.155]
Number of children (age<15)	-0.045	-0.057*	-0.033
	[0.134]	[0.056]	[0.257]
The age of hh head	-0.009*	-0.008*	-0.008
	[0.072]	[0.095]	[0.115]
Average years of schooling of adult hh members	0.011	0.023	0.025
	[0.722]	[0.444]	[0.412]
Constant	1.563***	2.116***	1.773***
	[0.000]	[0.000]	[0.001]
Observations	634	634	634
R-squared	0.304	0.335	0.459

Note: *** denotes p<0.001; **denoted p<0.05; * denotes p<0.1. Numbers in brackets are p-value.

Table 14. The Determinants of Paddy Yield (t/ha)

	(1)	(2)	(3)
		No dummy	
	OLS	IV (2sls)	IV (liml)
Adoption of MVs	0.745***	1.378**	1.634**
	[0.000]	[0.010]	[0.015]
Chemical fertilizer use (kg/ha)	0.006***	0.029***	0.039***
	[0.000]	[0.001]	[0.002]
Transplanting in rows (dummy)	0.295	-1.089	-2.055
	[0.144]	[0.400]	[0.253]
Plot with bund (dummy)	-0.024	-0.004	0.041
	[0.862]	[0.985]	[0.855]
Leveled plot (dummy)	0.186	0.351**	0.412**
	[0.161]	[0.039]	[0.038]
Distance to the district capital (km)	0.006***	0.008***	0.009***
	[0.000]	[0.000]	[0.000]
=1 if plot is irrigated	1.242***	0.751**	0.627*
	[0.000]	[0.011]	[0.083]
Size of the plot (ha)	-0.155***	-0.123**	-0.119*
	[0.000]	[0.021]	[0.056]
Number of cows and bulls owned	0.011**	0.014**	0.015**
	[0.019]	[0.013]	[0.021]
The age of hh head	-0.011**	-0.008	-0.006
	[0.013]	[0.170]	[0.379]
Average years of schooling of adult hh members	0.007	-0.036	-0.050
	[0.808]	[0.335]	[0.264]
=1 if female hh head	-0.163	-0.231	-0.254
	[0.350]	[0.270]	[0.293]
Experience in rice production in 5 years	0.048	0.034	0.031
	[0.148]	[0.408]	[0.513]
Constant	1.737***	1.538***	1.417***
	[0.000]	[0.000]	[0.005]
Observations	634	634	634
R-squared	0.326	0.034	-0.271
First stage F of MV		12.04	
		[0.000]	
First stage F of Chemical fertilizer		2.71	
		[0.002]	
First stage F of Transplanting in rows		3.01	
		[0.001]	
Under IV		19.50	
		[0.021]	
Over IV (Sargan statistic)		7.519	6.700
		[0.482]	[0.567]

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