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Role of Access to Credit in Rice Production in Sub Saharan Africa: The Case of Mwea Irrigation Scheme in Kenya

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This study investigates the possibility of boosting rice production in Sub-Saharan Africa with a special focus on the role of access to credit in rice farming in the large-scale Mwea Irrigation Scheme in Kenya. Using household level survey data, we find that the use of fertilizer and paddy yield per hectare are not significantly different among borrowers from the cooperative society, borrowers from rice traders, and non-borrowers. However, borrowers from rice traders receive lower incomes and profits compared to non-borrowers largely due to the higher interest charged. Considering that such farmers who borrow from rice traders are generally poorer in financial, physical, and human capital, and would have even made lower income and profit without rice trader credit, we suggest policies to facilitate further development of credit markets for both efficiency and equity of rice production in Mwea.

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1. Introduction

Food insecurity remains one of the main challenges facing many countries in Sub-Saharan Africa (SSA) despite some advancement in improving cereal grain yields especially for maize, wheat, and rice over the last several decades (Block, 2010; Tsusaka and Otsuka, 2013). In particular, rice has emerged as an important cereal in SSA as its demand has doubled over the past few decades due to rapid urbanization and population growth (Balasubramanian et al., 2007; Seck et al., 2010). However, rice production has remained significantly lower than consumption in SSA leading to heavy reliance on imports which now constitute one-third of all rice traded in the world market (Africa Rice Centre (WARDA), 2008). To ease this dependence on imports, SSA needs to replicate the rice Green Revolution similar to the one that occurred in Asia in the 1970s to 1980s (Otsuka and Kalirajan, 2006; Otsuka and Larson, 2013).

In Asia, the existence of irrigation was one of the most important factors promoting the dramatic improvement in rice productivity as modern high-yielding varieties were more productive and, hence, adopted faster in irrigated areas (David and Otsuka, 1994). In SSA, previous studies on large-scale irrigation schemes have shown that both the availability of water and application of fertilizer were essential to achieve high rice yields (Kajisa and Payongayong, 2011; Nakano and Otsuka, 2011). However, investments in irrigation infrastructure have remained significantly low due to the failures of large-scale irrigation projects in the past (Inocencio et al., 2007). Meanwhile, fertilizer use remains low in SSA because of: (1) high cost and limited access to credit which discourages many small-scale farmers who do not have adequate liquidity to cover the cost of chemical fertilizer and high-yielding variety seeds, (2) the high fertilizer prices relative to crop prices, (3) highly uncertain crop yields because of the volatility of weather and the absence or low quality of irrigation, and (4) dysfunctional fertilizer markets due to weak and dispersed demand (Rashid et al., 2004; Christen and Pearce, 2005; Morris et al., 2007; Duflo, et al., 2011; Matsumoto and Yamano, 2011). In recent times, the conditions for rice production in large-scale irrigation schemes in SSA have changed resulting in dramatic improvement in rice yields. The Office du Niger irrigation scheme is an outstanding example of how reforms, which saw the liberalization of rice farming and the involvement of farmers in the scheme's management, can lead to a sharp increase in rice yield (Aw and Diemer, 2005). This seems to suggest that yields in irrigated areas in SSA can be potentially high and similar to Asia. It is, therefore, important to explore the conditions for successful rice farming in large-scale irrigation schemes in SSA. Though previous studies on such schemes in SSA suggest that access to credit increases fertilizer use (Kajisa and Payongayong, 2011; Nakano and Kajisa, 2011; Nakano et al., 2011), they have not rigorously analyzed the impact of access to credit on the value of output, income, and profit from rice farming in these schemes.

In order to fill this gap, we examine the impact of access to credit on the performance of rice farming, using a household level data set collected in 2011 in Mwea irrigation scheme in Kenya. Remarkably, this scheme achieves the average yield of 5 tons per hectare, which is comparable to the average in irrigated areas in tropical Asia (David and Otsuka, 1994). This suggests that the rice Green Revolution has already taken place there. Unlike Uganda, where upland rice and rain-fed lowland rice are common (Kijima et al., 2011; Kijima et al., 2012), irrigated lowland rice production dominates in Kenya. The main source of credit for rice farming is the cooperative society, in which farmers must be members to access credit. Credit is offered in the form of inputs, and implicitly, the standing crop serves as collateral. Farmers in turn deliver paddy to the cooperative society which is sold to recover the value of input credit advanced. The cooperative society charges a monthly interest of one per cent. Another source is rice traders, who also use the standing crop as collateral. The farmer is advanced cash and repays in kind. A farmer can negotiate the interest to be paid to the rice trader which can be as high as 19 per cent per month. Although commercial banks are another source of formal credit, it is used primarily for non-farm activities. According to our interviews with farmers, those who borrowed from commercial banks used this credit for paying school fees, medical fees and investing in non-farm businesses. In addition, to obtain credit from commercial banks, one must maintain an account and provide collateral. There is also a rigorous vetting process to access the ability to repay. Therefore, we group farmers who borrow from the banks with non-borrowers. Furthermore, we did not find instances of family credit for rice farming. Family credit is limited to emergency purposes e.g. payment of hospital bills or burial.

We divide farmers into four categories based on their source of borrowing in the 2010/2011 cropping season: (1) those who did not borrow (non-borrowers), (2) those who borrowed from a farmer's co-operative society, (3) those who borrowed from rice traders, and (4) those who borrowed from both the co-operative society and rice traders. In our observation, almost all the non-borrowers are not financially constrained in farming. We use a set of regression models for our analysis, in which we explore the determinants of the source and amount of credit, and, in turn, investigate the impact of credit on farm performance. Although the provision of credit by traders is common and important in Asia (Bardhan, 1980; Nagarajan et al., 1992; Nagarajan and Meyer, 2005), it is rare in SSA to our knowledge. As described above, interest rates charged by traders are much higher than those of the co-operative society. Therefore, we focus on whether and to what extent borrowers from traders perform less well than other groups of farmers, even though they are still better off than being totally credit-constrained, which is revealed by their choice of borrowing from this source. It is expected that our analysis will contribute to the existing literature on the impact of access to credit on rice farming in large-scale irrigation schemes in SSA.

The rest of the paper is organized as follows. Section 2 provides a brief history of Mwea irrigation scheme. We describe the data used in our study and explain the descriptive statistics in Section 3. We also compare the performance of Mwea irrigation scheme with those in other large-scale irrigation schemes in SSA and in Asia. In Section 4 we discuss the main arguments of this study about merits and demerits of different credit sources and methodology of assessing them. We present the findings from the regression analysis in Section 5, and finally summarize the major findings and draw policy implications in Section 6.

2. Brief History

Mwea Irrigation Scheme (MIS) is the oldest and largest among the four major irrigation schemes based on gravity systems for growing rice in Kenya. The scheme was established in 1954, and approximately 6,200 hectares have been developed for paddy production. MIS produces 80 per cent of the paddy rice produced in Kenya. The scheme is divided into five sections: Mwea covering 1,300 hectares, Tebere 1,400 hectares, Thiba 1,200 hectares, Karaba 1,100 hectares and Wamumu 1,200 hectares.[1] Each section is further divided into units, and in

[1] MIS has a total area of 12,000 hectares of which 6,200 hectares have been developed for irrigation. In its development, Mwea and Tebere were the first established sections. Later the scheme expanded to Thiba, Wamumu

total there are 59 units in the scheme, each of which is about 100 hectares roughly distributed equally among five sections. The government retains ownership of the land in the irrigation scheme with farmers being allocated land with transferable use rights. Farmers were initially allocated four one-acre parcels of land per household (1.6 hectares), but some farmers have bequeathed land (use rights) to their offspring. Currently the average farm size is 1.2 hectares.

MIS was managed by the state through an agency, the National Irrigation Board (NIB), until 1999. During this period, NIB was in charge of irrigation management, rice production and marketing. NIB provided farmers with inputs on credit such as seed, fertilizers, other chemical inputs, and farm machinery services. Farmers had to strictly adhere to one crop per season per year and the cropping calendar which ran through from June to November. Farmers were allocated a quota of the harvest for their own consumption, and the remaining harvest would have to be delivered to NIB. Farmers then received the revenue from NIB after it deducted the cost of inputs and irrigation fees from the sales revenue of rice.

Similar to the inefficient state management in managing local commons such as large-scale irrigation schemes in Asia (e.g., Ostrom, 1990; Bardhan, 2000; Bardhan and Dayton-Johnson, 2002), NIB's management suffered several shortcomings. Water distribution was not efficient and farmers committed moral hazards such as the over-exploitation of water by head users (Abdullahi et al., 2003). In addition, returns to rice farming for farmers were very low as the price of paddy offered by NIB was far below the market price. Consistent with the experience in large irrigation schemes in Asia (Hayami and Kikuchi, 2000; Fujiie and Hayami, 2005), farmers in MIS revolted against NIB's management as they sought to have representation in the scheme's management.

In 1999, the government reformed irrigation laws so as to liberalize the rice farming system in MIS. Farmers were now in charge of their own production and marketing decisions as well as irrigation management through a water users' association. Farmers cultivate around 1 ha of farmland in the main season from December to April and in the sub season from July to

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and Karaba sections in that order. There is an out-grower section covering 2,300 hectares where irrigation infrastructure has not been developed but rice farming is taking place. Farmers in this section use water drained from the main scheme. The rest of the scheme is used for settlement, public utilities, subsistence and horticultural crop farming.

November. They use both family and hired labour, and, more importantly, they apply chemical fertilizer (see, Figure 1).

NIB retained the role of carrying out operations and maintenance of the irrigation infrastructure for which farmers paid an annual irrigation fee. Liberalization also allowed the entry of input retailers, rice traders, and rice millers into the market. Under the community management, farmers altered the cropping calendar and could now have a ratoon crop.[2] The ratoon crop takes a shorter time to mature and requires smaller amounts of inputs, thereby providing extra benefits to farmers. However, only farmers who plant basmati variety in the main season and happen to have good access to irrigation water during the dry season can have a ratoon crop.[3]

Farmers also started leasing out land, a practice that was prohibited under the NIB management, after the community took over the management of the scheme. In our interviews with farmers, we found that the majority of the lessees were the children of original settlers who did not inherit land or inherited very small pieces of land. The major reason for leasing out land was the lack of capital required for rice farming.[4] Selling of land use rights in Mwea is uncommon, and farmers are unable to use the land use rights as collateral to access credit from formal sources such as commercial banks. The amount of land rental is negotiated between the leaser and lessee and it is paid at the beginning of each season.

A farmer's co-operative society, Mwea Rice Growers Multi-Purpose Co-operative Society (MRGM), which was previously established as a savings and credit co-operative, was expanded to a multi-purpose credit society and took over the role of supplying farm inputs on credit from NIB. All farmers who were farming rice in 2000 were absorbed as members of MRGM and had access to input credit. MRGM charged a monthly interest rate of one per cent on the value of credit advanced to farmers. The system used to disburse input credit was similar to the system that was in place under the NIB management, but the departure from the previous

[2] For the ratoon crop, farmers cut the rice stalks at the base once they harvest the main crop, after which they flood the fields. A new crop sprouts from the stump and is referred to as the ratoon crop.
[3] It is estimated that about 80 per cent of farmers grow basmati variety in MIS. Approximately half of the farmers in our survey had a ratoon crop in the 2010-2011 cropping season
[4] Other reasons given for leasing out land were to cover huge household expenditures such as medical emergencies and school fees.

practice was that farmers were only required to deliver paddy that would be enough to cover their credit and could sell the remaining harvest to any buyer of their choice.

This new system faced potential challenges. First, farmers were not paid immediately after delivery because MRGM needed time to collect paddy from all farmers, sell the rice at the markets, and deduct the credit owed by farmers. Second, there was a possibility for farmers to receive prices that were much lower than the market price because of storage and post-harvest management costs for paddy as well as administrative costs and possibly excessively high commission. Third, MRGM is not subsidized and might not have had sufficient capacity to adequately play the role played by NIB.[5]

In 2000, the first year of operation under community irrigation management, some farmers, who tended to be endowed with less human, physical, and financial capital, and, thus, more vulnerable to negative production shocks, did not deliver paddy to MRGM after harvesting in that season despite the fact that these farmers received credit. Farmers who had delivered paddy to MRGM in 2000 were not paid on time as was anticipated. This was because the MRGM management faced difficulties in managing the co-operative with the expanded mandate for the first time and this was compounded by the lack of repayment by some farmers. According to interviews with farmers, they received a higher pay-out for their paddy in comparison to what they used to receive from NIB.

The membership of farmers who did not repay what they owed to MRGM was suspended, and eventually revoked. In principle, these defaulters have permanently lost access to the credit from MRGM. It is clear that those farmers who defaulted did not expect the strict policy of MRGM and underestimated the benefit of being members, as MRGM was a new marketing and credit organization. Meanwhile, some farmers who had the ability to finance the cost of their rice farming but were dissatisfied with the MRGM's delayed payments chose to stop receiving input credit from MRGM. These farmers could purchase inputs directly from input retailers and sell their paddy to rice traders. To counter the problem of defaulting, the MRGM management added a requirement that farmers must deliver paddy to the MRGM at the end of

[5] NIB benefitted from yearly disbursements from the government. Therefore, they had enough resources to procure inputs on a large scale and cover their administrative costs.

the previous season to access credit in the following season in addition to being a member. These requirements combined with the farmers' increasing recognition of the benefit of credit provided by MRGM substantially reduced the case of default since then.

To fill the credit demand of farmers who could not access credit from MRGM, many rice traders started providing credit to farmers in the early 2000s. Majority of the rice traders are self-employed without hired workers and mainly offspring of original settlers, and they have good knowledge about rice farming and farmers. The number of farmers receiving credit from traders has been increasing even though the interest rates charged by them are as high as 100 per cent for three months or so particularly because of high perceived risks influenced by their history of default on the MRGM credit. The contract between farmers and traders is such that the trader provides cash at the beginning of the season, while farmers will repay in kind, i.e. a predetermined amount of paddy at the end of the season. The price of paddy is market-determined. In good harvest, the "effective" interest rate charged by traders is low since the paddy price at the end of the harvest is low. During unfavourable seasons, the interest charged is high because paddy price at the end of the harvest is high. A potential disadvantage to farmers may arise from strong monopoly power of traders over farmers (Bell et al., 1997). In our case, however, the contract between the farmers and traders is likely to be competitive as there are hundreds of traders and thousands of farmers, and the market is liberalised with the traders competing with larger institutional buyers such as MRGM to purchase paddy from farmers.

3. Data

The data used in this study come from a household survey in MIS conducted by the senior author in February and March 2011. We randomly selected seven units in each section for a total of 36 units (out of 59 units).[6] We then randomly selected a feeder canal in each unit. Next, we used the list of registered farmers in MIS to randomly select eight farmers along each feeder canal and interviewed them.[7] If a feeder canal had fewer than eight farmers, we interviewed all the farmers along that feeder canal. We collected data on a farmer's parcel of land or randomly

[6] Our sample is randomly distributed across the sections. The number of farmers, sample plots and sizes of the plots are not different across sections.

[7] NIB maintains records of farmers who have been allocated land in the scheme.

selected two parcels where a farmer had cultivated more than one parcel. In total, we collected data on 406 plots from 259 households. We interviewed the farmers using structured questionnaires about their rice farming practices for the 2010/2011 cropping season including questions to elicit information on: (1) household demographics and non-farm occupation, (2) characteristics of land holdings, (3) input and output for rice, (4) source and amount of credit, and (5) agricultural assets held.

3.1. Descriptive analysis

Table 1 shows the summary of household characteristics by source of borrowing. There are 138 households not borrowing, 72 borrowing only from MRGM, 34 borrowing only from traders, and 15 borrowing from both MRGM and traders. Farmers who borrow only from MRGM and from both MRGM and traders are older and have longer years of experience in rice farming than those borrowing only from traders and non-borrowers. Households borrowing from traders have the lowest education attainment among non-head household members. The members of non-borrowing households were more likely to be engaged in non-farm jobs in comparison to other households. This is not surprising because education increases the likelihood of getting non-farm jobs, and earnings from these jobs can be used to finance rice farming (Reardon, 1997). Because households borrowing from traders have the lowest percentage of educated members, they are least likely to be able to finance rice farming by themselves. A larger proportion of female headed households borrow from MRGM or both MRGM and traders.

// Table 1 here //

Households who borrow from traders cultivated the smallest-sized land, similar to findings by Carter and Wiebe (1990). Additionally, these households have the lowest level of assets, which is likely to limit the amount of potential credit, while those who borrow from both MRGM and traders have the largest assets. Farmers who borrow only from traders and those who borrow from both MRGM and traders had more incidence of leasing out land in the past. Since the major purpose of leasing out is to receive rent in cash in the beginning of the cropping season, farmers who borrow from traders are more likely to have past experience of facing more severe credit constraints than non-borrowers and those who borrow only from MRGM.[8]

We present the distribution of membership to MRGM and the source of borrowing by section in Table 2. Karaba section, followed by Thiba section, had the highest proportion of households who were members of MRGM at the time of the survey. Mwea and Tebere sections had the highest rates of dropouts from MRGM, probably because being the oldest sections and being near the major town, these farmers were most vocal in the revolt from NIB, and may have been sceptical of a system that seemed to resemble the system under NIB. It is also possible that these farmers felt confident to purchase inputs independently and sell their output owing to their proximity to the market. Though three-fourths of the dropouts do not borrow from any source, some of the dropouts in Mwea, Tebere, and Wamumu sections borrow from traders. Interestingly, we find that about five per cent of the households that were members of MRGM chose to get credit from traders instead. This could be due to the attractive features of informal credit such as timeliness, flexibility in lending and low negotiation costs.

// Table 2 here //

3.2. Computation of costs and benefits

In order to assess the impact of access to credit on farm performance, firstly, we estimate the income from rice farming by deducting the paid-out costs from the value of output.[9] We then compute the residual profit by deducting the imputed costs of family labour and owned capital inputs from income by using the average market wage and input prices.[10] The residual profit is supposed to capture the returns to land, management ability, and possibly imputation errors. We expect that other things being equal, higher residual profit indicates higher efficiency of farming.

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[8] We found that MRGM collects information about their members who lease out land. These members are unable to access credit from MRGM for the period they have leased out their land.

[9] The paid-out costs comprise of fertilizer costs, the cost of other chemical inputs purchased by the farmer, the rental price of capital such as hiring tractors and oxen ploughs, and wages paid out to hired labour.

[10] Own costs include the imputed cost of own capital for oxen ploughs obtained using the average rate of hiring oxen ploughs per hectare, the imputed cost of self-supplied inputs such as manure calculated using the average price of these inputs, and the imputed cost of family labour obtained using the wage rates for various activities of hired labour.

In our approach, we take into account the interest costs in the total production costs incurred by rice farmers. We have three types of interest rates: (1) interest rates charged by traders, (2) the interest rate charged by MRGM, and (3) the interest rate on bank deposits in Mwea. The interest rate on bank deposits is used as a proxy for the opportunity cost of capital. In order to consider the interest cost in a cropping season, we divide the rice cropping calendar into three main periods. The first one is the planting, crop establishment and crop care period, where farmers incur costs for land preparation, establishing the nurseries, transplanting, weeding, irrigation management, and pest control. The second period is the harvesting period, when farmers who sell their paddy to rice traders receive payment immediately after harvest. The third period is when farmers who sell paddy to MRGM receive payment after waiting for several months since harvest. Thus, we have to evaluate the costs and benefits at different points in time in terms of the value at a certain period by "discounting" using the appropriate interest rates. In this study, we evaluate the revenue and cost at the time when MRGM members receive payments.

We thus use a simple model of three periods to illustrate our approach. In the first period, a non-borrowing farmer incurs a cost per hectare of cultivated farmland, X, while in the second period he receives revenue that is equal to his gross value of output per hectare of cultivated farmland, Y. Non-borrowers do not borrow their capital for rice farming but face an opportunity cost. If these farmers had saved their money in the bank for the same duration, it would have earned an interest. The bank deposit rate in Mwea is very low at an annual interest rate of five per cent at the time of data collection. The net benefit for non-borrowers at the third period can be expressed as

$$Y_N\,(1+i) - X_N(1+i)^2, \qquad (1)$$

where i is the bank deposit rate, $Y_N\,(1+i)$ is the value of output per hectare of cultivated farmland for non-borrowers when the MRGM pays its member farmers, and $X_N(1+i)^2$ is the cost per hectare of cultivated farmland incurred for two periods, the first from input application to harvesting and the second from harvesting to the time when farmers receive payment from MRGM.

Farmers who borrowed from MRGM pay an interest, τ, which is one per cent per month for the two periods they have borrowed.[11] These farmers deliver the paddy to MRGM, who sell the paddy and deduct their loan and interest due and pay the residual to farmers. Therefore, the interest is collected when the payment to farmers is made. We present their costs and benefits as

$$Y_M - X_M(1+\tau)^2, \tag{2}$$

where Y_M is the value of output per hectare of cultivated farmland for farmers who borrowed from MRGM, and $X_M(1+\tau)^2$ is the cost of inputs per hectare of cultivated farmland for farmers who borrow from MRGM at an interest rate τ for one period.

Since the interest and principal amount loaned is collected by traders at the time of harvest, a farmer j who borrowed from them pays an interest, r_j, which ranges from 30 per cent to 100 per cent, for one period. We use the interest, i, as an opportunity cost of capital to get the value of the cost and benefit evaluated at the third period. Thus, the net benefit can be shown as

$$Y_T\,(1+i) - X_T\left(1+r_j\right)(1+i), \tag{3}$$

where $Y_T\,(1+i)$ is the value of output per hectare of cultivated farmland for farmers who borrowed from traders evaluated at the time when MRGM farmers receive payment, and $X_T(1+r_j)(1+i)$ is the cost of inputs per hectare of cultivated farmland at the same time.

The rest of the farmers borrowed from both MRGM and traders. Following the above expressions, the two-period gross interest rate on credit provided by MRGM is $(1+\tau)^2$, and the corresponding interest rate on credit from trader is $(1+r_j)(1+i)$. We can present their cost and benefit as the sum of equations (2) and (3).

3.3. Comparison of farm performance

We present the yields, value of output and input costs per hectare of cultivated farmland incurred for the main crop of the 2010/2011 cropping season in Table 3. The mean values for yield, value of output and quantity of fertilizer used are not statistically different among those who borrow from MRGM and those who borrow from traders and non-borrowers. The costs of

[11] We explained toward the end of Section 2 that the trader's interest rate is variable ex-ante. But we use the ex-post interest rate on trader's credit, because the purpose of this model is to explain how we computed the present discounted values of costs and benefits to be compared across different borrowing sources.

fertilizer and rental cost of capital are lowest for households who access credit from MRGM and highest for those who access credit from traders.[12] This is consistent with our expectation that farmers who are borrowers from MRGM are able to benefit from the lower price of fertilizer and capital inputs. The income and residual profit for farmers who borrow from MRGM is statistically higher than those of farmers who borrow from traders.

// Table 3 here //

In summary, the households who borrow from traders manage to apply amounts of fertilizer, labour and other inputs not different from other groups of households, even though the income and residual profit of households who borrow only from traders are significantly lower than those who borrow only from MRGM. This is probably because the MRGM farmers would like to buy more inputs since it is so cheap, but are constrained by the 3 bags/acre rule and this is why the ultimate usage looks similar. In order to evaluate the relative performance of trader credit rigorously, however, we need to examine whether these differences are large after controlling for various factors. We thus perform regression analyses in Section 5.

3.4. Comparison with Large-Scale Irrigation Schemes in Asia and SSA

A remarkable observation from Table 3 is that paddy yields are surprisingly high in MIS, compared with the average yield of 1.8 tons to 2.0 tons per hectare in SSA and four tons per hectare in Southeast and South Asia. The average yield of 5 tons per hectare is comparable to the average in irrigated areas in tropical Asia reported by David and Otsuka (1994). In order to confirm the validity of this conjecture, we would like to undertake a comparison of yield between MIS and large-scale irrigation schemes in Southeast and South Asia as well as in other schemes in SSA.

For this purpose, we use data reported by Nakano et al. (2011) on large-scale irrigation schemes in SSA in recent years, and data reported by David and Otsuka (1994) on irrigated areas in Asia in the late 1980s. For SSA, we have data from Mozambique, Senegal, Tanzania and Uganda. For Asia we have data from Bangladesh, Indonesia, India, Nepal, the Philippines and Thailand. Our expectation is that although rice productivity is higher in Asia than in SSA, there

[12] Non-borrowers and those who borrow from traders must purchase their inputs from the market. The MRGM price of inputs is lower that the market price because bulk purchase by MRGM is likely to attract some discounts.

should be no large difference in production function parameters in irrigated areas between the two regions. This is because Asian-type modern varieties (MVs), which are highly responsive to both the availability of water and application of fertilizer (Estudillo and Otsuka, 2006), are planted in many of these areas in SSA. Although the most popular variety in MIS is not an Asian-type MVs but improved Basmati variety, it is fairly responsive to fertilizer application and hence, high-yielding.[13] Therefore, differences in production are likely to be due to differences in inputs but not in production efficiency.

Panel (a) in Figure 1 shows the relationship between rice yields and fertilizer use per hectare in large-scale irrigation schemes in SSA and Asia. In both SSA and Asia, we find a positive relationship between fertilizer use and rice yields. The most critical observation is that the relationship between yield and fertilizer use per hectare in SSA is not markedly different from that in Asia. Thus, the hypothesis that the production functions in the irrigated areas of Asia and SSA are identical may not be rejected. Panel (b) in Figure 1 compares the relationship between the fertilizer price relative to the paddy price and the fertilizer use per hectare. We find a negative relationship between the cost of fertilizer and the amount of fertilizer used in irrigated areas, particularly in SSA.

// Figure 1 here //

The low fertilizer use in Mozambique and Uganda is consistent with the findings from previous studies that the high price of fertilizer relative to output price and the lack of access to credit were major constraints on fertilizer use in SSA (Rashid et al., 2004; Christen and Pearce, 2005; Morris et al., 2007; Matsumoto and Yamano, 2011). In contrast, farmers in Indonesia applied the largest amounts of fertilizer largely because of the low subsidized fertilizer price (David and Otsuka, 1994). Thus, similar to SSA, the real fertilizer price, as well as the availability of credit, seem to be the major determinants of fertilizer use. “Effective” fertilizer prices are different depending on the access to credit. For example, the interest rate charged on credit by MRGM is lower than that offered by traders (Table 1). Therefore, in this study we

[13] Basmati varieties were introduced from Pakistan, while MV called the BW196 variety was introduced from Sri-Lanka. BW 196 is an IRRI-type variety in terms of traits and yields. The adoption rate of BW196 is roughly 20 per cent.

focus on the analysis of the effect of credit sources on the application of fertilizer and other inputs as well as overall farm performance.

4. Merits and Demerits of Alternative Credit Sources

4.1. Main arguments

The success of the MRGM operation hinges on its effectiveness to lock out members who default on the repayment to the co-operative. We have discussed in the earlier section that the MRGM management suspended membership for those who did not repay their debts. MRGM also hired qualified personnel who report to the board of directors who are elected amongst members to run the co-operative. This ensures that there is no corrupted behaviour such as personal favours due to social and personal connections. Additionally, the management stipulated that farmers have to be members and must have delivered paddy to MRGM in the previous seasons in order to access input credit in the current season. The management then used information about land that a farmer has (use rights of) to determine the amount of credit a farmer is eligible to receive.[14] The amount of credit is fixed per acre of land, in that a farmer gets three bags of fertilizer per acre.[15] A farmer can choose the type of fertilizer but cannot get more than three bags of fertilizer per acre in total. Demerits of using MRGM is that a farmer must bear the fixed amount of transaction costs, i.e., visiting the MRGM office, filling out application forms, and showing the certificate of land use right when applying for a loan from MRGM every year. Another demerit is the late payment of the revenue for farmers. Therefore, we expect that farmers who borrow larger amounts of credit will have lower average transaction costs. These farmers would stand to benefit more from acquiring credit from MRGM. We, therefore, expect that farmers cultivating larger farms choose to borrow credit from MRGM because it is more profitable due to the fixed costs in transaction with MRGM.

Alternatively, we could also argue that larger farmers may borrow from MGRM because they are less likely to have defaulted in the past. For example, a farmer may default if he unexpectedly has a negative shock right before harvest and needs the money for something else

[14] MRGM acquired records on land area allocation to farmers from NIB.
[15] In addition, a farmer gets two litres of other chemical input (herbicides and pesticides), 20 kilograms of seed and services such as hiring of tractors.

and cannot wait so many months. Since the larger farmers are less likely to be in such a distressed situation, they would have been less likely to default in the past, and therefore more likely to be members now. If this is the case, the farm size will not be correlated with the likelihood of borrowing from MRGM, once we control for the MRGM membership or the experience of dropout from MRGM.

In addition, larger farmers may have better ability to wait for months to receive their harvest payment because they are likely to be richer and less liquidity constrained. This could be another reason why they are more likely to be in MRGM, although this could also be a reason that larger farmers are less likely to demand for credit from any source. We will examine the effect of non-farm income and the value of assets to explore this possibility.

A group of farmers were denied access to credit from MRGM because of default in the past. According to defaulting farmers, they did not correctly anticipate the merit of MRGM membership which allows access to cheap credit. These farmers would be heavily handicapped in access to credit if there had been no other sources of credit available to them. Rice traders, however, may fill an important gap for these farmers. Although credit from traders may not be an extremely attractive option for farmers because it is expensive, it is an alternative for farmers who have been rationed out from cheaper formal sources (Bardhan, 1980), such as MRGM. A merit of credit from traders is quick and easy access to it. An empirical question is whether and to what extent farmers who were denied access to credit from MRGM managed to decently perform with the help of trader credit.

If the performance of farmers who received credit from traders is not substantially inferior to that of farmers who received credit from MRGM and those who do not need credit, it would suggest that the credit from traders played a significant role in boosting farm performance for farmers who were denied access to credit from MRGM. We learnt from farmers during our interviews that there was increased demand for credit from traders after 2000, when rice traders started to provide credit. We may postulate that there is no significant difference in input application per hectare of cultivated farmland as well as the value of production, income, and profit per hectare of cultivated farmland among borrowers from MRGM, borrowers from traders, and non-borrowers. Needless to say, this argument may not be supported entirely to the extent that informal credit market supported by rice traders is not functioning effectively due to information asymmetry and imperfect contract enforcement.

4.2. Methodology of estimation

We use censored regression to investigate the determinants of credit amount per hectare of cultivated farmland by borrowing source and linear regressions to investigate the determinants of the agricultural performance of the rice-producing farmers. We initially intended to examine the causal effects of the amount of credit by source on the agricultural performance of the rice-producing farmers. But because of the lack of proper instruments, we have decided to estimate the set of regression models and explore the statistical associations between the credit and the farming performance.[16]

We present the household's choice to receive credit from MRGM, traders, or both as follows:

$$C_{ij} = \begin{cases} C_{ij}^{*}, & if C_{ij}^{*} > 0 \\ 0, & if C_{ij}^{*} \leq 0 \end{cases}, \tag{4}$$

where C_{ij}^{*} is the latent amount of credit received by the household i from source j where j =1,2,3 for MRGM, traders, and both MRGM and traders, respectively, and is observed as $C_{ij} = C_{ij}^{*}$ only when a household i receives credit $C_{ij}^{*} > 0$ from credit source j. Observed amount of credit accessed C_{ij} is zero when $C_{ij}^{*} \leq 0$.

We specify the latent variable as linear in regressors with an additive error such that:

$$C_{ij}^{*} = X_i'\beta_j + \varepsilon_{ij}, \tag{5}$$

where X_i is a vector of explanatory variables, β_j is the vector of parameters to be estimated, and ε_{ij} is the error term.

We also estimate the determinants of farm performance as follows:

$$\Pi_i = X_i'\delta + \sum_j \gamma_j C_{ij} + \mu_i, \tag{6}$$

where Π_i is the value of output, paid-out costs, income, imputed costs of family-owned inputs, or residual profit in thousand Kenyan shillings per hectare of cultivated farmland for the *i*-th household; δ and γ_j are vectors of parameters to be estimated; C_{ij} is the amount of credit per hectare received from credit source j by the *i*-th household; and μ_i is the error term. The

[16] We are grateful to the editor and the two referees for suggesting these empirical strategies.

estimated parameters are consistent, if the credit amount and the other explanatory variables are not correlated with the error term.

The explanatory variables included in the model consist of (1) the number of farmers along a feeder canal where household plots are located to measure the coordination cost of water allocation, (2) the average distance of plots cultivated by the household from the intake of the feeder canal in kilometres, (3) the average time taken from the household to the plots in hours, (4) the total size of the cultivated land by the household in hectares, (5) the rental value of land in thousand Kenyan shillings as a proxy for the quality of land, (6) the age of the household head, (7) a dummy for female head, (8) the highest education attainment among non-head members, (9) the proportion of dependents in the household, (10) a dummy variable for farmers who dropped out from MRGM, (11) a dummy variable for farmers who started rice farming after 2000, (12) the value of assets, (13) two dummies for groups for water rotation (there are three groups in each section, the third of which was the last to receive water and is the base group)[17], (14) four location dummies for the four sections with Karaba section as the base. Note that groups 1 and 2 for water rotation may have advantage over the third group in access to water. But this advantage is not likely to be significant to the extent that water users' associations allocate water more or less equally to each group.

5. Results

5.1. Determinants of Borrowing

We present the estimation results for the censored regression in Table 4 which correspond to the determinants of credit from MRGM, traders, or both, shown in columns one to three, respectively.[18]

// Table 4 here //

[17] The management of Mwea irrigation scheme creates a water sharing schedule to be used when water available for irrigation is not sufficient. Each section is divided into three fairly distributed groups mainly using the main and sub-main canal. This is to ensure that all farmers have sufficient water for rice farming. The groups receive irrigation water in rotation. After the farmers in the first group harvest, their main canals are blocked and water is diverted to the next group. This practise is common in water scarce periods such as when we collected our data.

[18] To check the robustness of our model, we estimated linear regression models and a multinomial-logit model based on the four borrowing categories. The findings are similar and consistent with the findings from our models shown in Table 4.

The size of cultivated land is positively correlated with the amount of credit per hectare received from MRGM even after controlling for the past dropout (i.e., defaulted on credit and lost membership) from MRGM, the value of assets and the highest education attainment of non-head household members. This result is in line with our argument that larger farmers are more likely to borrow credit from the MRGM because of fixed transaction cost. As may be expected, the dummy variable for farmers who dropped out from MRGM is positively correlated with borrowing from traders and negatively correlated with borrowing from MRGM. The value of assets is positively associated with borrowing credit from both MRGM and traders, even though the significance level is low. Higher educational attainment among non-head household members reduces the probability of getting credit from traders. This is expected as education increases the likelihood of getting a non-farm job whose earnings may be used to provide the capital required for rice farming. Farmers in Tebere and Wamumu sections were less likely to borrow from MRGM compared to farmers from Karaba section. As can be seen in Table 2, these sections had the largest number of farmers who never joined MRGM in addition to dropouts.

5.2. Determinants of Farm Performance

Table 5 presents the estimation results of factors affecting the farm performance measured for the main crop.[19]

// Table 5 here //

Farmers who borrowed from traders earned lower income compared to the other groups of farmers, but their profit was not significantly different from those of non-borrowers. Farmers who borrowed from both MRGM and traders made lower income and profits. This is not consistent with our argument that farmers who borrowed from traders performed as well as non-borrowers and farmers who borrowed from MRGM. But, importantly, the difference in residual profit is not statistically significant, and the difference in income is not very large. To see this, we multiply the estimated coefficient of credit amount from each credit source and the average amount of credit from traders. Farmers getting credit from traders earned income lower than that of the non-borrowers by USD 108 or 10%. Borrowing from traders and both MRGM and traders is positively correlated with paid input costs. This result suggests that trader credit is helpful in

[19] Following a reviewer's advice, we repeated this analysis, including the amounts of fertilizer used as an additional explanatory variable and found that the main results were not qualitatively different from our results in Table 5.

achieving high rice farming performance in MIS by enabling potentially credit-constrained farmers to apply fairly adequate level of inputs without which these farmers would have performed far much worse.

Living far away from the farm was likely to affect a household's rice farming performance negatively. Households that had more dependents were likely to be negatively affected in their rice farming performance, possibly because the larger number of dependents meant that fewer family workers are available to work. Higher quality of land, captured by its rental value, is positively correlated with the value of output, incomes, costs and residual profit. This implies that farmers are aware of their land quality, apply inputs accordingly, and earn higher income and residual profit as a result. Highest education attainment of non-head household members and the value of assets are positively correlated with farming performance.

We estimated the farming performance equation (6) not only for the main crop but also for the ratoon crop. The estimation results were essentially the same with our results for the main crop reported in Table 5.[20] Borrowing from traders was negatively correlated with farming performance. The rental value of land, which is a proxy for quality of land is positively correlated to farming performance. The value of assets is positively correlated with farming performance.

6. Conclusion

This study attempted to examine the role of access to credit in farm performance, which is measured in terms of the value of output, income and residual profit per hectare from rice farming in large-scale irrigation schemes in Mwea in Kenya. The regression analyses revealed that farmers who cultivated more land borrowed from MRGM presumably because of the fixed costs associated with borrowing from MRGM. Educational attainment among non-head household members reduced the likelihood to borrow from traders presumably because education increases the opportunity of getting a non-farm job whose income could be used to finance rice farming. Farmers who dropped out from MRGM, as well as asset-poor farmers, were able to access credit from rice traders, thereby easing their credit constraints.

[20] The estimation results are not reported in this paper, but available upon request.

In the case of Asia during the Green Revolution, farmers, who demanded credit to acquire fertilizer and other inputs but could not access formal credit due to the lack of collateral, received credit from rice traders and were able to achieve high rice yields (Nagarajan et al., 1992). The descriptive table reports that resource poor farmers borrowing from traders tend to have slightly lower income than farmers better endowed with financial capital. But trader credit ought to be helpful particularly to those farmers that self-select to take it. Farmers who borrow from traders are often by far poorer in financial, physical, and human capital, and they are most likely to be credit-constrained. Without trader credit, these farmers would have performed even more poorly.

Our empirical result suggests that MRGM credit helps farmers to attain the income and profit comparable to non-borrowing farmers. In all likelihood, the remarkable success in attaining high rice yields in the Mwea irrigation scheme depends on this availability of local credit. Simplifying the application process may reduce the transaction cost and benefit wider range of farmers to a greater degree.

According to You et al. (2010), it would cost between USD 3000-8000 on average per hectare to construct large-scale irrigation infrastructure in SSA. From our calculations, the average profit per hectare for the main rice crop was USD 1000. This could be higher if double cropping can be practiced. Therefore, for cases such as MIS, even with a single crop per year, profits are high enough to justify investment in irrigation because the rate of return for the irrigation project would be at least 12.5 per cent (i.e., 1000/8000), which is far higher than the 6.6 per cent estimated by You et al. (2010) for SSA countries.

These findings have important implications for boosting agricultural productivity in SSA. Many researchers have inquired as to why farmers in SSA apply little or no chemical fertilizer. It has been shown that high fertilizer price relative to output price and the lack of credit have greatly contributed to this situation (Morris et al., 2007). However, this study has demonstrated that farmers in MIS were able to achieve high yields as a result of the high application of chemical fertilizer. The supply of credit has played a significant role in helping farmers acquire fertilizer and other purchased inputs without which they would not have achieved high yields observed in MIS. Also important would be the high demand for fertilizer due to irrigation. It is likely that the high profitability of rice farming and high potential demand for credit under the irrigated conditions led to the development of informal credit markets, which helped to realize high rice yields in Mwea comparable to yields in Asia during the Green Revolution. Thus, the government should facilitate the credit market to ensure further penetration for both efficiency and equity. Fundamental policy is to strengthen land transfer rights, so that land can be used as collateral for borrowing. Also important would be the proper maintenance of irrigation facilities, equitable allocation of water, and effective pest and disease control, in order to reduce production risk in rice farming. In addition, governments in SSA and donor agencies should reconsider the profitability of large irrigation schemes in SSA in order to realize a rice Green Revolution in many areas of the continent.

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Table 1

Household Characteristics by Source of Borrowing

	Non Borrowers	MRGM only	Traders only	MRGM & Traders	Full Sample
HH size	4.3 (1.8)	4.7 (2.2)	4.3 (1.6)	4.8 (2.3)	4.5 (1.9)
Age of HH head	54 (16)	59 (13)	55 (14)	61 (14)	56 (15)
% of HH heads who started rice farming after 2000	35.5 (48.0)	25.0 (43.6)	26.5 (44.8)	6.7 (25.8)	29.7 (45.8)
Female headed HH (%)	17.4 (38.0)	22.2 (41.9)	14.7 (35.9)	26.7 (45.8)	18.9 (39.2)
Proportion of dependants in the HH (%)	36.0 (25.8)	35.2 (29.2)	35.5 (28.2)	38.8 (32.7)	35.9 (27.4)
Highest education attainment of non-head HH members	3.4 (1.1)	3.4 (1.4)	2.8 (1.1)	3.4 (1.2)	3.3 (1.2)
Dropout from MRGM (%) [a]	44.2 (49.8)	0	52.9 (50.7)	0	30.5 (46.1)
Cultivated farm size (ha)	1.05 (0.57)	1.41 (0.57)	0.94 (0.6)	1.51 (0.56)	1.17 (0.6)
Number of farmers along the feeder canal	16 (5)	16 (6)	14 (6)	15 (4)	16 (6)
Average distance from intake to plot (km)	0.54 (0.41)	0.53 (0.4)	0.49 (0.43)	0.39 (0.38)	0.52 (0.41)
Average time taken from HH to plot (hours)	0.62 (0.37)	0.63 (0.4)	0.59 (0.36)	0.76 (0.31)	0.63 (0.37)
Rental value of land [b]	336 (92)	347 (76)	345 (43)	352 (68)	341 (81)
Value of assets [b]	287 (552)	226 (177)	175 (154)	418 (460)	263 (433)
Credit from MRGM [b]	---	370 (144)	---	396 (195)	371 (188)
Credit from Traders [b]	---	---	263 (153)	232 (188)	144 (176)
Range of interest rate charged per month [c]	0.4	1	7-19	1 & 7-14	

Source: Own Calculations

Standard deviations are in parenthesis

[a] Dropouts are farmers who were members of MRGM in 2000 but are not members at the time of the survey.

[b] Rental value of land, assets and credit in USD (exchange rate was 1USD to 84.21 Kshs).

Assets include small livestock such as goats, sheep and poultry and light farm equipment

[c] 0.4% is bank deposit interest rate per month in Mwea in 2011. MRGM charges 1% interest rate per month. The interest rate for farmers borrowing only from traders ranges from 7% to 19%. The interest rate on trader's credit for farmers borrowing from both MRGM and traders ranges from 7% to 14%.

Table 2

MRGM Membership and Source of Borrowing by Section (% of Households)

	Current MRGM members	Non Members		Borrowing Categories							
		Dropouts	Never Joined	MRGM only	MRGM & Traders	Traders only			Non Borrowers		
						MRGM Members	Dropouts	Never Joined	MRGM Members	Dropouts	Never Joined
Karaba	76.8	16.1	7.1	42.9	12.5	3.6	1.8	0.0	17.9	14.3	7.1
Mwea	49.1	47.2	3.8	26.4	3.8	3.8	13.2	1.9	15.1	34.0	1.9
Tebere	35.8	39.6	24.5	11.3	0.0	7.5	11.3	0.0	17.0	28.3	24.5
Thiba	75.5	18.4	6.1	32.7	12.2	4.1	0.0	0.0	26.5	18.4	6.1
Wamumu	56.3	31.3	12.5	25.0	0.0	8.3	8.3	2.1	22.9	22.9	10.4
Total	58.7	30.5	10.8	27.8	5.8	5.4	6.9	0.8	19.7	23.6	10.0

Source: Own calculations

Borrowing categories is represented as a percentage of households by section

Table 3
Yields, Input Cost, Income and Profit by Source of Borrowing [a]

	Non Borrowers	MRGM	Traders	MRGM & Traders	Full Sample
Yields (ton/ha)	4.9	5.1	4.8	5.3	5.0
Value of output	2333	2494	2252	2575	2381
NPK(kg/ha)	140	140	138	133	139
NPK cost (USD/kg)	1.6	1.4	2.0	1.8	1.6
Fertilizer cost (USD/ha)	216	175	246	234	210
Cost of other inputs[b]	74	82	87	106	80
Hired labour in worker days	167	185	156	171	171
Hired labour (USD/ha)	574	647	688	850	625
Family labour in worker days	52	64	57	70	57
Family labour (USD/ha)[c]	235	294	252	403	263
Rental cost of capital[d] (USD/ha)	159	127	175	164	152
Imputed cost of capital (USD/ha)	39	35	20	17	34
Income (USD/ha)	1310	1463	1056	1221	1314
Residual profit (USD/ha)	1037	1135	784	800	1017

[a] In Kenya, mean exchange rate as of March 2011, USD 1 = Ksh.84.21 is used for conversion.
[b] Other inputs include cost of seeds, pesticides, herbicides and manure.
[c] The values of different activities are respectively estimated from the data for hired labour. Using the estimated values, the total cost of family labour is imputed.
[d] Capital inputs include tractor and animals.

Table 4
Determinants of Amount of Credit by source (Tobit)

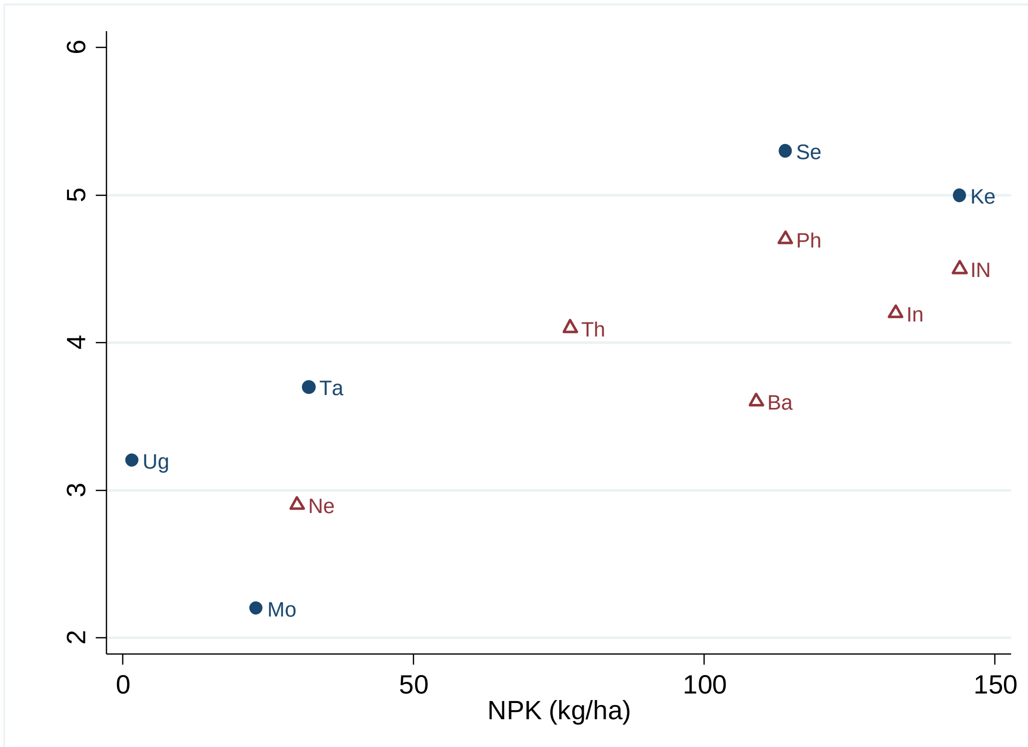
	(1) MRGM	(2) Traders	(3) MRGM & Traders
Number of farmers along the feeder canal	0.360	-0.516	-0.600
	(0.543)	(-0.765)	(-0.231)
Average distance from intake (km)	1.573	-5.114	0.742
	(0.219)	(-0.568)	(0.025)
Average time taken from household to plot	-7.826	-1.088	21.083
	(-0.981)	(-0.112)	(0.779)
Cultivated farm size (ha)	12.183**	-12.376	-14.115
	(2.193)	(-1.525)	(-0.448)
Rental value of land	0.498	-0.171	2.173
	(1.285)	(-0.378)	(1.446)
Age of HH Head	0.308	0.068	0.064
	(1.136)	(0.202)	(0.049)
Female headed HH	-3.517	-1.477	-2.903
	(-0.459)	(-0.141)	(-0.089)
Prop of dependants in HH	-18.486	0.583	17.857
	(-1.486)	(0.034)	(0.300)
Dropout from MRGM	-183.789***	14.385**	-418.171***
	(-16.808)	(2.026)	(-4.913)
Farming after 2000 dummy	9.821	-11.872	-61.947
	(1.170)	(-1.178)	(-1.245)
Value of assets	0.055	-0.080	0.383*
	(0.926)	(-1.272)	(1.670)
Highest education of non-head HH members	-1.302	-6.766**	-0.659
	(-0.507)	(-2.032)	(-0.049)
Group1 dummy	-7.673	1.692	39.220
	(-0.873)	(0.162)	(1.140)
Group 2 dummy	9.532	5.649	-18.544
	(0.942)	(0.525)	(-0.331)
Mwea section	-1.523	14.650	-35.613
	(-0.145)	(1.111)	(-0.800)
Tebere section	-32.970***	12.524	-445.661***
	(-2.611)	(0.854)	(-5.918)
Thiba section	-13.236	-6.173	-22.662
	(-1.301)	(-0.331)	(-0.555)
Wamumu section	-19.545*	17.748	-455.897***
	(-1.942)	(1.371)	(-7.387)
Constant	-35.882	-1.174	-170.014
	(-1.261)	(-0.041)	(-1.267)
Sigma	31.669***	35.029***	86.448***
	(13.526)	(10.074)	(6.578)
Observations	245	245	245
Log likelihood	-382.1	-221.2	-104.2
Robust *z*-statistics in parentheses	*** p<0.01, ** p<0.05, * p<0.1		

Table 5
Determinants of Value of Output, Costs, Income and Profits per Hectare (*Main crop*)

	(1) Value of Output	(2) Paid Cost	(3) Income	(4) Own Cost	(5) Residual Profit
Credit from MRGM	0.0526	0.109	-0.0563	0.127	-0.183
	(0.19)	(0.97)	(-0.19)	(1.10)	(-0.56)
Credit from Traders	0.161	0.916***	-0.755*	-0.214*	-0.541
	(0.33)	(5.62)	(-1.67)	(-1.97)	(-1.15)
Credit from both MRGM & Traders	0.185	0.642***	-0.457*	0.161	-0.618**
	(0.68)	(4.22)	(-1.70)	(1.39)	(-2.03)
Number of farmers along the feeder canal	0.540	0.232	0.309	-0.606**	0.915
	(0.70)	(0.81)	(0.38)	(-2.05)	(1.04)
Average distance from intake (km)	0.913	3.295	-2.381	-6.469*	4.088
	(0.09)	(0.96)	(-0.21)	(-1.76)	(0.33)
Average time taken from household to plot	-22.17**	2.099	-24.27**	1.469	-25.74**
	(-2.38)	(0.40)	(-2.41)	(0.33)	(-2.59)
Cultivated farm size (ha)	0.178	-1.111	1.289	-0.998	2.287
	(0.02)	(-0.40)	(0.12)	(-0.40)	(0.21)
Rental value of land	4.511***	1.440***	3.071***	0.551***	2.519***
	(6.84)	(3.95)	(5.50)	(2.79)	(4.12)
Age of HH Head	0.0637	-0.0612	0.125	0.0405	0.0844
	(0.17)	(-0.46)	(0.31)	(0.35)	(0.20)
Female headed HH	-2.006	3.024	-5.029	0.863	-5.892
	(-0.18)	(0.72)	(-0.46)	(0.20)	(-0.50)
Prop of dependants in HH	-27.66	10.41	-38.07**	-7.286	-30.78
	(-1.57)	(1.62)	(-2.08)	(-1.28)	(-1.65)
Dropout from MRGM	-3.805	3.632	-7.437	1.399	-8.835
	(-0.37)	(1.03)	(-0.68)	(0.46)	(-0.78)
Farming after 2000 dummy	16.65	-0.378	17.03	-5.024	22.05
	(1.36)	(-0.09)	(1.33)	(-1.52)	(1.58)
Value of assets	0.222***	-0.0108	0.233***	0.0320	0.201**
	(3.45)	(-0.41)	(3.13)	(0.88)	(2.52)
Highest education of non-head HH	8.542**	3.575***	4.968	-1.760	6.728
	(2.02)	(2.60)	(1.13)	(-1.44)	(1.49)
Group1 dummy	-10.69	0.0973	-10.79	4.717	-15.51
	(-0.95)	(0.02)	(-0.89)	(1.01)	(-1.21)
Group 2 dummy	10.59	1.634	8.959	-0.878	9.837
	(0.82)	(0.33)	(0.67)	(-0.17)	(0.70)
Mwea section	-23.30*	-5.404	-17.90	6.462	-24.36*
	(-1.95)	(-1.10)	(-1.42)	(1.24)	(-1.80)
Tebere section	-26.65*	-5.877	-20.78	-0.131	-20.64
	(-1.83)	(-0.95)	(-1.35)	(-0.03)	(-1.28)
Thiba section	6.258	-3.196	9.453	-2.062	11.52
	(0.46)	(-0.56)	(0.67)	(-0.36)	(0.83)
Wamumu section	-8.662	-6.348	-2.313	5.765	-8.078
	(-0.60)	(-1.09)	(-0.15)	(1.08)	(-0.50)
Constant	48.23	27.91*	20.31	23.28*	-2.965
	(1.41)	(1.76)	(0.57)	(1.88)	(-0.08)
Observations	245	245	245	245	245
R-squared	0.345	0.321	0.262	0.157	0.228
t statistics in parentheses	*** p<0.01, ** p<0.05, * p<0.1				

Relationship between Yield and fertilizer Use per Hectare

A



Relationship between Relative Price of Fertilizer and Fertilizer Use per Hectare

B

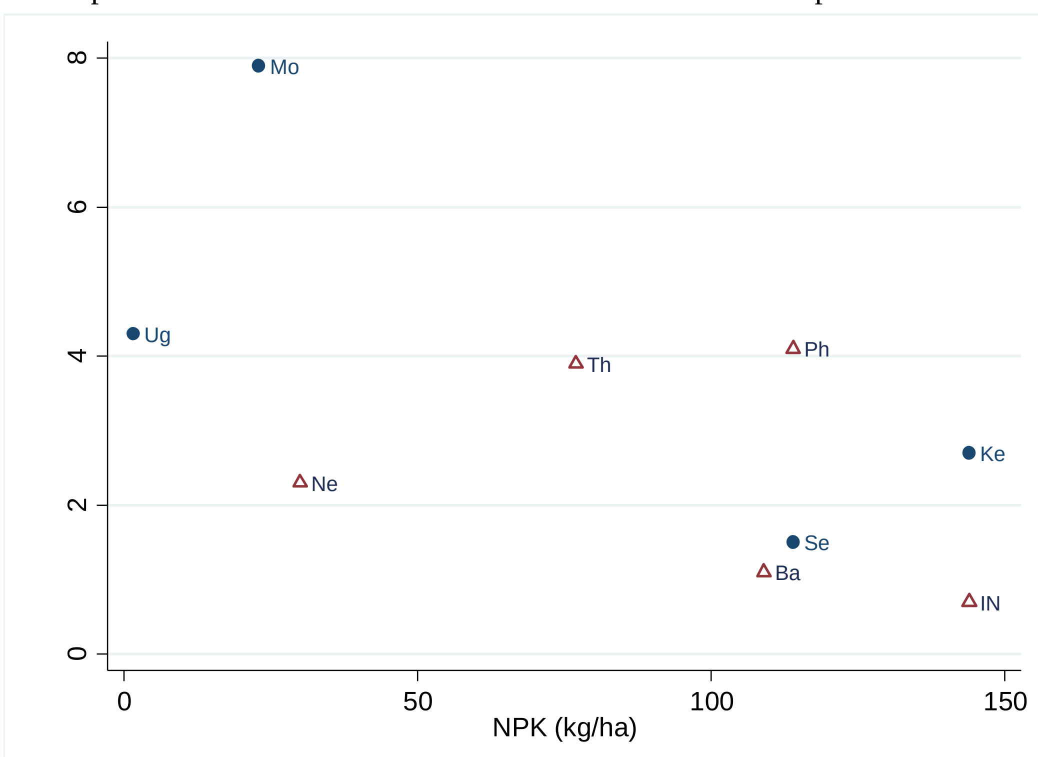


Figure 1: Yields, Fertilizer Use and Fertilizer Price relative to Output Price

Legend

Ba - Bangladesh	In-India	Ne - Nepal	Ta- Thailand
Mo - Mozambique	IN - Indonesia	Ph - Philippines	Tz- Tanzania
	Ke - Kenya	Se - Senegal	Ug - Uganda

Source: Survey data for Mwea were collected in 2011; Data for Uganda (Doho), Mozambique (Chokwe), Senegal (Senegal River Valley) are from Nakano et al., (2011). Data for Tanzania are from Nakano and Kajisa (2011). Data for Philippines (Central Luzon), Indonesia (Lampung), Thailand (Suphan Buri), Bangladesh, Nepal (Chitwan & Sarlahi Districts), and India (Tamil Nadu) are from David and Otsuka (1994).

Appendix

Table A1: T-test for Table 1

	Non Borrowers 1	MRGM 2	Traders 3	MRGM+Traders 4
Age of HH head	*** from 2 * from 4			
Experience (years)	**from 2 ***from 4	*from 4	**from 4	
% of HH heads				
Settlers	***from 2,4	* from 3	**from 4	
Started rice farming after 2000	***from 4	**from 4	*from 4	
HH size				
Number of HH member is working age group	* from 2			
% of Female headed households				
% of dependants in the household				
% of educated working age group members	*from 2 ***from 3			
% of women in working age group				
% of dropouts	***from 2,4		***from 2,4	
Farm Size (Ha)	***from 2,4	***from 3	***from 4	
% of households who have ever leased out land	**from 2 *from 3	***from3 **from 4		
Value of other assets owned	*from 4	**from 3	**from 4	

*** p<0.01, ** p<0.05, * p<0.1

Table A2: T-test for Table 3

	Non Borrowers 1	MRGM 2	Traders 3	MRGM + Traders 4
Yields (ton/ha)				
Value of Output				
NPK(Kg/ha)				
NPK cost per Kg	*** from 2,3	*** from 3 ** from 4		
Fertilizer cost	*** from 2 * from 3	*** from 3 ** from 4		
Cost of other inputs	** from 3,4	** from 4		
Hired labour	** from 2,3 *** from 4	*** from 4	* from 4	
Family labour	*from 4			
Rental cost of capital	*** from 2	* from 3		
Imputed cost of capital	** from 3, 4	** from 4		
Income		** from 3		
Residual		** from 3		

*** p<0.01, ** p<0.05, * p<0.1