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Limited usage of mechanical equipment in small-scale rice farming: a cause for concern

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Abstract: The role of mechanization in agriculture is well documented in terms of improving productivity of farm labour and land, and sustaining income status and welfare of small-scale farmers. In rice production, there is a high cost associated with labour intensive production practices especially in land preparation, weeding and harvesting; the limited usage/adoption of modern equipment in these operations remains an issue of concern. The current study investigates the usage of mechanical equipment in a setting where majority of farmers are exposed to such technologies against cases of non-usage or non-adoption. The choice of usage of mechanical equipment is analysed through probit and poisson models. Mechanization generally has a positive effect on production. However, the cost associated with its usage is high. Adoption and usage of modern/mechanical equipment requires that users are aware of the benefits, costs, technical requirements and how to handle the equipment. The equipment should be made available and affordable to farmers especially because demand for rent is not met.

Key words: mechanization, rice farming, choice of usage, agricultural technology adoption.

Introduction

In the recent years, global technological revolution has increased agricultural yields beyond the production benefits realized by expanding the cultivated area. The revolution has involved an increase of modern agricultural inputs such as improved seeds, fertilizers, pesticides and mechanical equipments or using modern irrigation practices. Such developments are necessary to meet the food needs of the growing population and urbanization respectively in terms of quantity and quality (Hazell and Wood, 2008). However, in the Developing World where the industrial base is not well developed, the proportion of labour in agriculture remains high. Out of an estimated

1.1 billion people engaged in agriculture in 2013, in sub-Saharan Africa, over 62% of the entire work force was involved in agriculture whereas in Developed economies and European Union, and in Northern Africa, this proportion only amounted to 3.6 % and 28% respectively (ILO, 2014). In Tanzania, in 2014 the share of agriculture in total employment was 68.1% (ILOSTAT, 2017). This keeps agricultural production 'a matter of human sweat and drudgery' (Hatibu, 2013). The limited adoption of technological innovations continues to limit food sufficiency targets due to the very low yields per unit of labour (Hazell and Wood, 2008; Hatibu, 2013). In general, great strides can be made by growing high-yielding varieties and using pesticides or fertilizer. However, their use meets a constraint represented by the crop response and production to agricultural inputs (Production response analysis). This implies that the crop potential is rarely maximized in field conditions. Due to the fact that labour is becoming more scarce and expensive with respect to land and capital as a result of rural-urban migrations and the rising per capita income; the usage/adoption of more capital intensive mechanical equipment remains pertinent to increase production and productivity (Feder *et al.,* 1985; Diederen *et al.,* 2003; Hazell and Wood, 2008).

According to Binswanger (1986), mechanization generally improves the productivity of farm labour and of land. Other advantages associated with mechanization are compiled by Curfs (1976). They consist of bringing additional land under cultivation including land unsuitable for hand cultivation, reducing labour requirements especially during slack periods, increasing total employment, raising agricultural productivity and farm income, and improving the timing of farm operations. Kienzle and Sims (2014) added that mechanization allows accomplishing tasks that are difficult to perform manually. Mechanization consequently improves the quality of work and products, reduces of drudgery in farming activities and makes farm work more attractive.

In rice farming, the necessity to mechanize farm operations is associated with the limited opportunity for expansion of the area under cultivation and availability of labour at critical times especially during land preparation, weeding, and harvesting. These farm operations make a large proportion of the cost of production. In the illustrative computations of production cost done by The Gates Foundation in 2012, the cost of land preparation, weeding, and harvesting was respectively estimated at 18, 45 and 19% of the total cost for growing 1.5 ton of paddy rice equivalent to 1 ton of milled rice on 0.6 hectares of land (Table 1).

Binswanger (1986) explains that land preparation requires mobile power sources such as animals, tractors or power tillers. Primary tillage is the most power-intensive operation. Weeding can be done by hand, or by using herbicides or mechanical equipment. Hand weeding is highly effective but labour intensive, herbicides are labour-saving and effective when properly applied, and mechanical weeding is effective but requires availability of equipment (Rodenburg *et al.*, 2015). Harvesting and threshing operations can also be very labor intensive if not mechanized.

Table 1 - Computations of production cost for 1.5 ton of paddy rice grown on 0.6 ha (equivalent to 1 ton of milled rice).

Farm operations and agricultural inputs	Cost (USD)	% of production cost
Seed	21	4
Harrowing & ploughing	96	18
Planting	48	9
Weeding	239	45
Chemicals	12	2
Fertilizer	0	0
Harvest	101	19
Storage bags	16	3
Total production cost	533	100

Assumptions: fertilizers are not used; yield of 2.5 MT /Ha for rainfed fields
Source: Gates Foundation, 2012

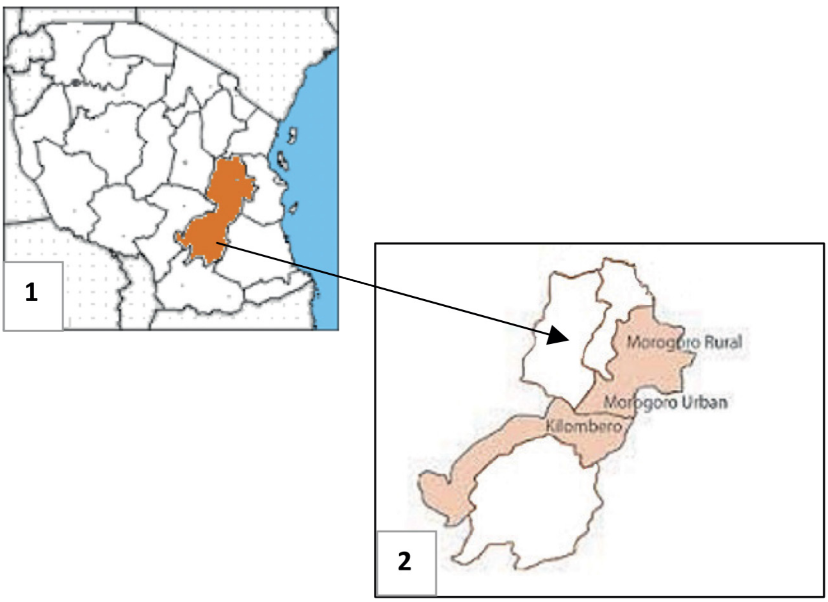

Figure 1 - Map of Tanzania (1) and study area (2)

Adoption studies in agriculture mainly focus on adoption decision taking into account either the time of technical adoption (e.g., Hall and Khan, 2002) or its impact (e.g., Panin, 1994; Diederen *et al.,* 2003; Diagne and Demont, 2007). The current study contributes to the literature on adoption of agricultural technology. In particular, it looks into the process of observed usage of equipment in a given season which may lead to continuous or permanent adoption implicit in the previous adoption studies. The current study focuses purposely on the usage of mechanical equipment in rice farming in a setting where (majority of) farmers are exposed to agricultural technology; nevertheless, the non-usage or non-adoption of rice mechanization is still prevalent. Generally, farmers make a choice to use or not to use the technology as a seasonal decision, unless the farmer has purchased the tool. In this later case of purchase, usage is intended to cover several seasons. Our emphasis is that the usage of mechanical equipment in the three highly labour cost rice farming operations, namely land preparation (harrowing and ploughing), weeding or harvesting is a utility maximizing outcome. A farmer may even decide to be 'fully mechanised' by using mechanical equipment for all cropping operations. In another case, he may adopt a 'partial mechanization'. This last option is-more frequent either when a farmer uses the mechanical equipment in substitution of high labour cost crop growth stages or when he can afford the cost of buying or renting certain tools. We analyse the factors determining the choice of using mechanical equipment and the effect of mechanization on rice production.

Methodology

Analytical framework and econometric model

In analyzing the usage of mechanical equipment, a decision model of innovation adoption at a specific moment has been here applied as the utility maximizing outcome behavior. Heterogeneity among adopters or users leads to the adoption or usage of agricultural technologies by some farmers, while others abstain. This does not prevent that over the time the parameters of the decision problem change with farmers that at the beginning abstained, but later decide in favour of adoption or usage. Moreover, a farmer using mechanical equipment for a certain crop operation may still use manual/traditional equipment for another one.

Following Besley and Case (1993), the gain to farmer of using the mechanical equipment is parameterized as:

$$y_i=\beta x_i+u_i \tag{1}$$

where x_i are farm and farmer characteristics and u_i is an independently and identically distributed farm random shock. The shocks are normally distributed. The probit model of adoption/use of mechanical equipment for land preparation or weeding or harvesting is estimated. It is expressed as:

$$\text{Prob \{adoption or use by farmer } i = 1\} = \emptyset\ (\beta x_i')\qquad (2)$$

where $\emptyset(.)$ is the standard normal distribution function that measures the influence of x_i on usage/adoption decisions such that the response probabilities are between 0 and 1. The model provides insight into the farm and farmer characteristics associated with ultimately accepting a new technology.

The decision to adopt/use mechanical equipment can also be looked at in terms of "full mechanization" when the farmer here is using mechanical equipment at three stages of farm operations or "partial mechanization" when the farmer is using the mechanical equipment at one or two stages of farm operations. Such "full vs. partial" mechanization decision can be investigated through the different levels of adoption as a count outcome ranging from 0 if the farmer is not using any mechanical equipment to 3 if the farmer is fully mechanized as just defined. The Poisson regression model is applied. According to Greene (2012), the model specifies that each y_i count is drawn from a Poisson distribution with parameter λ_i representing the expected probability of the count. It is related to the regressors x_i such that:

$$Prob\ (Y = y_i|x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}\qquad (3)$$

with $y_i = 0,1,2,3$

The log linear model is formulated for λ_i so that:

$$ln\ \lambda_i = x_i{}'\beta\qquad (4)$$

Assuming that there is a random sample of y_i and x_i, if the Poisson distribution is correct, the model leads to a consistent, asymptotically efficient and normal estimator for β. The mean and variance are assumed to be equal. They are given by:

$$E[y_i|x_i] = Var[y_i|x_i] = \lambda_i = e^{x_i{}'\beta}\qquad (5)$$

Furthermore, through a simple linear regression model for the production estimation, we analyse the influence of mechanical equipment usage and other characteristics on production level. The simple production equation is given by:

$$Q_i = F(Y_i, \beta;\ X_i, \alpha) + \varepsilon_i\qquad (6)$$

where Q_i is the production level.

Research design

Data were collected in July 2015 from Morogoro (Morogoro rural and Morogoro urban) and Kilombero districts in Tanzania; Figure 1 includes a map of the study area. The sampling strategy consisted of a selection of locations/villages where information exists on the past and current exposure to mechanical equipment and in the second stage, a random sample of 123 rice farmers was drawn irrespective of the level of usage of the mechanical equipment[1]. Table 2 illustrates the different traditional/manual and mechanical equipment used by farmers in Tanzania.

Table 2 - Traditional and mechanical equipment used in rice farming operations.

Farm operation	Manual equipment	Mechanical equipment
Land preparation	Hoe, ox plough	Tractor, power tiller
Weeding	Hoe	Push weeder
Harvesting and threshing	Machete, sickle, knife, stick	Harvester, thresher

The collected data pertain to farmer characteristics, farm characteristics, usage of different equipment and the advantages and challenges in using the equipment. The estimation of the choice models and analysis of include socio-economic factors, farm characteristics and geographical indicator as key determinants. Table 3 shows summary statistics of these factors.

Mechanical equipment is widely applied in land preparation (79%), much less in weeding (11%) and by a relatively small proportion (26%) for harvesting and mainly threshing. In terms of level of mechanization, about 19% of farmers do not use any mechanical equipment, while a proportion of 50% and about 30% use mechanical equipment at one farm operation and two farm operations respectively. Only 2% of farmers are "fully mechanized".

The proportion of female farmers in the sample is smaller than that of male farmers. In the age groups, the categories of farmers from 31 to 40 and 41 to 50 years comprise the largest proportions of farmers, namely 37% and 32% respectively. The level of education of a farmer indicates his/her capability to take up innovation, but only 19% of farmers have at least attended secondary school. The farming experience indicates the number of years dedicated to rice cropping, and for the current survey respondents, its average is 10 years.

It is widely assumed that large farms adopt (new) forms of mechanization considerably faster than those adopted by small farms. The average farm size is 9.6

[1] Other locations in Tanzania such as Mbeya are also known to use mechanical equipment; however, it was not possible to extend the survey to the region.

Table 3 - Descriptive analysis (N=123, as a random sample of 123 rice farmers).

Variable	Mean(SD) or Proportion (SE)
Use of land prep. mechanical equipment (1: yes)	0.79 (0.036)
Use of weeder (1: yes)	0.11 (0.028)
Use of harvesting equipment (1: yes)	0.26 (0.039)
Level of mechanization:	
No use of mechanical equipment	0.19 (0.035)
Use of mechanical equipment at 1 farm operation	0.50 (0.046)
Use of mechanical equipment at 2 farm operations	0.29 (0.042)
Use of mechanical equipment at 3 farm operations	0.02 (0.012)
Gender (1=female)	0.39 (0.045)
Age: 21-30 years	0.17 (0.034)
31-40 years	0.37 (0.044)
41-50 years	0.32 (0.042)
51 years and above	0.15 (0.032)
Education level (1: attended at least sec. school)	0.19 (0.006)
Farming experience (years)	9.9 (0. 758)
Farm size (acres)	9.6 (16.153)
Land ownership (1: individually owned)	0.85 (0.363)
Permanent labour (persons)	4 (3.258)
Rice growing purpose (1: commercial)	0.62 (0.488)
Production in 2014 (kg)	2377.6 (4290.7)
Land productivity in 2014 (kg/acre)	374.7 (369.478)
Awareness (1:yes)	0.94 (0. 021)
Kilombero district	0.61(0.045)

acres or 3.8 hectares. This size is larger than the average land size of 2.5 hectares found in Tanzania as computed from Diagne *et al.* (2013). Different forms of land ownership and management can be observed in Tanzania. In the study area, land is principally owned individually, that is by the household (85%). Individual ownership occurs by buying land or through inheritance. Collective ownership, for instance through an association or village ownership, can also be observed. While majority of farm households rely on family labour, some extra labour is hired on a permanent basis or temporarily during the crop growing season. On average 4 persons are thus permanently employed by the farming household. Instead, in the collectively owned plots, joint labour is common.

Rice is considered both as food crop and cash crop; often a surplus after meeting the household's food needs is sold. Growing rice for commercial purpose attracts a majority (62%). The production of rice in 2014 in the study zone was on average 2.4 tons, the calculation of the land productivity shows an average yield of 375 kg/acre or 900kg/hectare. The yield can be high, it varies depending on the rice variety grown and the farming practices.

Farmers who are aware of technology can use it; farmers can obtain information about the mechanical equipment from different sources such as research organisations, development organisations, private sector manufacturers and operators. The information includes usage and general instructions on how to operate the equipment. In this study, 94% of respondents confirmed that they have this information, establishing that the coverage of exposure to the technology was quite high. In terms of study area, the sample includes 61% farmers from Kilombero.

Results

Choice of using mechanical equipment

Two sets of estimations were done. Firstly, a choice of using mechanical equipment either in land preparation, weeding or harvesting was assessed through a probit model. Secondly, a log count of the level of mechanical equipment usage was assessed through a Poisson model. Table 4 shows the estimation results.

The age category of 51 years and above is the reference group for the age group.

The probit model reveals more than 80% correct classification; it indicates the proportion of correct predictions in the total sample. In other words, the predicted yi matches the actual yi (which we know to be zero or one). The Goodness of fit indicated by Hosmer and Lemeshow $\chi 2$ with 10 groups is not significant, indicating that there was no evidence of lack of fit[2]. Marginal effects are reported. They indicate how much the (conditional) probability of adopting a mechanical equipment changes when the value of a regressor is changing, holding all other regressors constant at some values. For categorical variables, the marginal effects show how Prob(Y=1) changes as the categorical variable changes from 0 to 1, after controlling in some way for the other variables in the model.

Female farmers, farmers who have attended secondary school or higher level

[2] The same conclusion is reached with Stukel test (Hosmer *et al.*, 1997).

Table 4 - Estimation results of the choice of using mechanical equipment.

Variable	Probit Model (Marginal Effects) (SE))			Poisson Model (coeff.) (SE))
	Land Prep.	Weeding	Harvesting	
Gender	0.042*** (0.023)	-0.060* (0.064)	0.018 (0.105)	0.033* (0.022)
Age group 21-30	0.091 (0.225)	-0.035** (0.001)	-0.077*** (0.062)	0.082*** (0.029)
Age group 31-40	-0.066 (0.065)	-0.114** (0.096)	0.048*** (0.018)	0.074 (0.118)
Age group 41-50	-0.010 (0.046)	-0.086*** (0.055)	0.135 (0.162)	0.043 (0.175)
Education	0.173*** (0.087)	-0.093* (0.101)	0.397*** (0.037)	0.319*** (0.114)
Farm size	0.028* (0.001)	-0.006*** (0.003)	0.034*** (0.002)	0.019*** (0.005)
Awareness	0.930* * (0.099)			1.519*** (0.178)
Experience	0.002 (0.004)	-0.005 (0.007)	0.002*** (0.001)	-0.001* (0.001)
Commercial purpose	0.052 (0.102)	-0.009 (0.040)	-0.121 (0.176)	0.098 (0.164)
Individual land ownership	-0.111** (0.117)	0.070 (0.069)	0.144** (0.046)	0.028 (0.178)
Constant				-1.894*** (0.079)
Log pseudo likelihood	-40.162	-36.195	-39.781	-133.647
Pseudo R^2	0.333	0.088	0.345	0.056
% Correct classification	84.3	88.0	81.5	
Predicted probability	0.88	0.10	0.21	
Hosmer-Lemeshow χ^2	12.27	8.17	6.10	

of education and farmers who are aware of the technology benefits are likely more inclined to use the mechanical equipment in land preparation. The awareness variable has the highest marginal effect. It indicates that farmers' prior high exposure to the agricultural technology is an important pre-requisite for usage and subsequent adoption. Moreover, as the farm size increases, the likelihood to adopt/use mechanical equipment in land preparation increases. Surprisingly, individual land ownership has a negative influence on the likelihood of mechanical equipment.

With regard to the usage of mechanical equipment in weeding or simply weeders, female farmers and farmers who have attended secondary school or higher level of education are less likely to use the equipment. In relation to the oldest category of farmers (aged more than 51 years old), the younger age groups are less inclined to use weeders. This unexpected result implies that the technology has attracted the oldest farmers whereas the other groups still prefer to do manual weeding or apply herbicides. In the same line, farmers who own larger farms have less likelihood to use weeders.

In harvesting, with reference to the category of farmers aged 51 years and above, the change in probability to adopt/use the harvesting machine by the category of farmers aged between 21-30 years decreases, but it is increasing for farmers aged between 31-40 years . Moreover, farmers who have attended secondary school or higher level education, farmers who own larger farms and farmers who have more experience in rice farming are more likely to use the harvesting equipment. Interestingly, individual ownership of land also increases the likelihood of using harvesting equipment.

Table 3 shows that 19% of respondents do not use any mechanical equipment. Such occurrence of 'zero' values can lead to zero-inflated Poisson model, if significant. The Vuong test compares the zero-inflated model with an ordinary Poisson regression model. In the study, the proportion of zero observations was not large enough to indicate zero-inflation as confirmed by an insignificant Vuong statistic. Furthermore, the unconditional mean and variance of the level of mechanization usage are not extremely different (Mean=1.133, Variance=0.531) indicating that there is no evidence for dispersion. The equi-dispersion assumption considers that the mean and variance values, conditioned on the predictor variables, will be equal or at least roughly equal. In the study, the assumption is assessed by the test for over-dispersion namely the likelihood-ratio test of dispersion parameter alpha=0; when this over-dispersion parameter is zero, over-dispersion is established. In this case, alpha is not significantly different from zero and thus reinforces that the Poisson distribution is appropriate.

Results show that the expected level of mechanical equipment usage significantly increases with being a female, having attended secondary education or higher, owning a large farm, owning land individually and being aware of technology benefits. The age group shows that compared to the age category of farmers who are aged 51 years and above, the expected log count for the youngest age group of 21 to 30 years old significantly increases. Hence, we infer that youngest farmers are expected to try out more equipment options.

The decision to use mechanical equipment is assumed to be done at the beginning of the rice growing season, with the purpose of obtaining a certain level of production. This assumption is linked to the usage of equipment through for instance the option of renting as opposed to ownership; ownership generally implies continuous usage. The beginning of the cropping season is indeed the time of assessing the cost-effectiveness of using the equipment against the conventional/traditional or manual methods. Aspects to consider include for instance labour availability, technological requirements and equipment availability in relation to potential demand. Intuitively however, the expectation of reaching a certain production level leads the farmer to use the equipment or even apply certain inputs. We tested whether the level of mechanization is endogenous to the production level or in other words whether the production level is instead one of the factors which explain the choice of mechanization. Statistically, the Durbin score and Wu-Hausman tests indicate that the level of mechanization is indeed endogenous: for the null hypothesis Ho that the level of mechanization is exogenous, Durbin chi2 = 21.5372*** and Wu-Hausman F= 24.760***. Consequently, the predicted estimates from the Poisson model are used to correct the endogeneity. Table 5 shows the regression results.

Table 5 - Regression estimation results of production level (kg).

Variable	Coeff. (SE)
Level of mechanical equipment usage (predictions from Poisson model)	930.045** (399.417)
Farm size	134.377*** (51.925)
Experience	3.591 (20.267)
Labour	194.318*** (51.935)
District dummy (1: Kilombero)	-833.496** (392.519)
Constant	-608.704 (462.312)
Adjusted R^2	0.601
F statistic	31.99***

Production significantly increases in response to the level of usage of mechanical equipment, increase in farm size and increase in permanent labour usage. The district dummy shows that production in Kilombero district is significantly lower than production in Morogoro district. This may have to do with the rice growing environment in the survey area and the associated production system.

While proper usage of mechanical equipment leads to clear advantages at least in land preparation and harvesting, farmers associate it with other benefits such as saving time and energy (47.5% of respondents), simplifying work (18.8%) and efficiency in general (35.2%). Some farmers also claim that use of mechanical equipment such as tractor improves farm soil fertility on the farm. However, there are several challenges that limit mechanization. Table 6 lists the salient limitations to the usage of mechanical equipment indicated by farmers and the proportion of farmers who specified each constraint as most problematic.

Table 6 - Challenges associated with use of mechanical equipment as expressed by farmers.

Challenges	Proportion (%)
Knowledge and skills to operate the equipment	58.0
High cost	14.9
Owner	10.3
Availability spare parts	10.3
Field ecology &Technicalities	6.5

The main constraint is associated with operating the equipment. Although the majority of farmers are exposed to the technology, only a handful indeed knows how to operate or handle it properly. Without such knowledge, even the benefits from usage can be lost. The second inconvenience is associated with the high cost of purchase or rent. Inquiries to manufacturers/fabricators of machinery in the town neighbouring the survey area[3] indicates that new heavy equipment including tractors is purchased at between 8,000 and 20,000USD, while used equipment can be obtained at 5,000 to 7,500 USD. In any way, the price is too high to be afforded by small farmers individually; hence, a few entrepreneurs purchase the equipment to rent to farmers. The rent cost of a tractor and a power-tiller is on average 100,000 Tanzanian Shilling per hectare (approximately 50 USD) from the service providers as explained by farmers. Weeders are mostly donated by institutions and renting is not yet occurring as farmers/women predominantly do manual weeding. All in all, the high cost deters usage especially when this is compared to the low returns from selling rice. Another factor is associated with the owner of equipment. Entrepreneurs who appear in the villages seasonally or farmers, who have acquired the equipment, rent the machinery in a given period of time depending on the farm acreage. However, the time of usage can vary depending on the capacity of the equipment and professionalism or skills of the operator. In cases when there are delays in the time used by a farmer, it has negative consequences on the expectations of the next waiting farmer(s). This leads to broken promises as this second farmer waits for his turn longer than he was promised or in

[3] Six such manufacturers/fabricators were identified and interviewed in the industrial area of Morogoro.

vain; 10% of responses are in this line. Owners are also accused of hiking the rent when demand for equipment increases in the farming season. Availability of spare parts is also another challenge expressed by farmers. This is because the continued usage of the machine with the old parts, which need replacement, at the end becomes ineffective. Owners mention that such parts are not only difficultly available but are also expensive. Another challenge mentioned by a few farmers include the ecology of the field and other technicalities such as the pre-requisite suitability of the equipment to irrigation and certain soil types or the need to have planted in lines, specifically in order to use weeders while farmers normally broadcast seeds haphazardly.

Discussion and conclusions

Proper usage of mechanical equipment especially in land preparation and harvesting leads to clear advantages in rice production. Large farms are more suitable for using mechanical equipment than small scale farms. This is because the large machinery creates economies of scale. Moreover, large scale farms have a higher ability to bear risk in comparison with the small scale farms (Binswager 1984; Diederen *et al.*, 2003). Differences in the type of equipment usage show that certain equipment may preferably be used on small farms. This may be the case for weeders. It is because, to use a weeder, it is necessary that planting is done in lines with of 20 to 25 cm of spacing. Depending on the labour needs and supply, farmers may find it more cost effective to sow rice by broadcasting it rather than transplanting in straight lines. As mentioned earlier, manual labour or using herbicides may be applied to remove weeds.

The preference for equipment is associated with an assessment of the technical requirements. As stressed by Curfs (1976) and recently by Hatibu (2013), mechanization should be applied alongside other necessary inputs, such as high yielding varieties and fertilizers and other agricultural practices such straight line planting and water control. Otherwise, it may prove to be uneconomic or a failure, especially if the necessary technical and managerial support is inadequate. In the case of weeders, a trade-off is hence made between broadcasting but incurring high labour charges in weeding (because the plants are not in line), or incurring the high labour charges at the time of line planting with relatively lower weeding cost. Such trade-off arises because there is no technology available for planting/transplanting in small-scale rice farming in Tanzania. Thus, in large individual farms the agricultural practice is to broadcast rice seeds and to use herbicides for weeding, or not do any weeding at all; in commercial farmers importing seddlers or transplanting machines is an affordable investment. Collective action can be a solution to organize farm activities such as planting through farmers groups, thus lowering the cost for the individual farmer. The use of herbicides is more effective than using weeders.

However, herbicides are expensive and the cost of purchasing herbicides is recurring each season. Weeders on the other hand, besides being environmentally good, can be used for several seasons (Rodenburg *et al.*, 2015).

About weeders, it is also surprising that female farmers are less likely to use the equipment whereas it is designed to reduce their drudgery. It may be the case that women are not really aware of the technology. Technical aspects or appropriation of technologies by a different social group (e.g. old men) may also be at play. This is certainly an aspect to investigate further as it may limit its adoption.

Still on potential areas of investigation, the role of youth in agricultural technology needs to be assessed. The analysis in the Poisson model shows that the youngest farmers are more inclined to use more equipment options. However, when these technologies are considered separately, we notice that in reference to the oldest group of farmers, the probability to use equipment by young farmers is smaller. There may be challenges to access the equipment; these must be assessed so that the youth becomes more involved in rice farming for instance in provision of service for machinery operation.

Another unexpected result is associated with land ownership specifically in regard to the land preparation equipment. Literature suggests that secure rights reinforce the adoption of productivity enhancing technologies. According to Alchian and Demsetz (1973) and Besley (1995), tenure security determines the level of investment on land. However, in the current case, individual ownership can be associated with a cost too high to be borne by an individual farmer and this deters usage. To improve usage, the capital requirement to access the equipment needs to be somehow lowered or to have the possibility to share the costs. This calls for a deeper understanding of the rental market as an opportunity to expand usage. The rental markets were previously mentioned by authors such as Binswager (1984), Panin (1994) in Botswana, Hatibu (2013) in Uganda, and Sims *et al.* (2011). Such markets enable the use of mechanical equipment without implying ownership especially when the small size of farms does not make it technically optimal for smallholder farmers to own the equipment. The rental market is easily established for those operations which are not time-bound and do not necessarily occur at roughly the same time. In case of rice cropping operations, land preparation has to be timely done for planting purposes and managing water; weeding and harvesting are time-bound for appropriate plant growth and preservation of rice output quality respectively[4]. This explains why farmers are inconvenienced when the machinery owners do not respect the renting time . In Uganda, conflicts of timing among the tractor hire services subsidized by the Government were even reported (by Kibalama (1993) in Hatibu (2013). Threshing, on the other hand, can be stretched over long periods.

[4] See http://www.knowledgebank.irri.org/postproductioncourse/index.php/what-is-harvesting/harvest-at-the-right-moment for the importance of timely harvesting on rice quality.

The presence of numerous owners can allow competition in the rental market. Ownership of machinery can be increased through different policy measures which favour local manufacture and fabrication. The measures include for instance subsidies to farmers and preferential tariff treatments to manufacturers and fabricators so that the production costs are lowered. The understanding now is that these measures should lead to the advantage not only of creating employment within the country, but also of limiting drain on the foreign exchange, in particular in the case of imported equipment when the price of materials and fuel is rising (Curfs, 1976). Hence, a balanced approach needs to be taken to make the equipment both available and affordable.

It is important to realize that output growth resulting from mechanization necessitates that the elasticity of final demand is high. This implies that a market for the generated product should exist (Binswager 1984). The market is important because farmers always weigh the benefits and costs of the technology before adoption. The improvement in land or labour productivity and increase in production are the targeted benefits. The market concretizes the financial returns to the investment in mechanical equipment. The current case shows that the market aspects need to be investigated further.

Improvement of usage of mechanical equipment in agriculture needs a multi-pronged approach, certainly including making the equipment available and affordable to farmers. Firstly, awareness need to be increased in terms of training users on technical aspects directly related to the technology or other pre-requisites that make the technology usage more appealing and profitable. Secondly, other constraints need to be addressed in terms of institutional backup such as forms of collective action and involving youth, introducing technologies taking into account the needed complimentary components or other technologies, and developing markets for the product. The market provides incentives for adoption through expected returns. As the demand for rent to use is not currently satisfied, the number of available machines needs to be increased through local manufacture and fabrication. Options to improve access to equipment by farmers can be explored through their groups which can acquire the equipment collectively and through increased involvement of service providers and youth.

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