Smallholder Rice Farmers' Technical Efficiency: Implication for Competitiveness through Agricultural Marketing Co-operative Societies in Tanzania

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Abstract
Agricultural Marketing Co-operative Societies (AMCOS) are increasingly being advocated by the government of Tanzania as a way to enhance smallholder farmers' competitiveness countrywide. Yet, the smallholder rice farmers' competitiveness is low. This paper analysed the smallholder rice farmers' competitiveness in terms of Technical Efficiency (TE) in Morogoro and Mbeya regions, Tanzania. Data were collected from 382 smallholder rice farmers. The Cobb-Douglas stochastic frontier model was used to establish the frontier line of the farmer's production potentials by a single-stage Maximum Likelihood Estimates. The findings show that the mean TE indices for Kapunga, Madibira and UWAWAKUDA AMCOS were 84.9%, 87.6% and 79.1% respectively. Across AMCOS, it was found that intermediate costs, labor costs, fixed costs and amount of fertiliser influenced productivity (P<0.05) while access to training, water distribution, ploughing time, planting systems, and access to credit influenced TE (P<0.05). The mean TE for the whole sample was 83.8% indicating that smallholder rice farms in the study area have been operating below the maximum level of production frontier and given the available technology, farmers can increase their production by 16.2%. The rice production in terms of TE has not reached a plateau, hence there is a potential for improvement. This study recommends that policymakers should prioritize the implementation of targeted training programs and enhance access to agricultural inputs and credit facilities to improve the technical efficiency of smallholder rice farmers. The Local Government Authority and development partners espoused with improving smallholder farmers' livelihoods should ensure farmers' access to credit and increase farmers' linkages to credit providers in the rice farming schemes.

Keywords: Competitiveness, technical efficiency, smallholder farmers, credits

Introduction

Rice is consumed by many people globally because of its nutritional value (Patunru and Ilman, 2020). In Sub-Saharan Africa (SSA) rice is considered to be an important food crop for fighting hunger and malnutrition. Tanzania ranks second after Madagascar in rice production and consumption within the SSA region (Kadigi *et al.,* 2020). Demand for rice has been increasing by 6% annually faster than any other staple food in SSA (CGIAR, 2016; Africa Rice, 2020). The 2019/2020 National Sample Census of Agriculture in Tanzania results show that 2.9 million Metric Tonnes (MT) of rice was produced, which is a more than 100% increase compared to the 2007/08 Agriculture Census which recorded 1.4 million MT (URT, 2020). About 90% of rice produced in Tanzania is under a smallholder system with sizes of farms ranging from 2.22 to 7.41 acres, with an average farm size of 3.21 acres (URT, 2019). The average rice yields in the 2016/17 cropping season for Morogoro and Mbeya were 1.62 and 0.89 tonnes/acre respectively, with a national average yield of 0.81 tonnes/acre (URT, 2018; URT, 2019). This productivity is far below that of the top ten rice-producing countries of China, Japan, and Brazil which have average yields of 2.87, 2.75, and 2.47 tonnes per acre, respectively (Mtembeji and Singh, 2021).

Rice production in Tanzania does not meet the increased demand which is largely caused by rapid population growth and a shift in consumption status (Kulyakwave *et al.,* 2020). The potentiality of Agricultural Marketing Co-operative Societies (AMCOS) lies in their ability to foster collective action, enhance market access, reduce transaction costs and provide support services to smallholder rice farmers (Bijman and Iliopoulos, 2014). By leveraging these potentialities, AMCOS can contribute to reducing the gap between production and demand, ensuring a more sustainable and profitable rice farming sector. AMCOS in the co-operative context is viewed as a vehicle for increasing smallholder farmers' productivity and linking them to markets, as well as sources of credit, inputs, finance, information and collaborations (Tyagi *et al.,* 2019). AMCOS plays a great role in ensuring the supply of inputs and increasing output among smallholder farmers (Brito *et al.,* 2015). Agricultural co-operatives play a valuable role by offering support services that greatly enhance the TE of their members. They achieve this by making it easier for members to obtain production inputs and establishing connections for extension services (Abate *et al.,* 2014). Various government interventions have been in place to address the rice demand in Tanzania. Such initiatives include the National Rice Development Strategy, input subsidy programs, training and development, rehabilitation of irrigation infrastructures and co-operative formation. Yet smallholder farmers experience high production costs that reduce farmers' competitiveness in terms of Technical Efficiency (TE) in Sub-Saharan Africa (SSA), Tanzania inclusive (Nkuba *et al.,* 2016; Ngenoh *et al.,* 2019). Enhancing smallholder farmers' competitiveness in terms of TE is believed to be an effective approach to increasing returns, reducing rural poverty and improving livelihoods (Rigg, 2019).

Studies have been conducted in Bangladesh, Nigeria, Myanmar, Tanzania and Ghana to analyse the TE in rice farming among smallholder farmers (Idiong, 2007; Rahji and Omotesho, 2007; Anang *et al.,* 2016; Mkanthama *et al.,* 2017; Hasnain *et al.,* 2015; Linn and Maenhout, 2019; Chukwujekwu *et al.,* 2020). Regarding TE, studies revealed significant inefficiencies in production and thus a high scope for improving farmers' TE through better use of available resources. Furthermore, factors such as education level, sex, experience, membership of co-operative/farmer association, access to credit, quantity of inputs and access to irrigation revealed to have an influence on TE among smallholder farmers. Despite this plethora of studies, limited literature is available on the competitiveness of smallholder rice farmers in terms of their productivity and TE in the context of Agricultural Marketing Co-operative Societies in Tanzania. For example, a study by Kangile (2016), focused on the price competitiveness of smallholder rice farmers under irrigation schemes in the Coast and Morogoro regions of Tanzania. It was found that farming experience, planting methods, frequency of weeding, degree of specialization and source of purchased inputs influenced cost efficiency. This study focused on price efficiency leaving TE among smallholder rice farmers untouched. Similarly, another study compared the TE of farmers in the irrigated and rain-fed lowland ecologies in the Coast and Morogoro regions of Tanzania (Mkanthama *et al.,* 2017). The two studies were conducted in the same regions, moreover, the later study considered lowland rain-fed sites in Morogoro leaving aside the irrigation schemes managed by AMCOS. This paper addresses this research gap by assessing competitiveness among smallholder rice farmers in terms of TE and examining factors influencing TE in the context of AMCOS in Mvomero and Mbarali districts. Specifically, the study assessed productivity and TE; estimated levels of TE among smallholder rice farmers and examined the determinants of TE among smallholder rice farmers in the study area.

Review of Concepts

Smallholder Farmers' TE and Productivity

A smallholder farmer is considered technically efficient in production if can achieve maximum output with a given level of inputs and production technology (Adeyemi *et al.,* 2017). Farrell (1957) in his pioneering study, distinguished three types of efficiency: (1) TE, (2) allocative or price efficiency and (3) economic efficiency. TE represents a farm's ability to produce a maximum level of output from a given level of inputs (Khan and Saeed, 2011). Various methods of estimating smallholder farmers' efficiency exist in the economic literature (Anang *et al.,* 2016). Measuring efficiency can be technically defined by non-parametric and parametric methods (Latruffe, 2010). The parametric approach employs SFA while the non-parametric approach normally employs DEA (Anang *et al.,* 2016). This paper focuses on TE using the Cobb-Douglas SFA function which is the most widespread method to measure efficiency. Hasnain *et al.* (2015); Kibiego *et al.* (2015); Anang *et al.* (2016) and Tadesse *et al.* (2017) in their studies, fitted SFA to input and output data to measure TE in Ghana, Bangladesh, Kenya, Ethiopia and Nigeria where results showed significant inefficiencies in production. When appropriately applied, the Cobb-Douglas SFA can provide valuable insights into TE and inform policy interventions to enhance productivity. A similar model was used by Bahta (2014); Osung *et al.* (2014) in the measurement of competitiveness in smallholder livestock systems in Botswana and cassava production in Nigeria respectively. Productivity has been used as an indicator of competitiveness among smallholder livestock systems in Botswana (Bahta, 2014). The higher the productivity, the greater the level of competitiveness. Increasing productivity per unit of land and labor through efficient use of resources in production is a definite way of reducing the per-unit cost of production and ensuring competitiveness in production (Osung *et al.,* 2014).

Smallholder Farmers' Competitiveness

Competitiveness is an ambiguous concept that can be defined in several ways and addressed from different perspectives. It has been termed by various scholars as a multidimensional and relative concept since the criteria of competitiveness vary with time and context (Pigatto, 2020). The current study contributes to the analysis of competitiveness at the level of smallholder farmers by applying the concept developed by (Latruffe, 2010) that competitiveness entails the capability of smallholder farmers to offer goods that satisfy consumer demands in terms of price, quality, and quantity while making profits that allows them to thrive. The smallholder farmers' competitiveness has a close relationship with AMCOS as they play a great role in ensuring the supply of inputs and increasing output among smallholder farmers (Brito *et al.,* 2015).

Methodology

Study area, Sampling techniques and Sample size

The research on which this paper is based was conducted in Mbarali and Mvomero Districts in Mbeya and Morogoro regions respectively. The regions are among the major rice-growing regions, with the two districts which fall within suitable agroecological zones for rice production (URT, 2019). Mbarali District is located at latitude: 8°51' 60" south and longitude: 33°51' 0" east. It is one of the seven districts of Mbeya Region, bordered to the north and east by Iringa Region, to the south by Mbeya Rural District and to the west by Chunya District. Mvomero district lies at latitude 6°26' 0" south and longitude 37°32' 0" east bordered by Handeni District (Tanga Region) in the north, Bagamoyo District (Coast Region) in the east, Kilosa District (Morogoro Region) in the west and Morogoro Urban District (Morogoro Region) in the south.

The study adopted a cross-sectional research design and a mixed-methods approach in data collection and was collected from 382 smallholder rice farmers. The sampling frame consisted of smallholder rice farmers in Mbarali and Mvomero districts with individual smallholder farmers as the unit of analysis and unit of observation. Purposive and simple random sampling techniques were involved in the selection of geographical areas and individual respondents. From the two districts, three AMCOS were purposively selected based on their dominance in rice farming and their involvement in the business. A simple random sampling procedure was used to select respondents from the list of smallholder farmers obtained from the AMCOS offices. The sample size was estimated using Yamane (2001) assuming a 95% confidence level and p=0.05

$$n = \frac{N}{1+N(e^2)} \quad \text{.............(1)}$$

Where; n = sample size
N = population size = 4749
e = level of precision (Sampling error) = 5% or 0.05

A proportionate sampling technique was used to select farmers from the three AMCOS giving a sample size of 369 respondents as shown in Table 1.

Table 1: Proportionate sampling of rice farmers in the study area

AMCOS	Number of registered farmers	Sample size
UWAWAKUDA	949	74
Madibira	3000	233
Kapunga	800	62
Total	**4749**	**369**

Data Collection

The methods used to collect data were household surveys, Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs). Quantitative and qualitative data were collected by using a pre-structured questionnaire with both open and close-ended questions. Four FGDs were conducted, each accommodating eight participants. Additionally, seven Key Informants involved the extension officers, co-operative officers, input suppliers and co-operative leaders. Data were gathered in February 2022 and farmers were asked to provide information on the previous cropping season (2020/2021).

Data Analysis

Descriptive statistical analysis was computed to establish farming characteristics, production inputs and levels of TE among smallholder farmers in the study area. Data analysis on factors affecting smallholder rice farmers' TE was computed using STATA software in the SFA framework. Estimates of the generalized Cobb-Douglas production were projected using a single-stage maximum likelihood estimates (MLE) method for the TE and technical inefficiency effects. According to Greene (2002), MLE is more effective than corrected ordinary least squares because it employs the precise distribution of the disturbance term. ML estimations is the most effective estimating method in the class of estimators that use the information on the distribution of the endogenous attributes given the exogenous attributes (Greene, 2002; Wooldridge, 2002). The parameterization of the half-normal model by (Tsionas, 2023) in terms of

there are no technical inefficiency and all inefficiency in the SFA are due to

$$\sigma^2 = \sigma_v{}^2 + \sigma_{z\delta}{}^2 \text{ and } \gamma^2 = {\sigma_{z\delta}{}^2}/{\sigma_v{}^2} \geq 0 \text{ if } \gamma = 0$$

stochastic process. By using above kind of parameterization, the log likelihood function is specified as;

$$lnL(y|\beta,\sigma,\gamma) = -{}^1/_2 \, ln\left({}^{\pi\sigma^2}/_2\right) + \sum_{i=1}^{1} ln\phi\left({}^{-\varepsilon_i\gamma}/_\sigma\right) - 12\sigma^2 \sum_{i=1}^{1} \varepsilon_j{}^2 \text{..(2)}$$

Where: y is a vector of log output (kg/acre), $\varepsilon_1 = v_i - z_i\delta_i = lnq_i - x_i\beta$ is a composite error term and $\phi(.)$ is the accumulative distribution function of the standard normal variable evaluated at x. Therefore, the generalized likelihood ratio is given by;

$$\gamma = -2ln[(L(H_0)|L(H_1))] = -2[L(H_0) - L(H_1)] \text{.....(3)}$$

Where: $L(H_0)$ and $L(H_1)$ are values of the likelihood function under specification of the null H_0 and alternative H_1 hypotheses. The Cobb-Douglas production frontier is given by:

$$Y_i = f(x_i\beta_i)\exp(v_i - z_i\delta_i - w_i) \text{..............(4)}$$

$$lnY_i = \beta_0 \sum_{n=1}^{N} x_n{}^{\beta_0} \, exp(v_i - z_i\delta_i - w_i) \text{........(5)}$$

The technical efficiency of the i^{th} farmer is defined as (Equation 8);

Technical inefficiency of the i^{th} farmer is defined as (Equation 9);

All variables from equation four to eight are defined as;

$$lnY_i = \beta_0 + \beta_1 lnTIC_1 + \beta_2 lnTLC_2 + \beta_3 lnTFC_3 + \beta_4 lnQPF_4 + \beta_5 lnQTF_5 + v_i - (\delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + w_i) \quad ....(6)$$

$$lnY_i = \beta_0 + \beta_1 lnTIC_1 + \beta_2 lnTLC_2 + \beta_3 lnTFC_3 + \beta_4 lnQPF_4 + \beta_5 lnQTF_5 + v_i - \delta_0 - \delta_1 Z_1 - \delta_2 Z_2 - \delta_3 Z_3 - \delta_4 Z_4 - \delta_5 Z_5 - \delta_6 Z_6 - \delta_7 Z_7 - \delta_8 Z_8 - \delta_9 Z_9 - \delta_{10} Z_{10} - \delta_{11} Z_{11} - w_i \quad ....(7)$$

$$TE = Exp(-z_i \delta_i - w_i) \quad ....(8)$$

$$z_i \delta_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + w_i \quad ...(9)$$

v_i stands for inefficiency effects and all deviations or inefficiencies from the frontier due to noise; Y_i represents the normalized output of the ith productive units for i=1,2,3…. n where the output refers to yield in rice farming kg/acre and productive units refers to farmers. TLC=Total Intermediate Costs, TFC=Total Labor Costs, TFC=Total Fixed Costs, QPF=Quantity of Planting Fertilizer and QTF=Quantity of Topdressing Fertilizer.

u_i stands for inefficiency effects; Z_1=Age of respondent, Z_2=Household size, Z_3=Planting

Table 2. Variables used in the Cobb-Douglas production frontier

SN	Variable(unit)	Definition	Expected hypothesis
1.	Intermediate costs (TZS)	Expenditures on intermediate inputs, which are goods or services used in the production (cont...)	-
2.	Labor costs (TZS)	Expenses incurred in employing workers in rice farming (cont…)	-
3.	Fixed costs (TZS)	Constant expenses paid to AMCOS every year in rice farming (cont…)	-
4.	Productivity	Total yield harvested in kg per acre (cont…)	+
5.	Quantity of planting fertilizer	Quantity of fertilizer used in kg per acre (cont…)	+
6.	Quantity of top dressing fertilizer	Quantity of fertilizer used in kg per acre (cont…)	+
7.	Farming experience	Number of years in rice farming (cont…)	+
8.	Access to credit	1=access, 0=otherwise(dummy)	+
9.	Attended training	1 if the farmer attended training, 0=otherwise(dummy)	+
10.	AMCOS experience	Years of membership in AMCOS (cont…)	+
11.	Age	Age of respondents in years (cont…)	-
12.	Planting system	1=row planting, 0=Zig-zag planting (dummy)	+
13.	Water distribution	2= Good, 1= Fair, 0=Poor (cat….)	+
14.	Sex	1=male 0=female (dummy)	+
15.	Source of seeds	3=Fellow farmers, 2=Research institute, 1=farmer groups 0=Own saved seeds (cat…)	-
16.	Education level	3=Informal education 2=Primary 1=Secondary 0=Tertiary (cat…)	+
17.	Economic activities	2= Livestock 1=Business 0=Farming, livestock and business (cat…)	+/-
18.	Ploughing time	1=early, 0=late ploughing (dummy)	+

systems, Z_4=Water distribution, Z_5=Attended training, Z_6=Access to credit, Z_8=Source of seeds, Z_9=ploughing time, Z_{10}=Sex, Z_{11}=Education level, Z_{12}=Marital status, Z_{13}=Economic activities, ϑ_i=error term, δ_0=a constant term, δ_1-δ_{12}=Estimated parameters. Variables that were subjected to SFA and the inefficiency model are specified in Table 2.

Results and Discussion

Socio-demographic Characteristics

The results on smallholder rice farmers' socio-demographic characteristics shown in Table 3 indicate that the majority (73.6%) of farmers had at least a primary school education. Level of education is anticipated to be an important factor that would affect the level of competitiveness in rice farming as educated farmers find it easier to comprehend information concerning production technologies and farming practices. These findings agree with the findings of Ndakije (2020) in which 82% of rice farmers had formal education. The study further reveal that the majority (70.7%) of the respondents

Table 3: Socio-demographic characteristics among farmers in the study area (n=382)

Variable	Classes	AMCOS			Pooled statistics n=382
		Kapunga (%)	Madibira (%)	UWAWAKUDA (%)	
Sex	Male	74.2	72.6	62.80	70.7
	Female	25.8	27.4	37.2	29.3
Marital status	Single	11.3	10.3	7.1	9.7
	Married	88.7	89.7	92.9	90.3
Education level	Informal education	1.6	3.8	5.8	3.9
	Primary	69.4	71.4	82.6	73.6
	Secondary	4.8	19.2	7.0	14.1
	Tertiary	24.2	5.6	4.7	8.4
Economic activities	Farming (Other crops)	40.3	42.7	22.1	37.7
	Livestock	0.0	1.3	2.3	1.3
	Business	0.0	12.8	23.3	13.1
	Farming, livestock and business	46.8	34.6	33.7	36.4
	Rice farming only	12.9	8.5	18.6	11.5
Household size	Mean	5	5	5	5
	Max	9	14	15	15
	Min	2	1	1	1
Experience in rice farming	Mean	21.24	17.77	16.35	18.02
	Max	50	41	50	50
	Min	3	2	3	2
Years in AMCOS	Mean	11.85	15.21	12.43	14.04
	Max	22	33	19	33
	Min	2	2	3	2

In addition to quantitative analysis, Content analysis was used to organize, re-arrange and manage the qualitative data obtained from the FGDs and KIIs for triangulation purposes. The codes were created according to the thematic aspects of the research questions used.

were males while 29.3% of them were females. This implies male dominance in rice production in the study area which is supported by the study of Tadesse *et al.* (2017) on rice farming in Ethiopia. Also, 11.5% of farmers were recorded as having rice farming as their only economic activity. This means that farmers in this category devote most of their time to rice farming, but also having only one source of income is risky as may influence their competitiveness.

The study also found that the average household size was 5 members. Larger household sizes have the potential for providing cheap labor in farms that can enhance productivity and TE. Yet, the larger household sizes puts more pressure on household income that can be used to purchase inputs to improve productivity, henceforth the negative effect on TE. This finding is in agreement with Kulyakwave *et al.* (2019) who reported an average household size of 5 members in rice farming. The average years in AMCOS was 14.04. Mean years were found highest in Madibira (15.21) and lowest in Kapunga (11.85). This implies that Madibira has more experience in working with rice farmers and is probably able to deal with members pressing issues compared to Kapunga and UWAWAKUDA.

Farming Characteristics

The results on farming characteristics are presented in Table 4. The overall average paddy produced (kg/acre) was 2783, with the highest mean observed in Madibira (2886), followed by Kapunga (2884) and UWAWAKUDA (2421). This is above the target yield for irrigated rice production in 2019. The findings are different from the productivity of 1450 kg/acre and 1720 kg/acre reported by Mkanthama *et al.* (2017) and Nkuba *et al.* (2016) in Tanzania. One of the major reasons for the gains in productivity is that this study involved farmers in AMCOS who grew high-yield improved variety TXD 306 (Saro 5) in the irrigation schemes. The highest production by Madibira farmers can be attributed to the irrigation infrastructures which enable them to manage appropriately the water levels and availability throughout the season as revealed by having the highest number of farmers (62%) with access to good water distribution as shown in Figure 1.

The average land size under rice farming was 3.32 acres. This is in line with the average land size for smallholder rice farmers in Tanzania which is 3.25 acres (URT, 2015). Farmers in UWAWAKUDA had a minimum land size of 1 acre with the minimum land size of 2.5 acres in Madibira and Kapunga respectively. This variation is because the maximum average land rented to farmers in UWAWAKUDA was 1 acre while for Madibira and Kapunga the maximum land size rented to farmers was 2.5 acres per AMCOS member. The additional land was due to land borrowing from fellow farmers in the respective AMCOS. The average fixed costs incurred were found to be 123234 TZS/acre. These costs entail the cost of land and water infrastructures paid directly to AMCOS every season. The average intermediate cost of production was 605419 TZS/acre. These entail land preparation costs, storage, harvesting and transport costs, and costs involved in buying inputs including seeds, fertilisers, pesticides, herbicides and insecticides. The average labor

Table 4: Farming Characteristics

Variables	AMCOS			Pooled statistics n=382
	Kapunga n=(62)	Madibira n=234	UWAWAKUDA n=86	
Productivity	2884	2886	2421	2783
Intermediate costs (TZS/acre)	656242	641548	470474	605419
Labor costs (TZS/acre)	256879	250581	253890	252348
Fixed costs (TZS/acre)	34000	148800	118000	123234
Land size (acres)	3.38	3.39	3.05	3.32
Quantity planting fertilizer (kg/acre)	47.90	20.98	52.44	32.65
Quantity of topdressing fertilizer (kg/acre)	93.06	102.89	69.88	93.87

costs per farmer were 252348 TZS/acre. The overall mean value of fertilizers was 126.52kg/acre. The findings of the current study do not support the previous research of Mkanthama *et al.* (2017) who reported rice farmers using 76kg/acre. The less use of planting fertilizer was attributed to the fact that most farmers used decomposed paddy remains from the previous season. It was found that intermediate costs, planting fertilizers and top dressing fertilizers are positively related to the quantity of rice produced in kg/acre as shown in Table 6. For every unit increase in the intermediate costs which include costs of land preparation, irrigation, and costs of all inputs, the amount of rice produced increases by 0.210 kg/acre. Also, farmers' productivity was highly influenced by the amount of fertilizers used. These findings agree with the results of Tadesse *et al.* (2017) and Mwangi *et al.* (2020) who reported a positive influence of fertilizer on productivity among smallholders. Fixed costs are negatively associated with the quantity of rice produced (kg/acre) at a 5% level of significance as assumed before.

Smallholder rice Farmers' practices in AMCOS

The results on farmers' practices as presented in Figure 1 show that a good number of farmers in Madibira had good water distribution (86.5%) in their plots, Kapunga at 79% and UWAWAKUDA at 77.9%. This suggests that water infrastructures and management in Kapunga and UWAWAKUDA were not in good condition resulting in low TE and hence low competitiveness. The findings are in line with Lemus *et al.* (2020) who attributed smallholder farmers' low levels of competitiveness to poor infrastructures. The majority of farmers in all AMCOS used a zigzag planting system. The observation opens the salient fact on the planting system as observed in Table 4 that farmers at Madibira had high productivity and the gap is also revealed in technical efficiencies in Table 5. With training, 27.8% of farmers at Madibira were trained in rice farming with 10.5% and 9.7% for UWAWAKUDA and Kapunga respectively. Access to training may influence smallholder farmers' productivity and hence their competitiveness. The majority of farmers in Madibira had access to credit. This was attributed to the presence of Mufindi Community Bank, Victoria Finance, lending groups and Madibira SACCOS in the Madibira town center.

Distribution of TE as predicted by SFA

The findings as presented in Table 5 show that the mean TE indices for Kapunga, Madibira and UWAWAKUDA AMCOS were 84.9%, 87.6% and 79.1% respectively. The reasons for differences in TE may be because Madibira members rated higher in good water distribution in the rice farms and more members with access to training and credit as stipulated in Figure 1. The overall mean TE for the whole sample was 83.8% suggesting that rice farming was on average about 16.2% below the potential due to the specific inefficiencies connected to farming. Regarding this range of TE levels, for the inefficient farmers, there was a 0.162 chance to improve. The findings are in line with those of Chukwujekwu *et al.* (2020) who found the a mean

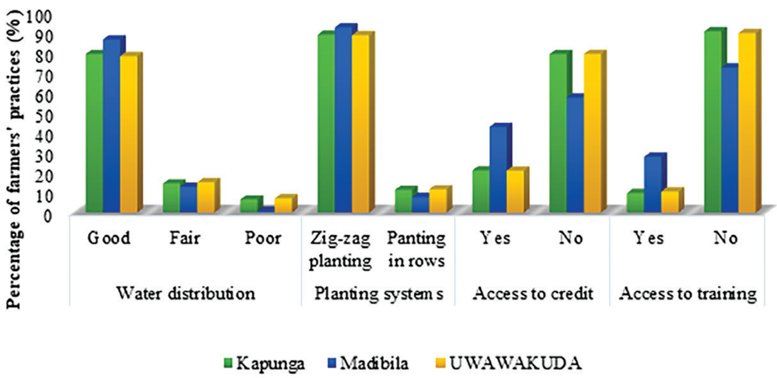

Figure 1: Farmers' practices through AMCOS

TE of 84.76% implying that the co-operatives were operating at 15.24% below their optimum production capacity in Nigeria. However, TE is less than the average TE of 96% reported by Mkanthama *et al.* (2017) in Tanzania. One of the reasons for the difference is that a study by Mkanthama *et al.* (2017) was conducted on a research site under International Rice Research Institute. Also TE in Table 5 ranges from 41.3% to 97.9%. This range agrees with that of cassava farmers reported by Osung *et al.* (2014) which ranged from 41.90 to 97.34% in Nigeria. The distribution of statistics in Table 5 follows a similar distribution revealed by Mwangi *et al.* (2020) on TE in tomato production among smallholder farmers in Kenya.

Findings as presented in Table 5 also demonstrate the distribution of TE by AMCOS and the total distribution, whereby about 4% of rice farmers were operating below 50% TE, while about 10.3% of the rice farmers were operating between 60% and 69% efficiency level. The findings further signpost that roughly 33.7% of farmers were operating between 80% and 89% level of efficiency while 43.6% managed to achieve above 90% efficiency level. This indicates that the majority of farmers utilized their resources effectively and can produce output at a relatively high level compared to their inputs. It also suggests that there is room for other farmers to improve their efficiency levels by learning from the successful practices of majority farmers.

Table 5: Summary statistics of smallholder rice farmers TE in the study area (n=382)

Description	Efficiency range	TE score (%)			Pooled (%)
		Kapunga (n=62)	Madibira (n=234)	UWAWAKUDA (n=86)	
Low	Less than 0.50	7.3	0.9	4.9	4.4
Medium	0.50-0.59	5.5	0.9	7.3	4.6
	0.60-0.69	1.8	5.4	9.8	5.7
	0.70-0.79	1.8	6.8	15.9	8.2
High	0.80-0.89	27.3	27.6	46.3	33.7
	0.90-1.00	56.4	58.4	15.9	43.6
Total	**100**	**100**	**100**	**100**	
Mean	84.9	87.6	79.1	83.8	
Maximum	97.4	98.5	97.8	97.9	
Minimum	40.2	43.8	40.1	41.3	

Factors Influencing Smallholder Farmers' TE

The Maximum Likelihood Estimates for the parameters of the SFA and the inefficiency model are shown in Table 6. Variable with negative signs contribute to the TE while those with a positive sign contribute to technical inefficiency. Farmers with poor water distribution were highly associated with technical inefficiency at a 1% level of significance. This implies that an increase in the number of farmers with poor water distribution will decrease rice output by 0.503 units. This means that water supply is an important component for rice to grow well. The findings stand with those of Anang *et al.* (2016) who found that access to irrigation water enables farmers to maximise the use of other inputs such as fertiliser and seeds. Farmers who attended training in AMCOS were technically efficient at a 5% level. This implies that farmers who were trained increased their rice output by 0.274 units in the area. These findings are consistent with Tadesse *et al.* (2017) who found a positive significant effect of training on TE among rice farmers in Ethiopia.

In addition, farmers' technical inefficiency was associated with farmers' access to credit. This implies that most farmers who had access to credit either had small amounts that couldn't affect their TE or they failed to commit

Table 6: Maximum Likelihood Estimates of the SFA in Smallholder Rice Farming

Ln (paddy kg/acre)	Coefficient.	Std Error	P>z	Sig.
Frontier parameters				
Ln(Intermediate cost)	0.210	0.068	0.002	***
Ln(Labour cost)	0.016	0.029	0.577	
Ln(Fixed cost)	-0.006	0.002	0.006	***
Ln(Planting fertilizers)	0.001	0.000	0.000	***
Ln(Top dressing fertilizers)	0.003	0.000	0.000	***
Constant	4.907	0.897	0.000	***
Inefficiency parameters				
Farming experience	0.000	0.004	0.956	
AMCOS experience	-0.003	0.007	0.607	
Age	0.003	0.003	0.338	
Household size	-0.012	0.010	0.229	
Zig-zag planting	0.567	0.257	0.028	**
Poor water distribution	0.503	0.097	0.000	***
Access to training	-0.274	0.108	0.011	**
Access to credit	0.101	0.055	0.067	*
Inputs from farmer groups	-0.016	0.091	0.863	
Late ploughing time	0.064	0.025	0.009	***
Sex	0.036	0.055	0.510	
Level of education	0.406	0.167	0.015	**
Marital status	-0.068	0.079	0.393	
Economic activities	0.255	0.075	0.001	***
Constant	-1.031	0.434	0.018	**
U Sigma constant	-3.075	0.256	0.000	***
V sigma constant	-4.945	0.179	0.000	***
Sigma u	0.215	0.027	0.000	***
Sigma v	0.084	0.008	0.000	***
lambda	2.548	0.029	0.000	***

*** = significant at 1%, ** = significant at 5% and * = significant 10% levels. std =standard.

the borrowed money to the rice production, resulting in a decrease in rice output by 0.101 units. These findings are consistent with Anang *et al.* (2016) who found the insignificant effect of credit on TE among rice farmers in Ghana. However, Idiong (2007) reported access to credit positively influenced the farmers' efficiency in the Cross River State of Nigeria. It was found that farmers who attained a tertiary level of education were highly associated with technical inefficiency. The argument posited by the findings was supported by FGD participants who reported that;

"..... farmers with tertiary level of education are more likely to catch up jobs outside farming which may restrict the time allocated to farming activities" (FGD, Dakawa Village, February 2022).

The findings suggest that the level of education of smallholder rice farmers may not affect their TE due to the time allocated to farming as one Key Informant stated;

"....but we also provide services through telephone, especially for the farmers who

are employees. They also communicate with the laborers on the phone due to their tight schedules" (Key Informant, Madibira Ward Extension Officer, February 2022).

The findings from the Key Informant indicate that farmers with tertiary level of education had a negative impact on the TE as farmers may have less physical visits to their farms and relied on labor. The meager effect of education level in farming isn't surprising, similar findings have been reported by Balde *et al.* (2014) and Anang *et al.* (2016) who found that educated farmers had technical inefficiencies in the rice production in Northern Ghana and Guinea respectively.

The findings opposed those of Idiong (2007); Osung *et al.* (2014); Linn and Maenhout (2019); Tadesse *et al.* (2017) who found that rice farmers' TE increased with an increase in years of schooling. Likewise, farmers with no other economic activity were associated with technical inefficiency at a 1% level compared to farmers with other economic activities such as business, livestock and farming other crops. This means that smallholder rice farming is not a standalone business as farmers may depend on other sources of income to sustain his/her farming business. Therefore a farmer having no other economic activity and solely dependent on rice farming had a decrease in rice output by 0.255 units.

Smallholder rice Farmers Competitiveness in AMCOS

The overall average paddy produced (kg/acre) was 2783.691, with the highest mean observed in Madibira (2886.329), followed by Kapunga (2884.016) and UWAWAKUDA (2421.209). Productivity has been used as a measure of competitiveness among smallholder livestock systems in Botswana (Bahta, 2014). The higher the productivity, the greater the level of competitiveness. Therefore, members of Madibira were more competitive in terms of productivity compared to Kapunga and UWAWAKUDA. The possible reasons for differences in productivity were because Madibira members rated higher in good water distribution in the rice farms and more members with access to training and credit. This is the contribution of AMCOS in improving the competitiveness of smallholder rice farmers in Tanzania through increased productivity from the current 0.81 tonnes/acre to a potential 1.62 tonnes/acre by 2030 for self-sufficiency in rice with a margin to export to neighboring countries in the region (URT, 2019).

A technically efficient firm produces the maximum output for a given amount of inputs, conditional on the production technology available to it (Adeyemi *et al.,* 2017). Efficiency is one of the main drivers of competitiveness where the higher the TE, the lower will be the unit cost of production hence more the competitiveness (Balde *et al.,* 2014). Madibira is therefore classified as competitive in terms of TE when compared to Kapunga and UWAWAKUDA. A study by Rahji and Omotesho (2007) on TE and competitiveness of rice farming in Nigeria found that about 85% of the farmers had their TE greater than or equal to the mean TE. And hence classified rice production as being competitive. Likewise, a study conducted by Sinaga *et al.* (2021) on the competitiveness of cassava farming in Indonesia revealed that the TE of cassava production becomes the determinant of competitiveness and the more efficient the production at the farm level, the higher the competitiveness. Consequently, more efficient rice farmers would have better chances of persisting and flourishing in the future than less efficient ones.

Conclusions and recommendations

Smallholder rice farmers in Madibira AMCOS are more competitive compared to Kapunga and UWAWAKUDA due to their high productivity (kg/acre), slightly higher TE than the average, and a good number of members in the high-level TE. The rice farms in the study area have been operating below the maximum level of production frontier, hence there is a potential for improvement. Factors influencing smallholder rice farmers' TE are access to training, water distribution, ploughing time, planting systems and access to credit. Despite the establishment of AMCOS being increasingly advocated by the government, findings provide no evidence that co-operatives have so far directly affected agricultural productivity and

TE. Instead, the findings provide evidence that AMCOS has affected the TE of smallholder farmers through coordinated training, the use of water-saving irrigation technologies, water infrastructures and access to credit. AMCOS in the irrigation schemes should consider proper water distribution in the rice plots, planting in rows and providing training on rice farming best practices to increase smallholder farmer's TE. Policymakers should prioritize the implementation of targeted training programs and enhance access to agricultural inputs and credit facilities. The Local Government Authority and development partners espoused with improving smallholder farmers' livelihoods should make sure that farming credits are properly channeled to farming and are given to farmers who exhibit the need for it. Further studies should be done to compare the competitiveness of smallholder farmers who are members of AMCOS and those who are not members.

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