An economic efficiency analysis approach for smallholder rice producers in Maramvya irrigated scheme, Burundi

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Abstract

This study assessed the extent to which rice producers from Maramvya irrigated scheme could raise their productivity and cost discounts if they efficiently use inputs in producing rice. To achieve this objective, we applied simple random sampling to select and collect cross-sectional data for 230 rice producers in the study area. Stochastic frontier analysis was used to evaluate how rice producers are technically, allocatively and economically efficient. The study applied Cobb-Douglas functional form for the stochastic frontier production and cost functions. In addition, a one-step maximum likelihood approach was used to derive parameters for stochastic frontier models. The study further assessed factors affecting efficiency levels among rice producers. Findings of this study revealed that rice yield elasticities with respect to land, labour, seed and fertilizer were 0.41, 0.45, -0.11 and 0.24 respectively, meaning that labour variable was more responsible in rice production increase while seed variable was in negative relationship with production levels. Globally, technical, allocative and economic efficiency scores averaged at 82%, 71% and 58% respectively, implying that rice producers were technically efficient than they were allocatively and economically, with 42% room to expand productivity and cost discounts. Furthermore, the results pointed out that the major factor affecting efficiency levels positively in the study area was the level of education while age of the farmer, household size, access to credit and shortage of water significantly impact efficiency levels negatively. The study recommends introduction of new techniques rather than relying on expansion of land and labour intensification. Focus should be on input market and availability, but also in the long run, focus should be oriented on education and maintenance of canals for irrigation.

Keywords: Economic efficiency, Smallholder producers, Productivity, Return-to-scale, Cost discounts

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1. Introduction

Based on statistics reported by the Burundian Institute of Statistics and Economic Studies (ISTEEBU), rice ranks second cereal produced after maize (ISTEEBU, 2015). Rice is mostly produced under three types of agricultural systems: upland system in country side, lowland rainfed system in southern Imbo and Moso and lowland irrigated system in central Imbo. Importance of rice is undeniable, but due to lack of details in the National Agricultural Account and data inconsistencies, it is not easy to quantify the exact contribution of rice to the economy. For example based on year 2011 data, the value of total rice produced was estimated at 75 billion of BIF (Government of Burundi-GoB, 2014), that is 16% of Gross Domestic Product (GDP). But reports for following years whether from ISTEEBU, Government or Central Bank of Burundi do not systematically give details on the evolutionary trend on how rice subsector contributes to GDP.

Given its importance with regard to both poverty and food security (some of advantages of rice production relate to easy storage, well adapted to hydromorphic land during rainfall season and high potential demand), rice has become a strategic crop. It is at the center of key strategic roadmap documents for agricultural development namely, Strategic Framework for Economic Growth and Poverty Reduction (SFEGPR), National Agricultural Strategy 2008 – 2015 (NAS), National Program for Food Security 2009 – 2015 (NPFS), National Program for Agricultural Investment 2012-2017 (NPAI) and finally National Strategy for Development of Rice Sector 2014 (NSDRS-B).

However, despite its significance in poverty reduction and food security, Burundi's production level for irrigated rice is low if we compare to yields in other African countries for irrigated rice which range from 3.5 to 7 tonnes/ha (FAO, 2016). The productivity is actually estimated at 4 tonnes per hectare (ISTEEBU, 2015) but irrigated ecosystems provide potentials for high yields because of better control of water. The Government of Burundi and non-government stakeholders are actively investing in rice production improvement, the motivation being the desire to combat food insecurity and turning rice into cash crop (GoB, 2008).

Interventions made to increase rice productivity have basically focused on agronomic practices while efficient use of inputs in producing rice as a source of increased productivity and profitability have been less surveyed (Ndayitwayeko and Korir, 2012). Rice producers in Maramvya irrigated scheme would benefit from additional information on efficient production in order to enhance the profitability of their rice farming activity.

Recently, rice has turned into the main staple food for Burundi's population due to rapid urbanization, refugee repatriation and high quantity demanded by boarding schools, army and police (ADISCO, 2012). There is therefore a potential demand for rice due change in consumption pattern especially in urban areas (ADISCO, 2012). This potential demand in rice is presented as an opportunity for rice producers. Nonetheless, this advantage can only be exploited if rice farmers produce efficiently.

Furthermore, with a population density of 329 inhabitants/km^2 in arable land area, it is unlikely to develop new schemes in Burundi. Chances to increase rice production by bringing more land to rice cultivation are reduced. The only alternative achievable, not only on the short run view, but also because it is cheaper, is the efficient use of existing means of production. It is therefore through efficient production where farmers can enhance productivity and profitability by tracking opportunities offered by rice industry.

Varied empirical works have applied stochastic frontier approach (SFA) to economic efficiency analysis in rice production at global level. For instance, Magreta*et al.* (2013) employed the SFA to assesshow rice producers in Nkhate irrigated scheme in Malawi are economically efficient. The authors assessed also what factors are like to explain efficiency levels for each individual farm. The study used trans-log production and cost frontiers to analyze the technical and the cost efficiencies. As per their findings, there were about 35% of potential to expand productivity and about 47% of cost discounts if inputs are adjusted rationally. It has also been found that there are factors that can be associated with individual level of efficiency. These include the number of years farming activity, credit accessibility, number of people leaving in the farmer's household and soil fertility status.Similar results have been reported by other studies in economic efficiency studies, for instance Ouedraogo (2015) in Burkina Faso, Hye-Jung Kang and Yu Yu Tun (2015) in Myanmar and Le Quang Long *et al.* (2013) in Vietnam.

Systematic literature review done in this study however, shows little evidence on the existence of research on Economic Efficiency (EE) for Burundi rice sub-sector, that is an analysis that combines technical and allocative views to efficiency analysis. An attempt by Ndayitwayeko and Korir (2012) focused on TE living a gap on Allocative Efficiency (AE) for understanding the overall EE on rice sub-sector in Burundi because as highlighted by Mubarak and Byerlee (1991), technical and economic changes follow each other. For Burundi rice industry, it is not clear whether efforts aiming at increasing production levels would ultimately lead to profit improvement. As such, a complete EE analysis would fill this literature gap and contribute to explore the potentials offered by rice industry through coupled improved productivity - profitability.

Before presenting results and subsequent discussions in section three, the following section of this paper presents details on the methodological process that have been used. After results and discussions, the last section concludes with key findings of this study and related policy recommendations.

2. Methodology

2.1 The study area

The study was carried out in Maramvya irrigated scheme located in Bujumbura province (Central West of Burundi), where the Imbo Region Development Society (SRDI), a parastatal company, initiated a scheme by which rice producers are supplied both agricultural inputs (mainly seeds, water and sometimes fertilizers) and other crucial agricultural services on credit basis. SRDI is also the main buyer of rice produced whose payments exclude the deduction of the credit in kind given to farmers.

Maramvya irrigated scheme is one of the irrigated schemes of central Imbo where the bulk of rice is produced in Burundi. It is located at 25 km from Bujumbura capital city and it covers a total area of 171 ha. The scheme has a total of 595 farmers and on average, the land holding par farmer is 0.26 ha whereby the production is currently estimated at 4000 kg/ha according to the reports by ISTEEBU (2015). The region is located in the Imbo agro-ecological zone with mean altitude of 1000 m and mean rainfall of 900 mm. The prevailing climate is warm tropical where temperature ranges between 24°C and 28°C and dry season from five to six months.

Maramvya irrigated scheme was selected to be the area of interest for the study for two reasons. First, it is located in the plain of Imbo where the bulk of rice is produced in Burundi. Therefore studying efficiency in rice sector using the highest production scheme as empirical basis shades light and provide insights useful for research, policy and practice. Second, with respect to the study, the scheme offers an advantage of being well organized in such a way that farmers keep record of rice farming activities and therefore data on rice production in Maramvya irrigated scheme are realistic and updated to be consistent for the study.

2.2 Sampling procedure and sample size

Given that the total number of rice farmers in the scheme is known (N = 575), the targeted population is finite and hence the sample size was determined by applying the standard method as proposed by Krejcie and Morgan (1970) as follows:

$$n = \frac{\chi^2 * N * p * q}{d^2 * (N-1) + \chi^2 * p * q} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where n = sample size, χ^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (at 95% confidence level, χ^2 = 3.8416≈ 3.84), N = total number of farmers, p = population proportion considered to be 0.5 to provide maximum sample size, q = (1-p) = 0.5 and, d = degree of accuracy expressed as a proportion (d = 0.05). Applying formula (1), the sample size for the study is n = 230 rice farmers.

The list of all farmers in the scheme was obtained from ASSOPRO Maramvya. The sample frame was therefore obtained by arranging alphabetically names of all rice producers. Having arranged all 575 rice producers in alphabetical order, simple random sampling was applied to constitute the sample. As such, the sampling interval was $\frac{575}{230} = 2.5 \approx 2$. Hence each 2nd farmer was selected to be interviewed.

2.3 The Data

Secondary and primary data have been used in this study. Secondary data were sourced from various agricultural surveys and agricultural stakeholders'reports and publications. These are the Ministry of Agriculture, the Institute of Statistics and Economic Surveys of Burundi (ISTEEBU), the International Rice Research Institute (IRRI), the Institute of Agronomic Sciences of Burundi (ISABU), Imbo Regional Development Society (SRDI).

Using structured questionnaire, primary (cross-sectional) data for season 16/A have been collected from rice farmers in Maramvya irrigated scheme. The questionnaires captured data on rice yields, input type and usage, production costs and farm-specific and social economic characteristics. To acquire more accurate and reliable information to test the hypotheses of the study, the questionnaire was constructed to capture information related to each variable included in the analytical model (area planted, labour, seeds, fertilizers and all socio- economic variables assumed to affect efficiency levels among farmers). The questions were closed ended and oriented straightforward to the information needed.

2.4 The Theoretical Model

The study employed SFA to analyze how far rice producers are technically, allocativeley and economically efficient. The study applied further Cobb-Douglas specification for the production and cost frontier functions.

According to Greene (2008), the reasons for choosing Cobb-Douglas specification include the fact that it has a universally smooth and convex isoquant and the cost function behaving very well (non-declining in output and input prices) and also it allows one-step maximum likelihood estimation by incorporating technical efficiency effects in the model straightforward as developed by Battese and Coelli (1995). Results from technical and allocative efficiencies lead to derivation of economic efficiency levels. Furthermore, the inefficiency model was specified to analyze the factors that determine efficiency levels among rice farmers in Maramvya irrigated scheme.

The stochastic production frontier was specified following the model by Battese and Coelli (1995) as follows:

$$Y_i = f(X_i, \beta)\exp(V_i - U_i)\,;\, i = 1,2,\dots,n \quad \text{...} (2)$$

Where Y_i = the output produced by the ith farmer; X_i = the vector of inputs used by the ithfarmer; β = the vector of parameters to be estimate; V_i = the random error term for the ith farmer assumed to be independently and normally distributed as $N(0, \sigma_v^2)$; U_i represents non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero with mean μ_i and variance σ_u^2 ($N(\mu_i, \sigma_u^2)$, where: $\mu_i = z_i\delta$, where: z_i is a p×1 vector of variables which may influence the efficiency of a firm and δ is an 1×p vector of parameters to be estimated. According to Drysdale *et al.* (1995), a significant high value of U_i means that there is inefficiency.

Equation (2) allows derivation of elasticities of production levels with respect to each of inputs used in the study area as well as TE indices. For elasticities, the responsiveness of mean output produced by firm ith ($E(Y_i)$) with respect to each input (ε) can be assessed as follows:

$$\varepsilon_a = \frac{\partial lnE(Y_i)}{\partial lnX_a} \quad \text{...} (3)$$

Moreover, at the individual farmer level, the TE index can be calculated from equation (2) as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i,\beta)\exp(V_i - U_i)}{f(X_i,\beta)\exp(V_i)} = \exp(-U_i)\,;0 \le TE_i \le 1 \quad \text{..............} (4)$$

Where Y_i is the actual production level as given by data and Y_i^* the stochastic production frontier (potential output level).

From the stochastic production frontier, $U_i$stands for the technical inefficient component, leading to underscoring the theoretical production level, that is the frontier. For the cost frontier, the error term is altered from (V_i - U_i) to (V_i + U_i) to say that for the cost estimation, farmers who are allocativelly inefficient operate above the cost frontier. The following is the specification of the cost frontier according to Battese and Coelli (1995):

$$C_i = g(Y_i, p_i, \alpha)\exp(V_i + U_i) \quad \text{...} (5)$$

$i = 1,2, \ldots ,n$

Where C_i = the total production cost observed for the i^{th}farmer; Y_i = the output as defined before; p_i = vector of prices of inputs used by the i^{th} farmer; α = vector of parameters to be estimated; V_i and U_i are defined as mentioned earlier. According to Coelli*et al.* (2005), the cost function is assumed to be non-declining in output and input prices. The cost efficiency (CE) for each individual farmer is given by the following equation:

$$CE_i = \frac{C_i}{C_i^*} = \frac{g(Y_i, p_i, \alpha)\exp(V_i + U_i)}{g(Y_i, p_i, \alpha)\exp(V_i)} = \exp(U_i) \quad \text{..............................} (6)$$

Where C_i is the actual cost as given by data and C_i^* stands for what is supposed to the most efficient cost (stochastic cost frontier) or predicted minimum cost (Le Quang *et al.*, 2013) for the ith farmer.

The concept of CE is introduced to refer to the same technique used to derive TE using the FRONTIER 4.1 software. It is an intermediary step toward AE derivation, based on the specification of frontier cost function by the software as a theoretical minimal bound of efficient cost. It means that all farmers lie above the minimum cost, unless they are on the frontier cost (a 100 percent cost efficiency), implying that CE index is usually above 100 percent. Hence, CE is different from AE which lies between 0 and 1. AE is definitely the inverse of CE (Ogundari and Ojo, 2006), and at each individual farm level, AE index is derived from CE as follows:

$$AE_i = \frac{1}{CE_i} \quad \text{..............................} (7)$$

For each individual farmer, EE score is obtained by multiplying TE and AE according to Farrel's (1957) argument. This refers to a combination of Equation (4) and Equation (7). This approach to computing EE was also applied by Coelli*et al.* (2005), Ogundari and Ojo (2006), Le Quang *et al.*, (2013) and Magreta*et al.* (2013). EE is therefore computed as follows:

$$EE_i = TE_i * AE_i \quad \text{..............................} (8)$$

From the frontier production model, the farmer-specific technical efficiencies are estimated. The estimated efficiencies are then assumed to be explained by farm socioeconomic characteristics. Therefore the inefficiency model, following to Battese and Coelli (1995) specification, consists in regressing estimated mean inefficiency (μ_i)upon a vector of farm-specific socioeconomic characteristics susceptible of affecting inefficiency as follows:

$\mu_i = Z_i$..(9)

Where z_i, μ_i and δ are as defined previously.

From the above specification, U_i is not identically distributed given that it depends on farm socioeconomic characteristics. Before estimating the inefficiency model, we therefore have to test existence of inefficiency by setting the null hypothesis as$\sigma_u^2 = 0$ (Coelli *et al.*, 2005). Equation (9) is therefore estimated only in case of rejection of the null hypothesis, that is $\sigma_u^2 > 0$ (presence of inefficiency is evidenced).

2.5 The Empirical Model

The empirical model follows the one-step Battese and Coelli (1995) specification where the inefficiency component is incorporated in the model to enable the researcher to capture the inefficiency effects. The approach involves in regressing individual farm production level to input factors as well as farm individual socioeconomic characteristics susceptible of explaining efficiency differentials among framers.

The implicit Cobb-Douglas functional form is specified as:

$\ln(Y_i) = \beta_0 + \sum_{a=1}^{4} \beta_a \ln(X_{ai}) + V_i - U_i$ ....(10)

i = 1, 2, 3, ... , 230 observations

Where β_0,$\beta_{a,\ a = 1,2,3,4}$ are parameters to be estimated, Y_i, X_i, V_i and U_i are defined as previously. Explicitly, the model to be estimated is developed as follows:

$$ln(Y_i) = \beta_0 + \beta_1 lnLand_i + \beta_2 lnLab_i + \beta_3 lnSeed_i + \beta_4 lnFer_i + V_i - U_i \quad ..\ (11)$$

i = 1, 2, 3, …, 230 observations

Where Y_i = total paddy rice produced by the ith farmer in kg; $\beta_{a,}$ a = 0,1,2,3,4 are parameters to be estimated; $Land_i$ = total area planted by ith farmer in ares (a); Lab_i = total amount of labour utilized by the ithfarmer in man-days; $Seed_i$ = total quantity of seed utilized by the ith farmer in kg; Fer_i = total quantity of fertilizer utilized by the ith farmer in kg; v_i = random variable for the ith farmer associated with disturbances in the production process; u_i = farm social-economic characteristics related to the production inefficiency.

According to the specification by Battese and Coelli (1995), the implicit Cobb-Douglas stochastic frontier cost function is given by:

$$\ln(C_i) = \alpha_0 + \alpha_y \ln(Y_i) + \sum_{a=1}^{4} \alpha_a \ln(p_{ai}) + V_i + U_i \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

i = 1,2,3, … 230 observations

Where C_i = total cost for farm ith, α_y and $\alpha_{a,}$ a = 0,1,2,3,4 are parameters to be estimated, p_i = input price for the ith farmer and Y_i, V_i, and U_i are as defined previously. Explicitly, the model estimated in this study is specified as follows:

$$ln(C_i) = \alpha_0 + \alpha_1 lnY_i + \alpha_2 lnLandCost_i + \alpha_3 lnLabCost_i + \alpha_4 lnSeedCost_i + \alpha_5 lnFerCost_i + v_i + u_i \ \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

i = 1, 2, 3, …, 230 observations

Where C_i = total cost of producing rice for the ith farmer in Burundian Francs (BIF); $\alpha_{c,\ c=0,1,2,\ldots 5}$ are parameters to be estimated; Y_i as previously defined; $LandCost_i$ = the land lending price for the ithfarmer in BIF/are; $LabCost_i$ = the price of labour utilized for the ith farmer in BIF/man-day;

$SeedCost_i$ = the price of seed for the i^{th} farmer in BIF/kg and $FerCost_i$ = the price of fertilizer for the i^{th} farmer in BIF/kg.

Cobb-Douglas specification offers an advantage that results from estimation are straightforward conclusive about elasticities. Therefore from production function (equation 10), the elasticities of mean output with respect to each of the inputs are derived empirically as follows:

$$\varepsilon_a = \frac{\partial lnE(Y_i)}{\partial lnX_a} = \beta_a \text{..} (14)$$

Where a = 1,2,3,4 are the four inputs used in rice production in Maramvya irrigated scheme.

The standard form of the stochastic frontier model as preconized by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) allows estimating TE, AE and EE by postulating that the error term ε_i can be broken into two independent components, $\varepsilon_i = V_i - U_i$. Distributional assumptions on ε_i are that V_i is independently and identically distributed normally with mean zero and variance σ_v^2, while U_i is independently and identically distributed half-normally as truncations with mean zero and variance σ_u^2. The parametization of the log-likelihood function for a half-normal model, according to Aigner *et al.* (1977) is that:

$$lnL(Y\backslash\beta,\sigma,\gamma) = -\frac{n}{2} ln\left(\frac{\pi\sigma^2}{2}\right) + \sum_{i=1}^{n} ln\Phi\left(-\frac{\varepsilon_i\gamma}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_{i=1}^{n} \varepsilon_i^2 \ldots (15)$$

Where Y is a vector of output values transformed by logarithm operator and $\Phi(x)$ is the cumulative distribution function (cdf) of the standard normal random variable evaluated at x.

Sigma-Squared $\sigma^2 = \sigma_v^2 + \sigma_u^2$..(16)

and Gamma $\gamma = \frac{\sigma_u^2}{\sigma^2}$ .... (17)

The parameter σ^2represents the total variation in quantity of rice produced due to the compound error term, $\varepsilon i = Vi - Ui$. γ explains therefore the impact of inefficiency on the output.The Maximum Likelihood Estimation (MLE) of equations (11) and (13) using FRONTIER 4.1 software provides consistent estimators for β, σ and γ (Coelli, 1996). As preconized by the author, γ parameter is bounded as $0< \gamma <1$. As such, if the value of γ tends to the lower limit, there is no inefficiency and deviation from the frontier is attributable to random shocks. On the other side if it tends to the upper limit, we are in the presence of inefficiency.

From equation (15), solving for parameters β, σ and γ requires to calculate first order conditions, which becomes tricky as long as we end up with a system of non-linear equations (Coelli*et al.*, 2005). We therefore apply the FRONTIER 4.1software which can bootstrap using the iterative optimization approach by Shaka*et al.* (1985) and definitely be able to solve for model parameters. At the same time, the software generates TE indices for each ith farmer following the conditional expectation equation of TE as follows:

$$\widehat{TE} = E\{\exp(-u_i)\} = 2\Phi(-\sigma_u)exp\left\{\frac{\sigma_u{}^2}{2}\right\} \text{..............................} (18)$$

The inefficiency model involves in regressing the inefficiency component (U_i) upon the farm social-economic characteristics. Equation (8) is empirically specified as follows:

$$U_i = \delta_0 + \delta_1 Age_i + \delta_2 Sex_i + \delta_3 HHSiz_i + \delta_4 OffFarm_i + \delta_5 Adult_i + \delta_6 Prim_i + \delta_7 Second_i + \delta_8 CredAcc_i + \delta_9 Exp_i + \delta_{10} Irr_i) \;.... (19)$$

i = 1, 2, 3, …, 230 observations

Where U_i = as defined before; $\delta_{b.\ b=0,1,2,...10}$ are parameters to be estimated; Age_i = age of the ith farmer in years; Sex_i= sex of the ith farmer (1 = male, 0 = female); $HHSiz_i$ = size of the family of the ith famer (number of persons); $OffFarm_i$ = off-farm income (1 = if farmer earned off-farm income, 0 = if farmer did not earn off-farm income); $Adult_i$ = attainment of adult education level of the ith farmer (1= attained adult education, 0 = otherwise); $Prim_i$ = attainment of primary education level of the ith farmer (1= attained primary education level, 0 = otherwise); $Second_i$ = attainment of secondary education level of the ith farmer (1= attained secondary education, 0 = otherwise); $CredAcc_i$ = Access to credit by the ith farmer (1 = if farmer accessed to credit, 0 = no access to credit); Exp_i = experience of the farmer ith in years; Irr_i = shortage in water for irrigation for the ithfarmer (1= if the farmer has faced shortage, 0 = no shortage).

From equation (19), parameters for the inefficiency model were derived. It is important to note that equations (11) or (13), (15) and (18) are usually estimated simultaneously using MLE procedures with FRONTIER 4.1 software program.

3. Results and Discussion

3.1 Socio-economic characteristics of respondents

Farmers' socio-economic characteristics that are discussed here are those susceptible of influencing the efficiency levels among rice farmers in the scheme and are specified in the inefficiency model. These characteristics include age, sex, household size, off-farm income, educational level, access to credit, years of farming experience and availability of water for irrigation as indicated in Table 1.

Table 1: Socio-economics characteristics of rice producers in Maramvya irrigated scheme, Burundi

Characteristics	Frequency	Percentage
Age (Years)		
<15	0	0.00
15-24	1	0.43
25-34	16	6.95
35-44	44	19.13
45-54	64	27.82
55-65	69	30.00
>65	36	15.65
Total	**230**	**100.00**
Sex		
Male	150	65.22
Female	80	34.78
Total	**230**	**100.00**
Household Size		
1-4	23	10.00
5-8	108	46.96
9-12	82	35.65
>13	17	7.39
Total	**230**	**100.00**
Off-farm Income		
Off-farm Income	62	26.96
On-farm Income Only	168	73.04
Total	**230**	**100.00**

Education Level		
No formal Education Level	88	38.26
Adult Education Level	19	8.26
Primary Education Level	107	46.52
Secondary Education Level	16	6.96
University Education Level	0	0.00
Total	**230**	**100.00**
Access to credit		
With Access to Credit	167	72.61
With no Access to Credit	63	27.39
Total	**230**	**100.00**
Experience (Years)		
<5	1	0.43
5-10	16	6.96
11-15	20	8.70
16-20	52	22.61
21-25	10	4.35
>25	131	56.96
Total	**230**	**100.00**
Water availability		
Have Faced Shortage of Water	46	20.00
No Shortage of Water	184	80.00
Total	**230**	**100.00**

From Table 1, we can see that majority of the household heads (30%) in the study area are aged between 55 and 65 years followed by 27.8% of the 45 to 54 years category. This implies that most of household heads in the study area are too old compared to the mean age of 51 years. With these findings, it is apparent that most of the rice farmers are above the active age and they probably do not have enough capacity to manage their farm efficiently. Results further indicate that 65.22% of the respondents are male while 34.78% were female. This means that male population was more involved in rice production than female.

The findings show that the mean household size in the study area is 8 persons with the majority of families (46.96%) having the size ranging between 5 and 8 persons. It is also revealed that the proportion of families with large size (compared to the mean of 8 persons) is important, that is 35.65% for the class of 9 to 12 persons and 7.39 above 13 persons. This implies that rice farmers in the study area have to produce much in order to be able to feed their families and also derive surplus to fulfill other needs. In terms of income, 73.04% of rice farmers in the study area have no other sources of income other than farming activities. It implies that only a proportion of 26.95% have access to other sources of income. This means that majority of rice farmers in Maramvya irrigated scheme have to yield much from farming activities in order to fill the capital gap, unless they have access to credit in financing institutions.

Apparently, majority (46.52%) of the sampled farmers have primary education level. It was found however that a considerable percentage (38.26%) has not gone to formal school. Furthermore, the findings revealed that there is no single farmer with tertiary education in the study area. Concerning the access to credit, it has been revealed that 72.61% of rice farmers have access to credit facilities. According to information obtained from respondents, this is due to the fact that farmers in Maramvya irrigated scheme are affiliated with farmer's association which offers an advantage of reliability and confidence with regard to financing institutions. On the other side, a proportion of 27.39% rice farmers have no access to credit and have problem to fill the capital gap during intense activities.

The mean farming experience of the rice farmers in the study area was 25 years with the majority ranging above that mean (56.96%). This implies that most of the rice farmers have been in rice production for a long time and this matches with what we have found for age of rice farmers where the majority of farmers have aged above 51 years. Following this observation, we can conclude that most of plots used to grow rice in the study area are under family ownership where property rights are transmitted from generation to generation.

The study findings have further shown that rice farmers in the study area have no shortage of water in general (20% with shortage against 80% without shortage of water). That would lead to a conclusion that the small proportion of rice farmers facing shortage of water may perform poorly in terms of rice produced. According to information obtained from respondents, individual shortage of water is due to the miss leveling of farmers' plots and therefore the water captured from the canal fail to reach to whole surface of the plot. This leads to draught of some parts of rice plants before reaching maturity.

3.2 Production and input variables description

The summary statistics of the rice production and variables used for the stochastic production and cost function analyses is presented in Table 2. The findings indicate that the average rice production per farmer and per single season in the study area was 3547 kg/ha. This finding is within the estimation by ISTEEBU (2015) where it is reported that average rice production per hectare is 4 tonnes/ha for irrigated rice production.

On the other side, the analysis of inputs used revealed an average farm size of 0.26 ha per farmer and this confirms that the study covered smallholder rice farmers where farms are basically managed by the family. It has been revealed also that the majority (63.04%) of the rice farmers cultivated on small farm size ranging between 0 and 0.25 ha. From what we have found on age and experience of rice farmers, it can be concluded that most of land cultivated is not rented from private persons. The price of land used reflected therefore the payments (for acquiring rights to exploiting the scheme) to the owner of the scheme, the SRDI society. Hence the average price of the land was found to be 41128 BIF/0.25ha and the average total land cost represents 1.82% of the total cost of rice production in the study area.

Table 2: Descriptive statistics of production levels and input variables for rice in Maramvya irrigation scheme

Variables	Minimum	Maximum	Mean	Std. Deviation
Quantity of Rice Produced (kg/ha)	546.34	6912.00	3547.00	1027.45
Land Cultivated (ha)	0.09	0.92	0.26	0.12
Quantity of Labour Utilized (man-days)	194.74	543.59	422.42	52.06
Quantity of Seed Utilized (kg/ha)	43.48	240.00	119.58	37.54
Quantity of Fertilizer Utilized (kg/ha)	100.00	800.00	377.71	124.71
Price of the Land (BIF/are)	8160.00	177000.00	41128.00	30567.52
Price of Labour (BIF/man-day/day)	2718.00	5832.00	4108.60	614.15
Price of Seed (BIF/kg)	690.00	10332.00	1011.40	622.41
Price of Fertilizer (BIF/kg)	960.00	2286.00	1307.50	128.33

The average labour used was 422.42 man-days per season from first tillage to packaging. Referring to the small size of land holding in the study area (0.26 ha/farmer), we can conclude that operations are too manual and require much labour. Furthermore, the share of total labour cost in the total cost of rice production per season represents 72.64% on average in the study area. This huge amount of labour cost in the total cost of rice production would reflect the fact that techniques for rice production are rudimental and rice farmers depend heavily on human labour to do farming operations.

Findings revealed that on average, the quantity of seed utilized is 119.58 kg/ha. This level of seed utilization is almost the double of what is recommended from SRDI (60 kg/ha). According to the information received from sampled farmers, the behavior is motivated by the fact that some plots are not well leveled and thus water for irrigation may not cover the whole plot surface. Also, some other plots are under normal ground level and rice crops may face floods during growing period. Other arguments from farmers are the fear of diseases and other impediments before rice reaching maturing. Hence rice farmers may pretend reducing yield risk in doing so.

Due to this mismanagement of seed input, it could be expected that farmers utilizing less seed input with regard to SRDI and other research stations recommendations, and who further do a close management of their farms, may be more efficient and hence we may observe an inverse relationship between quantity of seed and yield level. The price of seed was on average 1011.40 BIF/kg and the total seed cost was not important on average as it was on average 5.06% of total cost of rice production in the study area.

The level of fertilizer utilization was found to be 377.71 kg/ha on average in the study area. On contrast with seed use, it has been found that fertilizer input is underutilized in the study area. This is due to the lack of capital as the majority of rice farmers have no off-farm income (73.04% of total rice farmers) and reliable sources of credit that would enable them to reduce capital gap and buy enough quantity of fertilizers. From that observation, it could be expected that farmers using enough quantity of fertilizers yield more than those ones using small amount of fertilizers, and hence fertilizer input could be assumed to significantly influence rice yield level. The price of fertilizer was 1307 BIF/kg and it has been revealed that total fertilizer cost ranked second important cost (20.48% of total cost of rice production) after labour variable.

3.3 Post estimation tests

The maximum-likelihood estimates (MLE) of the parameters of the production and cost functions specified in equations (11), (13), and (15) were estimated using the computer program FRONTIER 4.1 by Coelli (1996). The results for parameter estimates are presented in Tables 3. Before we can infer from these results, post estimation tests for the fitness of models and existence of inefficiency effects in the variation of rice produced and total cost of production have been done for both production and cost frontiers.

Table 3: Results from estimation

Frontier Production Function				Frontier Cost Function			
Variables	**Parameters**	**Coefficients**	**t-ratio**	**Variables**	**Parameters**	**Coefficients**	**t-ratio**
Intercept	β_0	3.26***	13.38	Intercept	α_0	-0.14	-0.13
LnLand	β_1	0.41***	2.69	LnY	α_1	0.18***	5.08
LnLab	β_2	0.45***	3.07	LnLand Cost	α_2	0.56***	39.27
LnSeed	β_3	-0.11*	-1.83	LnLabCost	α_3	0.52***	6.70
LnFer	β_4	0.24***	4.34	LnSeed Cost	α_4	0.11*	1.92
				LnFerCost	α_5	0.09	0.78
Fitness of the Model							
Log-likelihood Function		-18.96		Log-likelihood Function		105.48	
Likelihood Ratio Test Statistic	LR	74.32***		Likelihood Ratio Test Statistic	LR	27.65***	
Variance Parameter for the Error Component							
Sigma-Squared	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.46**	2.14	Sigma-Squared	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.02***	10.15
Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.92***	23.78	Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.46	0.56

*, ** and *** Significant at 10%, 5% and 1% respectively

As presented in Table 3, the Likelihood Ratio (LR) test statistic (74.32) for the frontier production function is significant at 5% level of significance, implying that independent variables included in the model globally explain the production level in the study area. With respect to each variable included in the model, the coefficients associated with land, labour and fertilizer variables were all significant at 5 % level of significance whereas coefficient associated with seed variable was not.

From the cost function, the explanatory power of variables included in the model was proved as the LR test statistic (LR = 27.65) was significant at 5% level of significance. The coefficients associated with production level, price of land and price of labour were 0.18, 056 and 0.52 respectively and were all significant at 5% level of significance. However, coefficients associated with price of seed and price of fertilizer were insignificant at 5% level of significance. All coefficients associated will cost variables were positive, implying that the assumption of non-decrease of cost function in output and input prices was satisfied.

3.4 Derivation of elasticities

One of the advantages offered by Cobb-Douglas production function specification is that first order derivatives are straightforward conclusive and are interpreted aselasticities. Based on this argument, yield level elasticities with respect to each of input used for rice production in the study area are reported in Table 4.

Table 4: Derivation of input elasticities

Input	Elasticity
Land	0.41
Labour	0.45
Seed	-0.11
Fertilizer	0.24
Return to Scale (RTS)	**0.99**

From Table 4, elasticities of rice production level with respect to land, labour and fertilizer were 0.41, 0.45 and 0.24 respectively were positive and significant at 1% level of significance. This means that levels of utilization of these inputs were below the optimal levels and hence an increase in input use for the three inputs would yield positive quantities of rice produced. The elasticity of production with respect to land was 0.41 meaning that, at that level of significance, a 1% increase in areas of land used in the production of rice would lead to an increase of 0.41% kg in the mean rice produced, holding labour, seed and fertilizer inputs constant. The elasticity of production with respect to labour was 0.45. This implies that a 1% increase in man-days of labour used would increase the mean rice produced by 0.45% kg, holding land, seed and fertilizer inputs constant. The elasticity of production with respect to fertilizer input was 0.24 implying that at a 1% increase in kg of fertilizer applied would lead to 0.24% kg increase in mean rice produced, holding land labour and seed inputs constant.

Contrary to land, labour and fertilizer which have positive responsiveness to rice production increase, elasticity of production with respect to seed input was negative (-0.11) and statistically significant at 10% level of significance, implying that, at that level of significance, a 1% increase in kg of seed used will lead to a decrease of 0.11% kg in mean rice produced, holding land, labour and fertilizer inputs constant. The justification being the reasons already detailed in the section about input description, where rice producers were on average over-utilizing seed input if we refer to what was recommended by research stations. The negative relationship between seed input and quantity of rice produced implies that the better way of efficient use of seed input would be to reduce quantities that were applied at the period of study.

The above results demonstrated highest responsiveness of rice produced with respect to labour followed by land and fertilizer while seed increase impact negatively the quantity of rice produced. Labour and land are the major inputs in terms of output responsiveness. Concluding the assessment of rice productivity in the study area, results in Table 4 showed that rice production technology in the study area exhibits a decreasing positive return-to-scale (RTS = 0.99). This means that rice producers are producing in stage two of production process and hence were likely to be more or less technically efficient in allocating their resources even though they may not a 100% efficient.

3.5 Technical, Allocative and Economic Efficiencies estimation

With the aim of assessing the extent to which rice producers could raise their productivity and profitability if they efficiently use inputs, TE, AE and EE were estimated in order to state whether rice producers in the study area still have a room to expand their productivity and profitability. Before deriving these indices, an assessment of existence of inefficiency effect in the variation of rice produced and total cost in rice production was conducted.

From Table 3, the estimated value of gamma (γ = 0.92, the variance parameter) for frontier production function was significant at 5% level of significance which indicated that technical inefficiency effect had an influence on the variation of rice produced in the study area at that level of significance. In other words, the variation in rice produced in Maramvya irrigated scheme was 92% explained by failure of farmers to efficiently use inputs technically.

On the side of frontier cost function, the cost inefficiency effect has insignificant influence on the variation of the total cost of producing rice, if we consider a significance level of 5%. But since allocative inefficiency is indirectly derived from cost inefficiency by inverting the cost inefficiency index (Ogundari and Ojo, 2006), we may not directly capture the significance of influence of allocative inefficiency effect, unless we combine technical and allocative inefficiencies.

Since there was technical inefficiency effect and given that economic efficiency combines technical and allocative efficiencies as defined earlier, we were able to support the claim that rice producers in Maramvya irrigated scheme were economically inefficient. Following to the above conclusion, TE, AE and EE indices for each individual farm level were computed as follows:

Table 5: Summary of distribution of TE, AE and EE indices for rice production in Maramvya irrigated scheme

Score interval	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0.00 - 0.14	1	0.43	0	0.00	1	0.43
0.15 - 0.29	0	0.00	0	0.00	1	0.43
0.30 - 0.44	2	0.87	0	0.00	21	9.13
0.45 - 0.59	16	6.96	5	2.17	45	19.57
0.60 - 0.74	13	5.65	154	66.96	134	58.26
0.75 - 0.89	72	31.30	71	30.87	28	12.17
0.90 - 1.00	126	54.78	0	0.00	0	0.00
Total	230	100.00	230	100.00	230	100.00
Mean	0.82		0.71		0.58	
Std. Deviation	0.13		0.06		0.11	
Range	0.82		0.32		0.71	
Minimum	0.14		0.57		0.08	
Maximum	0.97		0.89		0.79	

From Table 5, mean TE was found to be 82% implying that on average, rice producers in Maramvya irrigated scheme could raise their production level about 18% if they adjust input efficiently. This finding is in consonance with findings by Ndayitwayeko and Korir (2012) who confirmed that there is a room to expand rice production. Mean AE was found to be 71% implying that rice farmers are not producing with minimal cost and indeed farmers still have to reduce their cost about 29% in order to be efficient allocatively.

Globally, the mean EE was 58%. This implies that rice producers in Maramvya irrigated scheme could raise their profitability about 42% in case they undertake efficient allocation of inputs with the existing technology at the time of the study. On average TE level was higher than AE and EE but showed a strong variation within sampled farmers, with a minimum level of 0.14 and a maximum of 0.97. This high level of TE compared to AE and EE was confirmed by decreasing RTS of 0.99 proving that rice farmers were likely to be technicaly efficient compared to allocative and economic efficiency. These results are consistent with those reported by Battese and Coelli (1996), Ogundari and Ojo (2006), Le Quang Long *et al.* (2013) and Magreta*et al.* (2013) where it is revealed that rice farmers are more likely technically efficient than they are allocatively or economically.

3.6 Assessment of factors affecting efficiency levels

The results for this assessment are important to be able to determine which factors are key for productivity improvement. Table 6 summarizes results on determinants of economic efficiency levels among sampled farmers.

Table 6: Results for estimation of inefficiency model

Variables	Parameters	Coefficients	t-ratio
Intercept	δ_0	0.6869^{***}	17.31
Age	δ_1	-0.0017^{**}	-2.04
Sex	δ_2	0.0046	0.31
HHsize	δ_3	-0.0025	-1.33
Off – farm	δ_4	0.0029	0.21
Adult	δ_5	0.1105^{***}	5.91
Prim	δ_6	0.0573^{***}	3.55
Second	δ_7	0.0602^{***}	3.04
CredAcc	δ_8	-0.0535^{***}	-3.80
Exp	δ_9	0.0010	1.20
Irrig	δ_{10}	-0.1285^{***}	-6.93
F Statistic	**10.10^{**}**		
R-Squared	**0.36**		

*, ** and *** Significant at 10%, 5% and 1% respectively

Results from estimation of the inefficiency model showed that the model is globally significant at 5% level of significance since F test statistic (F = 10.10) is greater than critical value at that level of significance. However low R – Squared (R^2 = 0.36) indicated that socio-economic variables included in the model are far from being able to explain the total variation of efficiency levels among rice farmers in the study area and hence further studies are needed to determine other potential factors influencing efficiency levels in the study area.

The coefficients associated with levels of education of the farmer were positively significant at 5%. This means that attainment of education level, whether adult, primary or secondary, would improve positively the efficiency level of rice producers in Maramvya irrigated scheme. That finding was consistent with what was expected as long as farmers who are educated are more likely to have ability to adapt new techniques, but also rice production operations are so many and need minimum recording of information concerning production process form first tillage to storage of rice produced. Therefore, rice farmers with no minimum education are likely to be inefficient in managing their farms.

Age, access to credit and the shortage of water for irrigation with coefficients -0.0017, -0.0534, -0.1285 respectively were found to negatively influence efficiency levels among rice producers at 5% level of significance. Given age distribution of rice farmers which revealed that farmers were above their active age, this was consistent with what was expected as long as farmers may not have enough force to manage their farms and for this reason, younger farmers are likely to be more efficient than old ones. Access to credit also was expected to negatively influence efficiency levels because farmers with access to credit are likely to miss behave in allocating their budget to input resources, compared to those ones with no access to credit, indeed whom are more budget constrained because of lack of enough capital. Shortage of water for irrigation obviously harms efficiency since water is premier condition for rice growing.

Other factors like sex of the farmer, off-farm income earning and experience in rice growing were found to positively influence efficiency levels in the study area, but their influence was not significant at 5% level of significance. For sex variable, being male is found to be an advantage to the farm. That interpretation holds also for experience of farmers, where more experienced farmers are in a better position of understanding and integrating agricultural innovations and apply more rapidly new techniques. The influence of household size was insignificant at 5% level of significance, but with a negative impact on the level of efficiency. This was in sentence with our expectation because a big number of family members would lead to a big amount of charges, especially in the study area where we have found that most of farmers relied on on-farm income and where family labour was less employed on family farms.

4. Conclusion and Recommendation

4.1 Conclusions

This study aimed at estimating the extent to which farmers in Maramvya irrigated scheme could raise their productivity and profitability if they efficiently adjust inputs use. In that purpose, output responsiveness with respect to the level of inputs use is examined and TE, AE and EE are estimated. Factors affecting efficiency levels among rice farmers are determined as well.

Firstly, we had a specific objective of assessing output responsiveness with respect to each input used to produce rice in the study area. In that perspective, elasticities were estimated. Land, labour, seed and fertilizer elasticities were 0.41, 0.45, -0.11 and 0.24 respectively and put aside seed elasticity which was negative and insignificant at 5% level of significance, the three other input were found to positively explain rice production level at 5% level of significance. This means that levels of utilization of these inputs (land, labour and fertilizer) were below the optimal levels and hence an increase in input use for the three inputs would lead to an increase in rice production. Results demonstrated highest response of rice produced with respect to labour followed by land and fertilizer came at the last position while seed increase impact negatively the quantity of rice produced. Furthermore, results demonstrated that rice production process in the study area exhibits a decreasing positive return-to-scale (RTS = 0.99) and this means that rice producers were likely to be more technically efficient in allocating their resources even though they were not a 100% efficient, for instance seed input was over-utilized. Land and labour inputs being more responsive of rice production in the study area and referring to the small size of land holding in the study area (0.26 ha/farmer) where farmers used huge amount of labour with a share of total labour cost in the total cost of rice production representing 72.64%, this would reflect the fact that techniques for rice production are rudimental and rice farmers depend heavily on human labour to do farming operations.

Secondly, we had a specific objective to estimate TE, AE and EE indices to be able to determine whether rice farmers in Maramvya irrigated scheme are economically efficient or not. Findings revealed that there was an inefficiency effect in the variation of rice produced at 5% level of significance. On average, TE, AE and EE indices were 0.82, 0.71 and 0.58 respectively and it implies that rice producers were more likely to be technically efficient than they are allocatively or economically. Hence rice producers in Maramvya irrigated scheme could raise their profitability about 42% by efficiently adjusting inputs with the existing technology at time of the study.

Thirdly and finally, we had a specific objective of assessing socio-economic characteristics affecting efficiency levels in Maramvya irrigated scheme. Findings revealed that attainment of any education level, whether adult, primary or secondary, would improve positively the efficiency levels of rice producers in Maramvya irrigated scheme at significance level of 5%. This implies that farmers who are educated are more likely to have ability to adapt new techniques, but also rice production operations are so many and need minimum recording of information concerning production process.

Age, access to credit and the shortage of water for irrigation were found to negatively influence efficiency levels among rice producers at 5% level of significance. Age distribution of rice farmers revealed that farmers were above their active age and this was consistent with what was expected as long as farmers may not have enough force to manage their farms and for this reason, younger farmers are likely to be more efficient than old ones. Access to credit also was expected to negatively influence efficiency levels because farmers with access to credit are likely to miss behave in allocating their budget to input resources, compared to those ones with no access to credit whom are more budget constrained because of lack of enough capital. Shortage of water for irrigation was found to be harmful on efficiency level since water is premier condition for rice growing.

Other factors like sex of the farmer, off-farm income earning and experience in rice growing were found to positively influence efficiency levels in the study area, but their influence was not significant at 5% level of significance. For sex variable, being male found to be an advantage because it would enhance efficiency level. That interpretation holds also for experience of farmers, where more experienced farmers are in a better position of understanding and integrating agricultural instructions and adopt more rapidly new techniques. The influence of household size was insignificant at 5% level of significance, but with a negative impact on the level of efficiency. This was in sentence with our expectation because a big number of family members would lead to a big amount of charges, especially in the study area where we have found that most of farmers relied on on-farm income and where family labour was less employed on family farms.

4.2 Recommendation

With regard to findings of this study, the following recommendations have been formulated to rice producers, Government and SRDI which is the owner of the scheme but also some further studies are recommended.

Firstly, being revealed that increase in rice production was highly depending on land use and labour utilization, the implication is that rice production technology was rudimental and the exploitation was family based. It could be recommended to rice producers to apply new technologies for instance intensification of fertilizer use. Farmers should implement recommendation from extension department, for instance adjust seed use to what is recommended from experimental stations.

Secondly, the study revealed that there is a 42% room to expend rice productivity and profitability in Maramvya irrigated scheme. But some factors impacting efficiency levels may be exogenous to rice farmers' capability as socio-economic characteristics explained only 36% of variation of efficiency levels. Government and stakeholders involved in rice production increase should focus their intervention on permanent extension services aiming at acquiring of new skills in rice production techniques. In the long run, the Government should focus on education as it improves significantly efficiency in rice production. Furthermore, missuse of seed was due mostly to the fear of shortage of water because some plots were not well leveled. Intervention should be made by SRDI to maintain canals for irrigation because the cost of maintenance would be probably beyond farmers' capacity. Input market and input availability is also a task to be performed by Government and policy makers in order to reduce the production cost.

Lastly, the study recommends further studies on the following:

(i) The technical, allocative and economic gaps were found to be 18%, 29% and and 42% respectively. It can be assumed that other types of gaps may exist for instance scale inefficiency (technology restriction that is constant or non-constant return to scale – findings revealed a relatively constant return to scale), structural inefficiency referring to how an industry keeps up with its performance of best practice (van Dijk *et al.*, 2016) and inefficiency due to motivation, information, monitoring, and agency problems within the firm, the so called "X-inefficiency" by Leibenstein (1966). Further studies are needed to disentangle all these types of gaps in rice production.

(ii) $R^2 = 0.36$ for the inefficiency model is small implying that other studies should investigate other factors that are not included in the model that may influence efficiency levels among rice producers in Maramvya irrigated scheme.

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