Determinants of Technical Efficiency in Rice Production in Gihanga (Burundi) Irrigation Scheme: A Stochastic Production Frontier Approach

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Abstract

This paper estimated the technical efficiency of rice production under irrigation system in Gihanga, Burundi and attempted to unravel the determinants of technical inefficiency. A Cobb-Douglas stochastic frontier production function was used. The study showed that the average of technical efficiency was 73%. This meant that technical inefficiency of 27% constituted a challenge to overcome by the rice producers in Gihanga. According to Cobb-Douglas model, inorganic fertilizer and pesticide applications showed significant positive and negative effects on production function respectively. The inefficiency model revealed that technical efficiency increased significantly as result of experience but decreased with age of rice producers. There was room to expand rice production through appropriate farmers' training and timely pesticide delivery. Besides, the extension service should be aware of the experienced farmers as a resource with potentials to train the less experienced ones and focus their attentions on the aged farmers.

Key words: Rice production, technical efficiency, irrigation and stochastic frontier production

Introduction

Introduced in Burundi in 1960's, rice ranks third cereal produced behind maize and sorghum. It is mostly grown in the three provinces of Burundi; *inter alia*, Kirundo and Muyinga under rain-fed system and Bubanza under intensive irrigated production system. . The rice sector is challenged by three issues. First, the country has an ambition to turn rice into an import-substitution food as underlined in the country's strategy plan of 2008-2015

(GoB, 2008). This may be possible if Burundi achieves self-sufficiency objective in rice production.

Second, there is perennial food insecurity in the rice producing areas, that is, the north-west and northern parts of Burundi. The population growth and poverty have been singled out as the major determinants of food insecurity. In fact, the annual population growth in 1999 was 1% and jumped to 3% in 2008. Although the research stations have introduced high yielding varieties of rice, causing the trend of production to shoot up upwardly since 2000 (Ndayitwayeko, 2011), this did not meet the increasing demand for this commodity.

Third, once Burundi joined the East Africa Community (EAC) in 2008, much attention has been concentrated on its level of competitiveness in this regional block as well as the performance of its trade reforms. Many argue that being a member of EAC may threaten the economic growth of its industrialization, currently at its infant stage; while others support the idea of integration as the only opportunity of improving the efficiency of its production sector through competitiveness. The recent agreement on EAC common market and the trade liberalisation have resulted in massive food imports that may weaken the agricultural production capacity and in the long-term may cause poverty to farmers in general and rice producers in particular. This has been evidenced by many authors (Rusastra, *et al.*, 2008, and Kang *et al.*, 2009). Therefore, improving rice technical efficiency (TE) and quality may assist this sector to fulfil the government goal and be more competitive in the EAC region as well as in the entire Africa. TE is the ability to derive the greatest amount of output possible from a fixed quantity of input (Tijani, 2006).

The objective of the study was to estimate the technical efficiency of the rice producers in the largest irrigation schemes of Burundi and to derive the socio-economic determinants that impact on the production efficiency. The following section gives the brief of discussion on theoretical and analytical framework of the technical efficiency as well as the methodology and data. Section 3 and 4 present the results and discussion of the study. The final section ends with the conclusion of the main results and policy implication.

Materials and Methods

The main data source came from the survey of University Research Centre of Social and Economic Development (CURDES) done at the end of 2009. It was carried out in Gihanga located in the province of Bubanza (Northern-

West of Burundi), where SRDI-Rice (a parastatal company) initiated a scheme by which rice producers were supplied both agricultural inputs 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.

The region has a mean altitude of 1000 m with a mean rainfall of 900 mm and temperature ranging between 24°C and 28°C. It is located in the agro-ecological zone of Imbo which is dominated by divide of Nile and Congo watersheds rising to about 2660 m from which more than 6 rivers flow toward the Imbo plain where the most fertile sols of Burundi are found. A systematic random sampling procedure was used to select 125 farmers from the irrigation scheme zone. By the use of a structured questionnaire, data collected were mainly on the rice production and techniques used in improving the productivity of rice. Moreover, a series of socio-economic data were also collected. The analysis was done by the use of STATA version 10.

Empirical Model

The literature on the economics of rice production in Burundi is very scant at best. This is due to the fact that much research was concentrated on agronomic area, specifically on improving the varieties of rice. This study was based on the theory of efficiecy which has a long and rich history dating back to the 1950's. The efficiency of a firm is the ability to produce the greatest amount of output possible without varying its costs or from a fixed amount of inputs. The modern measurements of efficiency is provided by Fare *et al.* (1985, 1994), Battese (1992), Lovell (1993), Green (1999) and Kumbhakar and Lovell (2000).

There are two types of measurements: parametric (Stochastic Frontier Production - SFP) and nonparametric (FDH=Free Disposal Hull and DEA= Data Envelopment Analysis) efficiency measurement. This research followed the parametric or Stochastic Frontier Production (SFP) function that uses the one step-approach developed by Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991). This approach corrected the 2 step-approach that suffered the drawback residing in the fact that in its first step, inefficiency effects (u) are assumed to be independently and identically distributed. The one step-approach uses the maximum likelihood procedure in order to estimate all the parameters in the model.

There is a large empirical literature on stochastic frontier production function. For instance, Msuya and Ashimogo (2005) applied it in sugar cane production and found a significantly positive relationship between technical efficiency and some exogneous variables like age, education and experience. Besides, Mkhabela (2005) revealed the technical efficiency of 84.32% in vegetable based cropping systems. Kuria *et al.* (2003) and Nchare (2007) used it in rice production and coffee production respectively. . This study was different from the above in that it combined both endogenous and exogenous socio-economic variables in order to unveil the degree of technical efficiency in rice industry in Burundi.

The stochastic frontier production function indicates the existence of technical inefficiency of production of firms (Battese and Coelli, 1995; Kumbhakar and Lovell, 2000). It presents a production function of the standard regression model but with a composite disturbance term equal to the sum of the two errors components (Aigner *et al*., 1977 and Meeusen and Van den Broeck, 1977). It is defined by the following equation:

$$\text{Ln } Y_j = \text{Lnf}(X_{ij};\beta) + v_j - u_j \quad (1)$$

$$u_j = \delta z_j + \varepsilon_j \quad (2)$$

Where Ln Y_j is the logarithm of output of the jth farm, Ln Xij is logarithm of the vector of quantities of factors of production i used by the farm j, β and δ is a vector of unknown parameters, z_j is a vector of explanatory variables associated with the technical inefficiency effects and ε_j is an unbsorvable random variables, which are assumed to be identically distributed, $v_j - u_j$, where v_j is a stochastic variable with a zero mean and unknown variance σ_v^2 and u_j is the non negative stochastic term representing the technical inefficiency in production of farm j; its mean is m_j and its variance is σ_u^2. Two equations (1) and (2) are usually simultaneously estimated by maximum likelihood method following different parameterizations such as those of Battese and Cora (1977), Battese *et al.* (1988) and Battese (1992) defined as:

$$\text{Ln (L)} = -\frac{N}{2}\left(Ln\left(\frac{\pi}{2}\right) + \ln\sigma^2\right) + \sum_{j=1}^{N}\ln\left[1 - \Phi\left(\frac{\varepsilon_j\sqrt{\gamma}}{\sigma\sqrt{(1-\gamma)}}\right)\right] - \frac{1}{2\sigma^2}\sum_{j=1}^{N}\varepsilon^2 \quad (3)$$

Then, the technical efficiency of production for jth farm can be depicted in the conditional expectation as follows:

$$TE_j = \exp(-u_j) = \exp(-\delta - z_j - \varepsilon_j)$$

In this study, the Cobb-Douglas logrithmic function was adopted because its virtues of being simple and commonly used (Bravo-Ureta and Evenson, 1994 and Mkhabela, 2005).

The model used in this paper depicted in the following equation:

$$\text{Ln Lnprodq} = \beta_0 + \beta_1 \text{Lnfertilizer} + \beta_2 \text{Lnseedq} + \beta_3 \text{Lnlabor} + \beta_4 \text{Lnpesticide} + \beta_5 \text{LnIRR} + V_j - U_j \quad (4)$$

Where subscript j means jth farmer, $prodq_i$ = output of rice (kg/ha), Fertilizer = Quantity of fertilizer use (kg/ha), seedq = Quantity of seed (kg/ha), labor = Amount of Human labor-family and hired labor aggregated (Human day/ha), pesticide = litre/ha, IRR = any shortage of water for irrigation (0 = No and 1= yes), V_j-U_j = error term and from β_0 to β_5 are the parameters to be estimated.

Although the estimation of the technical efficiency of farmers is of a paramount importance in farm production, it is only regarded as the necessary condition of agricultural production diagnostics. A sufficient condition will be to detect the socio-economic determinants of technical efficiency between farmers in order to make recommendations to economic policies. The regression model that gives the estimation of the determinants is the following:

$$U_j = \alpha_0 + \alpha_1 \text{Age} + \alpha_2 \text{FarS} + \alpha_3 \text{OffFar} + \alpha_4 \text{Educ} + \alpha_5 \text{FarmExp} + \alpha_6 \text{Extser} \quad (5)$$

Where: age (years), FarS = Farm size (hectares), OffFar = Off-farm Income (1= off-farm income, 0= no off-farm income), Educ = Education of household head (years), FarmExp = Farm Experience (years), Extser = Extension service contact (1= contact, 0= no contact).

The stochastic frontier estimation chosen in this study was the truncated-normal distribution with truncation point at 0 rather than the half-normal normal distribution. Since the latter is the arbitrary choice due to lack of a priori justification for selecting the particular distributional form for the technical inefficiency effects. It has a mode at zero, which means that there is a high probability that the inefficiency effects are in the neighborhood of zero. Moreover, Kumbhakar and Lovell (2000) conveyed that the truncated normal distribution, with a non-zero mode, contains an additional parameter μ to be estimated. For this virtue, this paper adopted the truncated-normal distribution model in which the idiosyncratic component is assumed to be independently and normally distributed $N(0, \sigma_v)$ over the observation.

Results and Discussions

The description of the variables is presented in table 1.

Table 1: Description of variables

Variables	**Mean**	**Stand. Dev.**	**Min**	**Max**
Yield (Kg/ha)	4157.63	1598.01	1000	12000
Seed (Kg/ha)	105.10	14.15	60	160
Labor (MD/ha)	202.04	195.54	3.87	1046
Fertilizer (Kg/ha)	221.58	104.87	10	608.33
Pesticide (litre/ha)	7.62	4.71	1.2	30

Source: Authors' calculations

The yield of rice is 12% and 5% less than that of Kenya (4704 kg/ha, FAOSTAT 2009 database) and Rwanda (4395.6 kg/ha, FAOSTAT 2009 database) respectively. The institutions responsible for the performance of rice sector are ISABU (National Research Agronomy of Burundi) and SRDI-Rice (Imbo Regional Development-Rice Board) which provide both high yielding varieties, the essential agricultural inputs, irrigation technology, services on credit and market (Ndimanya and Ndayitwayeko, 2009). However a wide range of yields and inputs application as shown in table 1 may be due to the differences in farmers' resource applications and wealth.

Factors Affecting Technical Efficiency

Variables	**Parameter**	**Coefficient**	**Stand. Dev.**
Constant	β_0	8.61*	1.24
Ln fertilizer	β_1	0.20*	0.07
Ln seedq	β_2	0.25	0.25
Ln labor	β_3	-0,08	0.05
Ln pesticide	β_4	-0.23*	0.08
Irr	β_5	-0.54	0.08
Inefficient Effect model			
Constant	α_0	16.02*	6.58
Age	α_1	0.29**	0.15
Farm size	α_2	0.03	0.02
Off-farm income	α_3	0.50	2.18
Education	α_4	-0.29	-0.77
Experience	α_5	-0.04*	-2.54
Extension service	α_6	1.75	0.79
Variance Parameters			
Mu = -1.24, ilgtγ = 1.2, $\sigma^2 = 0.43$, $\gamma = [\sigma^2/(\sigma_u^2+ \sigma_v^2)] = 0.77$, 20, $\sigma^2_u = 0.33$, $\sigma^2_v = 0.33$, $\ln\sigma^2 = -0.83$			

***Note:** - * and ** Significant at 0,01and 0.05 level of significance respectively;*
Source: Authors' calculations

Maximum Likelihood estimates and OLS regression are presented in table 2. The estimated coefficients of five inputs are shown in the first part of the table. Chemical inputs such as fertilizer and pesticide emerged to be the variables that impact significantly on rice production in the SRDI rice scheme. Their coefficients are significant at 0.01% level. Fertilizer presents a positive value of 0.20. This means that the increment of fertilizer by 1% will increase output by 20%. This result is in agreement with that of Kuria *et al.* (2003). The pesticide used in rice disease controlling showed a negative value. A 1% of increase of application of pesticide will decrease the rice production by 23%. The pesticide is applied by the agents of SRDI once for all plots of rice in order to control specifically the notorious rice blast called *pycularia oryzae* disease. The negative and unexpected sign of pesticide signals that this chemical input may have been under- or over-utilized in rice disease control. It may be true also that a change in pest control options available to the users would bring a positive result. The buck stops with the SRDI that should monitor the application of this input by its agents since pesticide was expected to reduce losses due to pests and labor required to pest control. Hence, it allows the productivity of rice to increase (Fernandez-Carnejo, *et al.*, 2009). A further study is this area is required.

In the inefficiency effect model, only the age and experience of farm affect significantly the level of rice production. The former (age) showed a negative sign indicating that the older the farmer the less efficient. In contrary, the positive sign of experience meant that more experienced farmers tended to more efficient. The output of the inefficiency effects model reveals that the variance parameter *mu* is not statistically significant indicating the inefficiency is not part of the production processes of the farmers under consideration. The γ whose the optimization is the parameterization in terms of the inverse logit of γ or ilgtgamma as appeared on the output worksheet is high enough to be about 77%. This indicated that total variation captured by sigma squared (here 33%) is as result of the technical inefficiency in production processes of farmers under consideration while 23% may be attributed to the stochastic errors.

Frequency distribution of technical efficiency (TE)

Technical efficiency (%)	Rice Farms	Percentage
TE < 61	16	13
61 ≤ TE < 73	29	23
TE ≥ 73	80	64
Mean efficiency (%)	73.35	
Min. efficiency	25.44	
Max. efficiency	92.89	

Source: Authors' Calculations

Technical efficiency estimated shows that the average oriented-output efficiency score across all models for all farmers is approximately 0.73, which implies that on average the rice output produced is 73 percent of the frontier output, that is, an increase by 27 percent is possible through a more effective use of the input bundle given the present state of technology and above all an efficient practice of the agricultural husbandry of the particular rice variety planted.

Since price setting is unilateral and does not respect the normal trend of input market, the farmers end up paying a high price in order to access these crucial inputs for rice growing. Inputs are given on credit which is recovered during purchasing rice from the same farmers. The inefficiency in inputs allocation may be due to high prices of these inputs. This means that even if SRDI has given enough chemical fertilizer to the farmers, it intends to make it affordable so that farmers may use it efficiently. It is evident that if the cost of fertilizer is very high, it may impact of the farmers' income and therefore it is considered as a great source of desincitive for crop production. Other researchers that have evidenced the positive impact of fertilizer on the agricultural production are Khan *et al*. (2010) and Dlamini *et al.* (2010).

The estimated determinants in the inefficiency model are of particular interest in this study. The experience of farmers reduced the technical inefficiency. This may be due to the managerial skills that they learnt over time from both SRDI and ISABU (Institute of Agronomic Sciences of Burundi, a public research centre) agents. The latter should be aware of the experienced farmers as a resource with potential to train the less experienced. This is in consistence with the study of Khan *et al.* (2010). However, a higher age appeared to impede the technical efficiency. The age is regarded a proxy for risk aversion. As it has been evidenced by Nicholson *et al.* (1998), the older the farmers, the more conservative they are and their higher cultural values reduced the probability of the adoption on new technology. Hence, it is desirable that strategy and new approaches to reach out to these types of farmers be employed.

Conclusion and Policy Implications

The study aimed at estimating the technical efficiency scores and the factors affecting such efficiency. One identical model was estimated using the stochastic frontier approach. The technical efficiency of 0.73 was found for 125 farmers engaged in rice production in Gihanga rice irrigation scheme. Fertilizer, pesticide, age and experience are the determinants highly significant to explain the inefficiency. Only pesticide gives the unexpected result. This suggests a further study on optimal pesticide use.

The two major implications that emerged out of this study were that there is still room for the improvement of technical efficiency in rice production in Burundi. Farmers can take advantage on the scale economies through the increasing economies of scale. Care training is recommended in regard to the optimal use of pesticide to control rice blast. Besides, the producer's experience is the major variable through which rice production promoters may rely on during extension services and agricultural techniques demonstrations. Extension service agents are recommended to use appropriate approaches in order to relax the age constraint that impedes the technical efficiency in rice production. Given the technical inefficiency of 27%, the potential of expanding rice production is relative high if the government and other related institutions pay more attention to this sector.

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