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Economic Analysis of Factors Affecting Technical Efficiency of Smallholders Maize Production on Rwanda

N. Mulinga, Department of Agricultural Economics and Agribusiness, Faculty of Agriculture, National University of Rwanda,
Correspondance e-mail: mulinga2@yahoo.fr

Abstract

This study was conducted in Musanze and Bugesera districts of Rwanda .The objective were to estimate the level of technical efficiency in maize production. The study also attempted to determine some socio-economic characteristics which influence technical efficiency in maize production. It used primary and secondary data.

Primary data were collected using questionnaire from random sample of 276 farmers, and it covered the socio-economic characteristics of farmers. Secondary data were collected from different sources, e.g., Ministry of Agriculture and livestock, records, books, reports and internet. The Stochastic Production Frontier (SPF) analysis was used to estimate the technical efficiency of producing maize, and to determine the factors behind inefficiency such as age, educational level, marital status, family size, main occupation, type of seeds, and extension services. Also, descriptive statistics were used to analyze the socio-economic characteristics of farmers.

The results indicated that the mean technical efficiency for maize production in both districts is 27% which means that farmers can increase their output by 34%, through better use of available resources and existing technology if they are to be technically efficient.

The study concluded that age, educational level and access to credit were significant variables leading to technical inefficiency in Rwanda. On the other hand, marital status, family size, main occupation, type of seeds, and extension services, had no significant impact on farmers' inefficiency. To improve technical efficiency for maize production in the Rwanda, the study recommended improvement in education level of the farmers and availability of funds in the optimum time.

***Key words**: maize Productivity; Technical efficiency; stochastic frontier production*

Introduction

Agriculture is a significant sector in Rwanda economy. The sector plays a significant role in food security, poverty alleviation and human development chain. However, in more recent years, the agricultural sector is characterized by marked deterioration. Maize is one of the major staple crops in Rwanda grown on large land.

Favorable ecological conditions in the two districts of Bugesera and Musanze contributed to the production of the maize. Increasing productivity requires efficient utilization of scarce resources. However, there could be intervening variables which may hinder to the realization of this objective. Despite efforts made at improving maize production over the years, the problem of low productivity remains a major challenge resulting from inefficient use of resources, inadequate supply of quality seed, low output prices, lack of adequate extension and inadequate financial resources. Now the question arises: how can we increase the maize production in Rwanda, and especially in Musanze and Bugesera Districts?

An approach that can be used to answer this problem is the efficient utilization of scarce resources. This study focused on two questions: first, if farmers are technically efficient in maize production and second, what factors determine their level of efficiency? Answers to these two questions provide an answer on how we can assist maize growing farmers to be more efficient in allocating the resources employed in maize production. One of the challenges facing Rwanda today is to produce enough food to feed the nine million people, majority of who are smallholder farmers with limited inputs.

Since increased productivity is directly related to production efficiency, it is imperative to raise productivity of the farmers by helping them reduce technical inefficiencies. This could be achieved by investigating the nature of resource productivity and efficiency in production of the farmers. Therefore, there was need to examine the technical efficiency of maize production in Musanze and Bugesera Districts and factors affecting technical efficiency.

Methodological Framework

The stochastic frontier model which enables one to measure farm level technical and economical efficiency using Maximum Likelihood Estimation (MLE) a Correction of Ordinary Least Square (COLS). A stochastic model originally was pioneered by Aigner and Chu (1968) who proposed a composed error term. Building on the work of Aigner and Chu (1968) a stochastic frontier model was developed (Aigner, et al., 1977, Meeusen and van den Broeck, 1977, Battese and Corra, 1977). Following the specification stochastic production frontier can be written as:

$$Y_i = f\left(x_i, \beta\right) e^{\varepsilon_i} \qquad i = 1, 2, \ldots\ldots\ldots\ldots N \qquad (1)$$

where y_i is the yield of maize for the i-th farm, x_i is a vector of k inputs (or cost of inputs), β is a vector of k unknown parameters, ε_i is an error term.

The stochastic production frontier is also called "composed error" model, because it postulates that the error term ε_i is decomposed into two components: a stochastic random error component (random shocks) and a technical inefficiency component as follows:

$$\varepsilon_i = v_i - u_i \qquad (2)$$

The model used in this paper is based on the one proposed by Battese and Coelli et al., (1995) and Battese et al., (1996) in which the stochastic frontier specification incorporates models of technical inefficiencies effects and simultaneously estimate all the parameters involved in the production function. The stochastic production frontier functional form which specifies the production technique of the farmers is expressed as follows:

$$Y_i = f(x_i; \beta) \exp v_i - u_i \qquad (3)$$

Where Y_i represents the value of output, which is measured in Rwanda francs (Fws), x_i represents the quantity of input used in the production, v_i represents random errors assumed to be independent and identically distributed N(0, σ_v^2) and u_i represents the technical inefficiency effects assumed to be non-negative truncated of the half-normal distribution N(μ, σ_u^2).

The truncated-normal distribution is a generalization of the half-normal distribution.

It is obtained by the truncation at zero of the normal distribution with meanμ, and variance, σ_u^2. If μ is pre-assigned to be zero, then the distribution is half-normal. Only three types of distributions are considered in stata i.e. half-normal, exponential and truncated-normal distributions. The two error components (v and u) are also assumed to be independent of each other. The variance parameters of the model are parameterized as: $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$; $\gamma = \frac{\sigma_u^2}{\sigma_s^2}$ *and* $0 \le \gamma \le 1$ (4)

The parameter γ must lie between 0 and 1. The maximum likelihood estimation of equation (1) provides consistent estimators for the β, γ, and σ_S^2 parameter, where, σ_S^2 explains the total variation in the dependent variable due to technical inefficiency (σ_u^2) and random shocks (σ_v^2) together.

The technical efficiency of individual farmers is defined in terms of the ratio of the observed output to the corresponding frontier output, conditional on the level of input used by the farmer. Hence the technical efficiency of the farmer is expressed as:

$$TE_i = Y_i / Y_i^* = f(x_i;\beta)\exp(v_i - u_i) / f(x_i;\beta)\exp v_i = \exp(-u_i) \quad (5)$$

Where Y_i represents observed output and Y_i^* represents frontier output. Farrell's measure of technical efficiency (TE_i), takes a value between zero and one. It indicates the magnitude of the output of the i th farm relative to the output that could be produced by a fully-efficient farm using the same input vectors.

Research design

The study used both primary and secondary data. Primary data was gathered from farmers through face-to-face interviews using multi-stage and pre-tested questionnaires. A multi-stage questionnaire was used to collect primary quantitative data in the selected households through a household survey. Secondary data was obtained from the internet, published books and journals, and records of Ministry of Agriculture, Rwanda. Data was collected on socio-demographic factors such as age, gender, level of education, access to credit, land size, family size, experience, participation in extension services, membership to farmers Associations/Cooperatives societies and number of livestock in the farm area.

Sampling Procedure

The target population of this study was smallholder farmers involved in maize farming in each district. And the sample in one district was calculated by using Edriss, (2003) formula.

This means that for the whole study the primary data was collected using questionnaires from a random sample of 276 farmers growing maize.

Data analysis procedure

The data on characterization was analyzed using Stata to obtain the maximum likelihood estimates of parameters. Multiple regression analysis was used for the first objective which is to determine the relationship between maize yield and the farm's social economic variables. Multiple regression analysis was carried out with the use of Stata software to determine the relationships between farm yield and the various farm characteristics (explanatory variables). The specification model was as follows:

$\mu_i = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \epsilon$

Where

μ_i : Inefficiency effects
α_0 : Intercept term
Z_1 : Education level of household head
Z_2: Experience measured in years in maize production
Z_3: Credit access, Dummy variables(1=has access 0 = otherwise)
Z_4 : Age of maize growing farmer (years)
Z_5 : Family size (numbers)
Z_6 : Total farm area operated by the maize grower (ha)
Z_7 : Gender of household head 1=male,1famale
ϵ : Random error

To determine the technical efficiency which was the second objective, the study utilized stochastic production frontier which builds hypothesized efficiency determinants into the inefficiency error components (Coelli and Battese 1996). A Cobb-Douglas production function was specified and presented as below:

$$\ln Q_i = \ln \alpha_0 + \alpha_1 \ln AREA_i + \alpha_2 \ln LABOUR_i + \alpha_3 \ln FERTi + \alpha_4 \ln SEED_i + v_i - u_i$$

Where Stochastic CD production Frontier Model

$\ln Q_i$:	ln of maize output (Kgs)
lnAREA :	ln of total area grown to maize (ha)
lnLABOUR :	ln of amount of labour, family and hired labour per hectare (man days)
ln FERT :	ln of total fertilizer used (kg)
ln SEED :	ln of total Seed used (kg)
α_0 :	inefficiency effect
u_i and V_i :	the random error

Results and Discussions

A two step process of the Stochastic Frontier Approach was used to estimate TE using the maximum Likelihood method.

Stochastic Production Function and Sources of Technical Efficiency

Table 1 shows most variables are statistically insignificant. However, lambda λ (the variance parameter showing the ratio between the normal error term and half normal positive error term) is statistically significant. This is evidence that there are measurable inefficiencies in maize production probably caused by differences in socio-economic characteristic of the households and their management practices.

Data are also analyzed using Cobb-Douglas production functions. Table 2 shows results of the stochastic frontier model from their efficiency .The results shows that results of the input elasticities for each input in the Cobb-Douglas production function. A one percent increase in the quantity of fertilizer applied increase maize output by 1.5 percent. In addition, a one percent increase in seed rate increased output by 4.1 percent. On the other hand, a one percent increase in labor will probably increase maize yield by one percent.

The study shows that yield has the highest responsiveness to seed, followed by fertilizer and labor. The results showed that the yield never responds to the land size and this explained that the most of Rwandan land is the same in the study area.

The most efficient producers (technical efficiency greater than 74 percent) use more inputs than producers who are technically less efficient. Table details input use across various levels of technical efficiency. The technically efficient producers have the highest average yield of 9.2 tones per ha. They use the following combination of inputs: 28 kilograms of fertilizer per ha, 48 kilograms of maize seed per ha and 40 person-days per ha.

However, though efficient, they still use input below the recommended rates. For example, the amount of fertilizer used by the most efficient farmer is slightly below the recommended rate of 25 kilograms per ha. On the other hand, the quantity of seed used is slightly below the recommended rate of 25 kilograms per ha.

Table 1: Maximum likelihood estimation of the production frontier with inefficiency model (dependent variable: ln maize)

Variables	coeff.	S.E	t	P>|t
Ln fertilizer (kg)	1457148	0265474	5.49	0.000
Ln seed (kg)	4057468	0250929	16.17	0.000
Ln labor (man-days)	0606445	0186678	3.25	0.001
Ln land (ha)	-.0299756	0440445	-0.68	0.496
Log likelihood	-41.278321			
Wald chi2(4)	16728.84			
Prob > chi2				0.0000
lnsig2v	-2.537666	4515.252	-0.01	0.993
lnsig2u	-38.44656	4515.252	-0.01	0.993
sigma_v	.2811596	0119887		
sigma_u	4.48e-09	0000101		
σ^2	0790507	0067415		
Lambda	1.59e-08	.0119887		

Source: Computed by author based on Smallholder Farmer Survey, 2011

Technical Efficiency

TE of the ith farm is calculated from the following:
TEi=exp (-ui) *100 (TE is converted into a percent by multiplying this equation by 100)

The minimum estimated efficiency is 1.1 percent, the maximum 73.1 percent and the mean is 26.9 percent with a standard deviation of 20.6 percent.

Socio-Economic Characteristics And Technical Efficiency

Efficiency score were estimated by using Tobit robust model. A negative sign on a parameter inefficiencies means that the variable reduces technical efficiency, while a positive sign increases technical inefficiency.

Table 2: Technical efficiency and farm characteristics (OLS) Dependent variable: Technical efficiency index

Variables	**coeff.**	**S.E**	**t**	**P>|t**
Education level Number of years of schooling for the farmer	-.2361934	.0181694	-13.00	0.000
Experience (Number of years of experience in farming)	.0367327	.0697226	0.53	0.599
Credit access, Dummy variables (1=has access 0 = NO)	-.0841503	.0491145	-1.71	0.088
Family size numbers	.0055545	.0039261	1.41	0.158
Gender of household head 1=male,2=female	-.0071222	0133682	-0.53	0.595
Status	.0370044	.0449505	0.82	0.411
Profession	.0023742	.0141942	0.17	0.867
Education level squared	.0193834	.0023623	8.21	0.000
Experience squared	-.0235963	.0113952	-2.07	0.039
Age	.0420243	.0078077	5.38	0.000
Type of seed	0615104	.0486157	1.27	0.207
Age squared	-.0004863	.000096	-5.07	0.000
Log pseudo likelihood	211.84335			
F (12, 263)	168.53			
σ^2	1119976	.0079495		

Source: Computed by author based on Smallholder Farmer Survey, 2011

The results on above Table reveal that , the number of years in school, squared number of years in school ,access to credit, age, squared age, and squared experience reduce technical inefficiency or increase technical efficiency.

The negative sign on the years of school variable indicates that an increase in the number of school years decreases technical inefficiency; this relationship is significant at the five percent level. However, when years of schooling are squared (Schsq), the quadratic structure of age is positive implying that farm technical efficiency increases with an increase in the number of school years of the farmers. This finding is consistent with results from other studies (for example, Awudu, et al.,(2001) in their study on technical efficiency during economic reform in Nicaragua found that education increases production efficiency). A study by Seyoum, et al., (2000) on technical efficiency and productivity of maize producers in Eastern Ethiopia concluded that farmers with more education respond more readily to new technology and produces closer to the frontier output. The role of education in improving farmers' efficiency is widely known because it enables farmers to understand the socioeconomic conditions governing their farming activities and to learn how to collect, retrieve, analyse and disseminate information. Moreover, with higher levels of education, farmers are able to organize themselves into farmer groups or associations, thereby enabling them to source funding from lending institutions, especially from non-government organizations (NGOs) engaged in micro credit delivery. Education also enhances farmers' understanding of extension recommendations:

This finding is also consistent with results on structural adjustment and economic efficiency of rice farmers in Northern Ghana by Awudu and Huffman (2000).

The dummy variable for age is positive but squared age is negative but still signifant at 5 % level this shows younger farmers are more efficient than the older ones. The reason for this is probably because the age variable picks up the effects of physical strength as well as farming experience of the household head. Although farmers become more skillful as they grow older, the learning by doing effect is attenuated as they approach middle age, as their physical strength starts to decline (Liu and Zhung, 2000). Similar conclusions were made by Awudu and Huffman (2000).

However, the coefficients of gender, status , extension contact, family size , profession household size and credit are all statistically insignificant indicating no relationship between these variables and technical efficiency in maize production in the study area.while farmer's age, education and access to credit are important factors directly related to technical efficiency. These results call for policies aimed at improving farmers' access to credit, fertilizer, labor, and seed as well as targeting relevant policies for increasing technical efficiency in the study area.

Conclusions and Recommendations

The study observed that TE of maize farmers varied due to the presence of technical inefficiency effects in maize production. This shows that there is a great opportunity for farmers to increase their level of efficiency in maize production.

Again, Age, Level of Education and access to credit were significant variables greatly influencing TE of maize growers. Therefore education policy that would encourage farmers to be literate would increase the efficiency level of farmers and should be embarked upon by the government.

Finally, since an increase in age would lead to a reduction in efficiency levels inmaize production, policies that would make the youths to return to the land and take up maize farming would yield positive dividends to Bugesera and Musanze economy in particular and Rwanda in general. This study set out to provide estimates of technical efficiency in Rwanda maize production and to explain variations in technical efficiency among farms through managerial and socio-economic characteristics. Results show that the overall mean technical efficiency is estimated at 27 percent. However, TE ranges between 1 to 74 percent among the maize producers in Rwanda.

This study has concluded that increased input use (i.e. seed and fertilizer) and a household's characteristics impact yield across and within the study area. Given the empirical findings, the proposed recommendations are:

This study has shown that use of agricultural credit to purchase seed reduces technical inefficiency and thus shifts the actual production frontier closer to the potential frontier. Credit is necessary to encourage technical innovations, such as use of yield-enhancing inputs, which cost slightly more, but shifts production, transforming the entire input-output relationship. From this study, one could conclude that only 26 percent of farmers received credit during the 2010/2011 main harvest season.

The government should probably influence borrowing rates on credit and loans so as to spur agricultural development. Currently, commercial banks are trying to incorporate farmers in their clientele base by designing products suitable for agriculture. Another government intervention is to streamline the operation of microfinance institutions (MFIs) and Umurenge Saccos.

Based on the findings of this study, an effort to emphasize education will have a positive impact on the TE in maize production, Since 2003, the Rwandan Government has supported free 12 years education. If this education policy is sustainable, future maize producers could reap benefits of education in the form of increased maize production.

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