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ANALYSIS OF TECHNICAL EFFICIENCY OF SMALL SCALE ORGANIC MAIZE FARMERS IN RWANDA: A PARAMETRIC FRONTIER APPROACH

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ABSTRACT

This study aimed at examining the technical efficiency of organic maize production in Musaza sector of Kirehe district in Rwanda. Stochastic frontier production function model was adapted to measure farm level-efficiency. Farm level data were collected among 100 organic maize small scale farmers selected through a multi stage sampling procedures. Descriptive and inferential statistics were applied to analyse the data. The findings of the maximum likelihood estimates method showed that organic fertilizers and seeds were statistically significant and therefore being important factors in determining the level of organic maize output. The obtained value of return to scale of 0.97 means that organic maize production function in Musaza sector was following a decreasing return to scale indicating that organic maize was in stage III. Large elasticity of seed with high statistical significance shows that seed is an important input in organic maize production. Analysis of technical efficiency results reported that the mean technical inefficiency is 35 percent which implies that there is a chance to raise the output with the same level of inputs in order to operate closer or to the frontier curve. The study concludes that organic fertilizers and seed inputs are the determinants of organic maize production in the study area. The policy implication is that farmers need to increase organic maize production through the efficient use of inputs which will help them to increase net profits. The study recommends that, the farmers must participate actively in extension services extended to them and put into practice the lessons learned in order to increase the production of organic maize and therefore being efficient.

KEY WORDS: *Technical efficiency, Small scale, Organic maize farmers, Rwanda.*

INTRODUCTION

The agricultural sector has always been an important component of the Rwandan's economy. The Government of Rwanda has therefore made agricultural development a priority and mobilized significant funds to improve productivity. In this context the Ministry of Agriculture and Animal resources (MINAGRI) has set up a number of policies such as seed policy, fertilizers policy to enhance the development of a modern agriculture that abandons traditional subsistence practices. The strategies identified to achieve this transformation include the promotion of soil fertility through the use of organic fertilizers that improves soil fertility in a long-run. The Government of Rwanda acknowledges that organic farming can play an important role side-by side with inorganic farming and some of the practices promoted are supporting organic farming (Alexander, 2008). In 2005 Rwanda joined as a voluntary regional East African Community and ratified the first regional voluntary organic standard in Africa. In 2007, the Rwandan Organic Agriculture Movement (ROAM) was started and received its legal recognition in 2014, it coordinates producers, farmers' cooperatives, processors, exporters, importers who are involved in or support organic production, processing, marketing and exporting.

Farmers have been advised to adopt organic farming that does not require the use of chemicals in crop production. The Director General of crop production at the Ministry of Agriculture and Animal Resources, told the farmers at Mulindi agri-show ground where the farmers were exhibiting organic products, that organic products are highly needed at the international market as are bought at higher price compared to inorganically grown products (http://www.newtimes.co.rw/section/article/2015-08-04/191246/). Therefore, there is a need to increase organic production in Rwanda due to its eco-friendly environment system in general and its positive effects on soil health, human health and environmental health. For achieving agricultural transformation and increased rural incomes, the assessment of the technical efficiency in the organic sector is a major concern. Resources must be used efficiently, with more attention paid to eliminating misuse of the inputs. This will lead to an increase in productivity, incomes and thereafter achieving food security.

OBJECTIVES

The main objective of this research is to analyse the technical efficiency of small scale organic maize farmers in Kirehe district. Rwanda. This objective leads to the following specific objectives:

1. To estimate the stochastic frontier production for the small scale organic farmers in the Musaza sector.
2. To measure the technical efficiency levels of small scale organic maize farmers in Musaza sector.
3. To find out the type of return to scale for small scale organic maize farmers in Musaza sector.

Technical efficiency and stochastic frontier approach

Efficiency theories are related to production theories and the concept of isoquants focuses on the relationship between input and output (Dipeolu, 2007). The isoquants represent the boundaries of inputs while the frontiers are the boundary of the outputs. The production function serves as the basis for technical efficiency measurement.

Efficiency is the ability to avoid wasting of the resources in producing the output. Generally, it is the ability to perform things better in such away resources are not wasted. In contrary, if a farmer does not use efficiently the available resources, he or she fails to reach the frontier and therefore becomes inefficient by remaining inside the frontier. Economists defined three types of efficiencies viz technical, allocative and economic. This paper focuses on the analysis of technical efficiency of small scale organic maize farmers.

Measuring technical efficiency of farmers has been an area of interest to many agricultural economists. In this regard, stochastic frontier approach has been applied to measure the technical efficiency of production processes in order to assign the responsiveness of the yield to different resulting inputs. Thus, changes in this responsiveness are mainly due to differences in the level of technology that is applied by the farmers.

Francesco (2009) reviewed the parametric and non parametric methods of measuring the technical efficiency and concluded that the stochastic frontier method is the most suitable in measuring the technical efficiency as it provides the variation of actual output from the frontier due to inefficiencies and random shocks that can be measured through the stochastic frontier method. Coelli and Battese (1995) revealed that a non parametric method has been criticized as it does not consider the existing influence of random shocks such as measurement errors and other noises in the data. They concluded that the most advantage in the application of the stochastic frontier method over non-parametric is the consideration of the stochastic random noises that are beyond farmer's control in addition to the inefficiency errors.

The biggest concern of the non-parametric approach is that measurement errors and other sources of statistical noise are not taken into account. Hence, the present paper applies the stochastic frontier approach to measure the technical efficiency of organic wheat farmers. An obvious solution to the problem is to introduce another random variable representing statistical noise and the resulting frontier is known as a stochastic production frontier.

Aigner, Lovell and Schmidt (1977); Meeusen and Van den Broeck (1977) proposed the stochastic frontier production model of the form:

$$\ln Q_i = X_i\beta + V_i - U_i \qquad (1)$$

Where Q_i represents the output of the i^{th} farm, X_i represents the vector containing the logarithms of inputs; β is a vector of unknown parameters; and U_i is a non-negative random variable associated with technical inefficiency and V_i is a symmetric random error (statistical noise).

$$\ln Q_i = \beta_0 + \beta_i \ln X_i + V_i - U_i \qquad (2)$$
$$Q_i = exp(\beta_0 + \beta_i \ln X_i) \times exp(V_i) \times exp(-U_i) \qquad (3)$$

$exp(\beta_0 + \beta_i \ln X_i)$: Deterministic Component

$exp(V_i)$: Noise
$exp(-U_i)$: Inefficiency

The second objective of this paper is to measure the technical efficiency levels of small scale organic maize farmers in Musaza sector. Thus, the stochastic frontier analysis is directed towards the prediction of the inefficiency effects in which the most common output-oriented measure of technical efficiency is applied. Consequently, technical efficiency is measured as the ratio of observed output to the corresponding stochastic frontier output as shown in the equation (4):

$$TE_i = \frac{actual\ output}{potential\ output} = \frac{Y_i}{Y_i^*} \qquad (4)$$

$$= \frac{exp(X_i\beta_i + V_i - U_i)}{exp(X_i\beta_i + V_i)} = exp(-U_i\ ) \qquad (5)$$

Where TE stands as technical efficiency and the inefficiency effect U_i which lies between 0 and 1, when it is equal to zero, the production is on the frontier which indicates that $Y_i^* = exp(X_i\beta_i + V_i)$ then TE= 1 and therefore a farmer is technically efficient. When U_i is greater than zero (U_i>0) the farmer is technically inefficient (TE<1), since the production figure will be below the frontier line Kumbakhar and Lovell (1989).

The first step in estimating the technical efficiency is to compute the parameters of the stochastic frontier production which are shown in model (1) by using the FRONTIER 4.1 software. Before estimating the model, it is important to keep in mind that the stochastic frontier method needs a prior identification of the functional forms such as Cobb-Douglas and Translog as highlighted by Aigner et al. (1977) in their paper on the formulation and estimation of the stochastic frontier production models in which they pointed out that Cobb-Douglas is a special form of the translog form where only the differences reside in the squared parameters and the assumption of zero interaction terms of the variables in the translog frontier. Coelli and Battese (1998) also stated that the translog frontier production is likely to face a multicollinearity problem while the coefficients of Cobb-Douglas production constitute the output elasticity and easy interpretation. Hence, the present study prefers to estimate the Cobb-Douglas frontier type given the above reasons.

Cobb-Douglas Production frontier production function

The Cobb-Douglas functional form for organic maize farm in Musaza sector is defined as follows:

$$LnY = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + V_i - U_i \qquad (6)$$

Where Y_i is the total output of organic maize measured in kg, X_1 is the labour employed in man days, X_2 organic fertilizers in Kg and X_3 is the seed in kg. The choice of these inputs is motivated by the fact that these inputs are very important and commonly used for organic maize farmers in the organic maize production process in the study area. β's the parameters defined as the coefficients of inputs to be estimated by maximum Likelihood Estimation Method. V_i is the random assumed to be independently, identically and normally distributed i.e. N(0, σ_v^2) and Ui is a non-negative random variable assumed to be independently and identically distributed i.e N(μ, σ_μ^2).

METHODOLOGY

The data used in this study were generated by a cross sectional survey collected from 100 organic maize farmers in Musaza sector of Kirehe district, Rwanda. The multistage sampling method was adopted to select the area of the study. Since the eastern province of Rwanda has found to have large area of maize cultivation (National Institute of Statistics of Rwanda, 2013) and therefore has been selected purposively as the first stage. Eastern province consists of seven districts in that Kirehe district has high yield of maize (National Institute of Statistics of Rwanda, 2013) and hence it has been purposively selected as second stage of multi stage sampling. Kirehe district consists of twelve sectors. Musaza sector has been selected as the third stage of multi stage sampling since this sector consists of Cooperative des Agriculteurs de Céréales de Musaza (COACMU) which involves in cultivating cereals especially maize crop. In that cooperative 100 organic maize farmers were conveniently selected.

Results and Discussion

Table-1

Summary statistics of variables for stochastic production analysis

Variable	Mean	Std. Deviation	Min.	Max.
Maize (Kg)	736.9	533.69	50	3000
Labour (man days)	20	18.77	2	90
Organic fertilizers (Kg)	32.98	11.15	5	62
Seed (Kg)	16.25	17.40	2	80
Technical efficiency	0.65	0.19	0.12	0.88

Source: Computed

Table-1 summaries the statistics descriptive of the variables used in the stochastic frontier production function. The average output per farmer per season was 736.9 kg the average for inputs such as labour, organic fertilizers and seed were 20 man days, 32.98Kg and 16.25kg respectively. In the study area the average labour employed is low because the farmers operates on small plots ranging between 0.3-0.9Ha according to the classification of size pattern of holding in Rwanda by the National Institute of Statistics of Rwanda, 2012. The average of organic fertilizers apply reveals that maize farmers applied organic fertilizers at a reasonable quantity in which each farmers applies 32.98Kg of organic fertilizers per season. Average quantity of seed was 16.25Kg per season.

Table-2

Maximum likelihood estimates for parameters of the stochastic frontier production model

Variable	Parameters	Coefficients	Std.error	t-ratio
Constant	β_0	4.45	0.68	6.48
Ln (Labour)	β_1	0.19	0.17	1.15^{NS}
Ln(organic fertilizers)	β_2	0.19	0.67	2.98**
Ln (seed)	β_3	0.59	0.73	8.06*
Variance parameter				
Sigma-square	$\sigma^2= \sigma^2v+ \sigma^2u$	0.77	0.17	4.68*
Gamma	$\gamma= \sigma^2u/ \sigma^2$	0.89	0.67	12.95*
Ln likelihood function		-0.821982		
Mean technical efficiency	0.65			
Mean technical inefficiency	0.35			
Number of observations	100			

Source: Computed

* t-ratio is significant at 1% level of significance

**t-ratio is significant at 5% level of significance

NS- Non-Significance

Results presented in the Table-2 are the estimated parameters of the stochastic frontier production function, Cobb-Douglas type. The parameters of the stochastic frontier production model showed that all the estimated coefficients of the variables of the production function were positive. The positive parameters indicate that, these variables increased organic maize production. The result of the t-ratio test shows that all the variables except labour are statistically different from zero at 1 and 5 percent level of significance. Labour was found to be insignificant which opposes to the findings of (Asogwa, 2011) who found that labour was significant at 1 percent level.

The coefficient of organic fertilizers applied by farmers had a positive and significant relationship at 5% of level of significance with organic maize output.

The positive sign on organic fertilizer indicates that an increase in organic fertilizer would result in an increase in organic maize output. The estimated coefficient of organic fertilizers was positively associated with organic maize output at 5 percent level of significance. It implies that an increase of 1 percent in the quantity of organic fertilizers would increase organic maize output by 0.19% ceteris paribus. In other words, organic maize output in the study area would increase when organic fertilizer increases. This finding is in consistency with the finding of Kavi, 2015 who reported that organic fertilizer had a positive relationship with rice output in the ketu northern district of the Volta region, Ghana. In consistency with the finding of Ahmed et al. 2013 found that organic fertilizer was an important factor determining farm production of smallholder farmers in Girawa district of Ethiopia. In line also with the result of Okon, 2009 showed that quantity of organic manure was positive and influence garden egg (solanum Spp) production in Uyo Metropolis, Akwa Ibom State of Nigeria.

The estimated coefficient of seed was positively associated with organic maize output at 1 percent level of significance. It indicates that an increase in seed, leads to an increase in organic maize output. Therefore, an increase of 1 percent in the quantity of seed would increase organic maize output by 0.59% ceteris paribus. The finding of this study supports that of Nelson et al. 2015 who found a positive relationship between quantity of seed and maize production in Zimbabwe but opposes to the finding of Ahmed et al. 2013 that found that seed was significant and negatively associated with farm production of small scale farmers in Girawa district of Ethiopia.

RETURN TO SCALE OF THE PARAMETERS OF SFP FUNCTION

Returns to scale explains the technical property of production that shows changes in output due to a change of all inputs. One of the objectives of this paper is to find out the type of return to scale that exists in organic maize farming in Musaza sector. Hence, Table-3 shows the result of the input elasticities that enable the researchers to conclude about the type of return to scale and therefore achieve the above objective.

Table-3
Return to scale (RTS) and the parameters of SFP function

Variables	Elasticities
Labour	0.19
Organic fertilizers	0.19
Seed	0.59
RTS	**0.97**

Source: Computed

The RTS parameter of 0.97 which is the summation of the elasticities implies that maize production in the study area was in the stage III of the production. Stage III is the stage of decreasing return to scale or a diminishing return to scale or increasing costs in which the summation of elasticities is less than 1.

In this stage the output (organic maize) increases in a smaller proportion than that of the factors of production (Labour, Organic fertilizers and Seed). Hence, at this stage, farmers are advised to maintain the same level of input utilization and try to reduce the costs of each input as this will enable maximum output from a given level of input other things being equal. The main cause of the decreasing return to scale is that revenue is less than cost (economies are less than diseconomies). The result of this study is similarly to the result of Ogundari and Ojo, 2006 and Idris et al., 2013 who found that RTS was equal to 0.840 and therefore indicates a decreasing return to scale. Large elasticity of seed with high statistical significance shows that seed is an important input in organic maize production.

Technical efficiency

The MLE results from Table-2 showed that technical inefficiency effects existed in organic maize production in the study area as confirmed by the gamma (γ) value of 0.89 which is significant at 10 percent level. The gamma ratio indicates the relative magnitude of the variance σ^2, associated with the technical inefficiency effects. Hence, 0.89 reveals that about 89 percent variation in the total output of maize was due to technical inefficiency and the remaining 11 percent was due to the factors beyond the farmer's control including changes in climatic factors, natural disasters, changes in price policy and so forth. The mean technical efficiency (MTE) of the sample is 0.65 percent with a range spinning from 0.12 percent to 0.88 percent indicating that output can be raised by 35 percent without increasing the level of inputs.

CONCLUSION

The research was conducted with the objective of analysing the technical efficiency of small scale organic maize farmers in Kirehe district, Rwanda. The study adopted the stochastic frontier approach to analyse the technical efficiency of small scale organic maize farmers. Hence, Cobb-Douglas stochastic frontier production function was modelled and the parameters of the model were estimated by employing the maximum likelihood estimate method and thereafter the levels of technical efficiency of organic maize farmers were obtained. The MLE results indicated that organic fertilizers and the quantity of seeds applied influenced positively organic maize in Musaza sector of Kirehe district. With regard to the type of return to scale, the result showed that organic maize production was in the stage III indicating a decreasing return to scale. In this stage, Farmers are advised to maintain the same level of input utilization and try to reduce the costs of each input as this will enable maximum output from a given level of input other things being equal.

Average level of technical efficiency equals to 65 percent. This indicates that farmers can increase their farm production on average by 35% when they were technically efficient. In this context, there is a need to increase the output level with the same actual level of inputs in order to increase the level of technical efficiency.

To conclude, the study recommends that, the farmers must participate in extension services extended to them and put into practice what they learned in order to increase the production of organic maize and farmers' technical efficiency in the study area.

It is also recommended to the MINAGRI and its allied institutions to formulate and implement appropriate policies that govern organic farming such as Pricing policy (related to organic inputs) Price premium policy and other related policies to allow farmers to increase organic maize production and levels of technical efficiency in the study area in particular and in Rwanda in general.

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