TECHNICAL EFFICIENCY OF DAIRY FARMS IN SUDAN: A STOCHASTIC FRONTIER APROCH

-: Authors Details:-

Safa Abdelgadier Hassan [a], Hag Hamad Abdelaziz [b], Abdelateif Hassan Ibrahim[c]

[a] Department of Economics, Faculty of Economics and Social Studies, Bahr El-Ghazal, Wau, South Sudan.

[b] Department of Agricultural Economics, Faculty of Agricultural Studies, Sudan University of Science and Technology, Shambat , Sudan.

[c] Department of Agric-Economics, Faculty of Agriculture, University of Khartoum

Abstract

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This study examined the technical efficiency of dairy farms in East Nile locality, Khartoum State-Sudan in the year 2017. Information related to various aspects of dairy farming was collected from 85 farmers selected randomly using a structured questionnaire. Descriptive Statistics, Cobb-Douglas stochastic production frontier and technical efficiency models were used to determine the effect of each input as the production frontier and the principal factors that explain differences on farm efficiency. The results of the analysis revealed that the technical efficiency ranged between 23-100 percent for small farms and 42-96 percent for large farms, with a mean of 60percent of small farms and 76 percent for large farms. The results suggested that the same amount of milk produced by the farms in the sample could have been achieved with approximately 40and 24 percent with fewer resources if all farms would have operated at 100 percent technical efficiency respectively for small and large farms. The estimated gamma parameters (γ) for small and large farms 0.99 and0.98, showing that the farm specific variability contributed more to the variation in yield among the dairy farmers, indicating that 99% and 98% per cent of the differences between observed and the maximum production frontier output of milk among the farmers was due to difference in farmer's level of technical efficiency by adopting different management practices in small and large farms, respectively. These factors were under the control of the farmers and the influence of which could be reduced to enhance technical efficiency of the dairy farmers in East Nile locality, Khartoum State. The return to scale for the small and large farms revealed that the farmers operated in the increase return to scale of the production surface having RTS of 1.052and 2.11, respectively.

Keywords: ***Technical Efficiency, Stochastic Production Frontier, Dairy Farms.***

1. INTRODUCTION

Sudan comes in the front of the African and Arab countries in terms of animal resources and their products (MFE, 2008). The livestock population numbers were estimated at 108 million heads composed of 4.8, 30.93, 40.8, 31.66 heads of camels, cattle, sheep and goats, respectively (MRA, 2017).The average annual growth rate of this sector in the country was estimated at 5.6%), (MFE, 2006).

Livestock sector contributed 20.7% of Gross Domestic product (GDP) (MFE, 2017), and 45% of agricultural domestic products (MFE, 2008).

It also contributes to the country's total foreign earnings by about 121.7 million US $ representing about 3% of total foreign earnings (MFE, 2016) and provide job opportunities for more than 40% of the Sudan citizens (MFE, 2006). Livestock is the major component of agriculture in small scale holder systems of the tropical countries. It plays an important role in providing food to people, enriches their land with organic manure as fertilizers and provides direct and indirect cash income. Further, livestock can be used as capital assets, transportation and agriculture.

Dairy production is one of the most important sectors in Sudan as it plays a big role in achieving food security, it also considered as one of the main pillars of the country's development. Dairy products are among the most important products of livestock sector (FAO, 2006).

The up- grading of milk production during the 2006-2016 was attributed to the increment of cattle numbers, improvement of veterinary cares and increasing percentage of foreign bloods in the local breeds cross. But it seemed that the dairy producers aren't commercially oriented as only 50% of the total milk produced in the country is available for human consumption (Ministry of Animal Resource and Fishery, 2017).

There is a big gap between the estimated per capita consumption rate and the currently available milk for consumption in the country .Surely, this huge deficit has its impact on price by escalating the prices of milk and milk products up as the average price of fresh dairy milk in Khartoum state in 2017 was 5.2 SDG/ liter. To bridge the gap, the country has resorted on powder milk importation which was in steadily increased (Ministry of Animal Resource and Fishery, 2017).

In this study, the East Nile locality – Khartoum state was selected. However, despite the importance of the dairy sector to Sudanese economy and the huge livestock numbers, the country yet holds its full potential of this sector hasn't been achieved. In fact, the country imports milk and milk products to meet the demand of milk increasing.

Many factors militate against realizing full improvement of this sector and also effect on the productivity of the dairy among them are Lack and shortage of animal feed, high cost and poor quality and most producers also lack the knowledge of efficient utilization of animal feed resources, inefficient and inadequate milk processing technologies and also poor production hygiene and there are some policies imposed, these factors affect of milk productivity.

The results of this study may help the policy makers to take suitable decisions about, how and when to use resources in production process and help the government to reform several policies to increase dairy production and ensure self-sufficiency. Measuring dairy efficiency is important and is the first logical step in a process that leads to substantial resources saving.

Efficient milk production is a key to sustainable development of dairying. Feed cost is a major burden to use animals of good genetic merits. High disease incidence in the context of developing countries also compounds the main problem of research. In summary, development and extension services in animal breeding, feeding and animal health are the core elements to underpin efficient milk production.

The main objective of the study is to determine the technical efficiency of milk production in East-Nile locality, Khartoum state.

2. Methodology

This study has been carried out in East Nile Locality, Khartoum State, Sudan. It is mostly observed that there are two categories of dairy farms (small and large). The standing addressed the technical efficiency differences between small and large size farms. Random sampling technique was used to select the sample farms. Prior to sampling, complete listing of all the dairy farms in the area of study was conducted For the purpose of present study, the dairy farms were categorized into small, medium and large based on the herd size. The dairy farms categories and herd size of the farm used by (Ministry of Animal Resource and Fishery, 2016) in Khartoum State.

Accordingly, farms containing 1-25cows are small farms, 26-99 cows are medium farms and greater than 99 dairy cows are large farms. The result indicated that there were only few medium dairy farms in study area. Therefore, the study considered only small and large size farms. Out of the cross breed cows' farms, 63 were categorized as small farms and the 22farms were categorized as large. Information related to various aspects of dairy farming was collected from selected farmers by survey method with a well-designed and pre tested interview schedule. Details of inputs used like roughages fodder, concentrates with their quantities, labour and herd size with numbers and veterinary services expenses and data on outputs like milk production, manure and calves were also collected from the dairy farms for crossbred cows.

Technical efficiency was applied in the agriculture sector of Sudan by more researchers among them Alwaley (2015), Mahgoub (2015), El-hag (2010).

2.1Tools of analysis

The various tools used to analyze the data were as follows: Stochastic frontier production function: The frontier production function represents a maximum possible output for any given set of inputs setting a limit or frontier on the observed values of dependent variable in the sense that no observed value of output is expected to lie above the production function. Any deviation of a farm from the frontier indicates the extent of farm's inability to produce maximum output. From its given sets of inputs and hence represent the degree of technical inefficiency.

A production process may be inefficient in two ways, only one of which can be detected by an estimated production frontier. It can be technically inefficient in the sense that it fails to produce maximum output from a given inputs bundle; technical inefficiency results in an equi-proportionate over-utilization of all inputs.

The technical efficiency in production was generally estimated by using the stochastic frontier production function. The stochastic frontier production function was independently proposed by Aigner etal (1977) and Meeusen and Broeck (1977). The estimation of stochastic frontier production function made it possible to find out whether the deviation in technical efficiencies from the frontier output is due to firm specific factors or due to external random factors. A large number of studies are available on the use of stochastic frontiers for the measurement of technical efficiency in *production* (Dawson and Lingard, 1989; Kalirajan, 1990).

The stochastic frontier model can be represented as:

Yi = f (Xi; β) exp Vi – Ui ……….. (1)

Where Yi represents the value of output, Xi represents the quantity of input used in the production. The Vis are assumed to be independent and identically distributed random errors, having normal N (0, **σ2v)** distribution and independent of the Ui. The Ui are technical inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution N (μ, δ2u). This seems reasonable sense V represents the influence of factors outside the control of the farmer, while U represents technical efficiency under the control of the farmer.

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

TEi = Yi / Yi* = f (Xi; β) exp (Vi – Ui) / f (Xi; β) exp Vi = exp (-Ui) ……….. (2)

Where: Yi is the observed output and Yi* is the frontiers output (Coffen, 2006) The TE ranges between 0 and 1 that is 0”dTEd” 1.

2.2 Model specification

The stochastic frontier production function of the Cobb-Douglas type was specified for this study, and the model specified is as follows:

The model used was assumed to be specified by the Cobb-Douglas frontier production function which is defined by:

$$\ln Y_i = \ln\beta_i + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + V_i - U_i \quad (3)$$

Where Y = Annual Total milk production (litter)

X1= Herd Size (Number),

X2 = Labour (Number),

X3 = Health cost (SDG),

X4 = Quantity of roughages (kg),

X5 = Quantity of concentrates (kg),

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} \quad (4)$$

Where Z_1, Z_2 and Z_3 respectively age of farmers, educational level, and farming experience of farmers, these are included in the model to indicate their possible influence on the technical efficiencies of the farmers. The β's, σ's are scalar parameters to be estimated. The variances of the random errors, σ_v^2 and that of the technical inefficiency effects σ_u^2 and overall variance of the model σ^2 are related thus: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and the ratio $\gamma = \sigma_u^2/\sigma^2$, measures the total variation of output from the frontier which can be attributed to technical or inefficiency (Battese and Coelli, 1988). The estimates for all the parameters of the stochastic frontier production function and the inefficiency model are simultaneously obtained using Frontier 4.1

3. Results and discussion

3.1. Technical efficiency in milk Production

To estimate the level of efficiency in milk production, stochastic frontier production function was used. The frontier production function including an inefficiency model was extended in order to explain differences in technical inefficiency among farms

According to results, the estimated gamma parameters γ equal to 0.99and 0.98 for small and large farms, respectively, indicating that both statistical noise and inefficiency are important for explaining deviations from the production function. However, inefficiency is more important than noise. From this value, it could be inferred that the farm specific variability contributes to 99and 98% towards the variation in milk production among the dairy farmers, which means that the difference between observed and maximum frontier output can be explained by the difference in farmer's level of TE by adopting different management practices. Besides, it is possible to test the relevance of inefficiency component; using a likelihood ratio test .The quantity of milk produced in the dairy farms per cow was used as output variable. The explanatory variables included were the roughage fodder, concentrates, health expenditure, labour and herd size. In the Cobb-Douglas function, the output elasticities of the inputs are equal to the corresponding coefficient if all inputs are measured in logarithmic form. As in Table 1, all output elasticities were positive and statistically significant except health expenditure for large farms had negative sign and health expenditure, quantity of roughage in small farms had negative signs and statistical significant at 1 percent. These results revealed that the variables, herd size, feed (roughage-concentrate) and labour influence positively milk production in large farms and herd size, feed, concentrates and labour in small farms. This implies that at 1% increase in the percentage of the herd size that is used for milk production, labour; roughages and concentrate lead to increase in milk production by 1.39%, 0.70%, 0.055% and 0.040% respectively, for large farms and 1.09%, 0.022%, 0.111 respectively, for small farms. Of all input variables, the number of milking cows had the highest effect on productivity level with elasticity equal to 1.09 and 1.39 respectively for small and large farms. One possible reason that could explain the negative signs of health expenditure and roughage in the result is that, the producers use a lot of amount of roughages above stomach capacity and using doses and more veterinary services.

Stochastic frontier production function: The stochastic frontier production function parameters are given in Table 1. The result of the analysis showed that the health expenditure variable has a negative sign, but it was statistically significant at one per cent, all other explanatory variables influenced the milk production positively and were statistically significant at 1 percent for small and large farms, but roughage amount had a negative sign and statistically significant at 1 percent for small farms.

3.2. Return to Scale

The return to scale relationship between inputs and output could be seen from the sum of the regression coefficients (elasticities). It is assumed that the sum of elasticities of one, the return to scale is constant, if the sum is less than one; the return to scale is decreasing, and if the sum of elasticities is greater than one indicates increasing return to scale. That means for equal proportion increase in inputs, the response of milk output is at equal proportion, the scale is constant, the response is less than proportional, the scale is decreasing, and the response is greater than proportional, the scale is increasing. The sum of efficiency coefficients (elasticities) for small and large size farms was 1.052 and 2.11, respectively. The scale relationship between input and output (return to scale) were in the range of increasing return to scale for all farm size categories. These results indicated that, for 100% increase of the inputs in the production, the milk output would increase by 105% and 211% for small and large size farms, respectively. The increasing return to scale might be the results of economies of scale because of the factors of production may become efficient and more productive.

The estimate of the variance ratio (γ) in the table showed that the farm specific variability contributed more to the variation in yield among the dairy farms, indicating that 99and98 per cent of the differences between observed and the maximum production frontier output were due to difference in farmer's level of technical efficiency by adopting different management practices. These factors were under the control of the farm and the influence of which could be reduced to enhance technical efficiency of the dairy farms in Khartoum State.

3.3. The farm specific technical efficiency:

The farm specific technical efficiencies were estimated and the frequency distribution is presented in Table 2. From the table, it is clear that, the mean technical efficiencies for small and large farms were 0.60 and 0.76 per cent respectively, indicating that on an average the sample TE farmers tended to realize only 60 and 76 per cent of their technical abilities and approximately 40 and 24 percent of their technical abilities were not realized. This suggests that dairy farmers in Khartoum State can improve their productivity and efficiency if they implement more efficient farm practices.

In terms of technical inefficiency model, a negative sign on a coefficient indicates that an increase in the value of that variable results in a fall in inefficiency; a positive value indicates an increase in inefficiency. The results show that the three explanatory variables that were included have a significant negative impact on technical inefficiency., an increase in the age of producer, education years, experience year are associated with a lower technical inefficiency, implying better efficiency performance. However, the major determinant of efficiency differences are age and experience (-

0.019, -0.016) for large farms and education years and experience for small farms reflecting that these factors affect the efficiency.

Table 1: ML estimate stochastic frontier and inefficiency effects Models of kuku dairy farms

Variables	**Parameters**	**Coefficient Large Farms**	**Coefficient Small Farms**
Constant	B0	5.536	9.88
Herd Size (No)	B1	1.39••	1.09*
Labor (No)	B2	0.70••	0.022••
Quantity of roughage fodder (Kg)	B3	0.055•	-0.137••
Quantity of concentrate fodder (Kg)	B4	0.040••	0.111••
Health cost (SDG)	B5	-0.07 ••	-0.034 ••
Inefficiency Model			
Constant	δ0	-0.003	2.026••
Age of farmers (Year)	δ 1	-0.019••	-0.098••
Education Level (No of schooling year)	δ2	-0.004••	-0.169••
Farming Experience (No of year)	δ 3	-0.016••	-0.33••
Sigma square	δ 2	0.21	0.18
Gamma γ	Γ	0.98	0.99
Log likelihood function	Llf	0.23	0.14
LR			11

Source: Field Survey 2016

• five percent level of significance

••one percent level of significance

Table 2: Frequency distribution of farms technical efficiency

Farm in TE category	Farms numbers	Mean TE	Min. Efficiency	Max. Efficiency
Large Farms	22	76	42	96
Small Farms	63	60	23	99.9

Source: Field Survey 2016

4. Conclusions

The results of the stochastic frontier function analysis revealed that the variables of roughage fodder; concentrates, herd size and labor were statistically significant and had a positive sign while the health expenditure variable was negative and significant at 1 percent level of significance for small and large farms. Though roughage fodder variable had a negative sign and significant for small farms. The mean technical efficiency of the small and large farms was 60and76%, respectively, the estimate of the variance ratio (γ) were99.98 for small and large farms, respectively. **[Done]**

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