African Journal of Agricultural Research Vol. 5(9), pp. 935-940, 4 May, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X © 2010 Academic Journals

Full Length Research Paper

Technical efficiency of the small scale sugarcane farmers in Swaziland: A case study of Vuvulane and Big bend farmers

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Accepted 15 March, 2010

The technical efficiency of the small scale sugarcane farmers of Swaziland is investigated using stochastic frontier production functions for Vuvulane scheme and Big bend individual farmers. The stochastic production frontier function model of the Cobb-douglas type used incorporates a model for the technical inefficiency effects. Farm-level cross-sectional data were collected from 40 sugarcane schemes and 35 individual sugarcane farmers. The results revealed some technical efficiency levels of the sample farmers that are varied widely. For the Vuvulane sugarcane farmers, efficiency ranges from 37.5 to 99.9% with a mean of 73.6%, whilst for the Big bend sugarcane farmers it ranges from 71 to 94.4% with a mean value of about 86%. The sugarcane farmers at Vuvulane over-utilized land. Thus, an appropriate amount of land utilization could increase the sugarcane production for Vuvulane sugarcane farmers. For both groups of farmers, the technical inefficiency decreased with increased farm size, education and age of the sugarcane farmer, but increased when small scale sugarcane farmers engaged in off-farm income earning activities.

Key words: Technical efficiency, sugarcane, stochastic frontier function.

INTRODUCTION

The sugar industry in Swaziland comprises of sugarcane growing (which is classified as an agricultural activity) and sugarcane manufacturing (which is classified as an industrial activity). The agriculture sector accounts for about 8% of Swaziland's Gross Domestic Product (GDP). Out of this fraction, sugarcane growing makes up 6%. The manufacturing sector, which accounts for 35% of GDP, includes sugar manufacturing and refining (7%), as well as secondary sugar and molasses based production such as sweets and alcohol. The sugar industry, as part of the agricultural as well as the manufacturing sector, directly accounts for 18% of the country's GDP (Swaziland Sugar Association, 2007a).

The industry's contribution to employment creation is massive. This is because sugarcane production still requires a lot of labor. The 2001 official employment statistics showed that the industry contributed over 35% of the private sector agricultural wage employment. However the share is expected to have declined over the years, owing to restructuring activities of the major companies, which resulted in major retrenchment between 2002 and 2005 (Swaziland Sugar Association, 2007b). The Swazi sugar industry constitute of various participants which are the Swaziland Sugar Association, millers, and cane growers.

The sugar industry is regulated by the Sugar Act of 1967. The Swaziland Sugar Association regulates the functions of the industry, while the millers are responsible for producing sugar and apart from producing sugar, the millers also own sugar estates from which they produce sugarcane. The cane growers are responsible for producing sugarcane and delivering it to the mills (UNCTAD, 2000). Agriculture is the main livelihood in the Lowveld region of Swaziland. In the early 1980's the main agricultural activity in this region was rain-fed cotton farming. Other crops such as maize and beans were also grown predominately for subsistence, but cotton occupied relatively large areas and was the main source of cash income. In 1991, sugarcane farming gained momentum in Swaziland due to a combination of political and economic

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factors such as the allocation of sucrose quotas to Smallholder Sugarcane Growers (SSGs) on Swazi Nation Land and the financial support from the Swazi Bank to the farmers through credit (Terry, 1997). Smallholder farms were initiated on small scales as means of alleviating poverty in different community areas with assistance from the three sugar mills existing in the country, which are Mhlume, Simunye and Big bend mills. The government of Swaziland has recently embarked on rural community development projects as a first major step towards alleviating poverty and improving the rural standards of living in the country. Most recently, this commitment has taken the form of an exciting and innovative agricultural development project in the North-eastern Lowveld region along the Komati River. The first phase was the construction of the Maguga dam to provide water for irrigation. The second phase of the project was the implementation of the project downstream the dam known as the Komati Downstream Development Project (KDDP). The third phase is the on going project in the Southern part of the Lowveld which is the Lower Usuthu Smallholder Irrigation Project (LUSIP).

Today, each of these mills has a substantial proportion of their cane supplied by the small-scale sugarcane farmers (Cousens et al., 2002). The main objective for all of these projects was to provide income opportunities for homesteads through smallholder sugarcane production and by providing employment to the rural people who are working on the farms. Smallholder sugarcane growing is an important developmental instrument for the country, however, it is challenged by the increase in input prices for fertilizer and pesticides, the removal of preferential markets which has resulted in the reduction of sugar prices. There is a need for the smallholder sugarcane farmers to adopt new technologies that are cost effective so that they can still continue to make profits from the product, but the small-scale sugarcane farmers are not familiar with these new technologies (Dlamini, 2005). Stakeholders have shown a sustained vigor to ensure that smallholder sugarcane growers survive into the future. So far little rigorous work has been undertaken to quantitatively study the efficiency levels of existing sugarcane technologies with a purpose of identifying ways of improving efficiency. The estimation of efficiency level, for small-scale sugarcane farmers, will enhance identification of the sources where improvement can be made. The study attempts to fill this gap by examining the technical efficiencies of the small scale sugarcane farmers in a scheme (Vuvulane Irrigated Farms) and non-scheme farmers (big bend).

RESEARCH METHODOLOGY

As indicated earlier the sugarcane farmers in the Vuvulane area which are under the Vuvulane irrigated farms and the Big bend area were used for this study.

A stratified random sample size of seventy five (75) farmers was obtained. This sample size represents 80% of the total of ninety four (94) farmers from both Big bend and Vuvulane irrigated farms. Of the total sample of seventy five respondents thirty five (35) farmers were from Big bend (representing 90% of the small scale farmers in Big Bend) and forty (40) were from Vuvulane (representing 73% of the farmers in Vuvulane). The data were collected through a structured questionnaire administered on individual head of households using personal interviews. The data collected were cross-sectional data for the 2006/07 farming season.

The econometric model

Sugarcane production requires a wide-range of inputs levels at different growth stages, such as specific temperature, irrigation water, and soil type. Also sugarcane production requires physical inputs such as land, fertilizer, herbicides, and labour. Therefore, this study was designed to determine the technical efficiency of the physical inputs among the different types of small scale sugarcane individual farmers and farmers under a smallholder scheme.

The stochastic frontier production function method was adopted to estimate the technical efficiency of small scale sugarcane farmers in the study areas.

Also such a model is appropriate because agricultural production in general exhibits shocks, hence there is need to separate the influence of stochastic variables (random shocks and measurement errors) from resulting estimates of technical inefficiency (Battese, 1992). Despite its well known limitations, the Cobb-Douglas functional form was used to fit separate stochastic production frontiers for the two farming groups. Binam et al. (2004), argued that as long as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology, the Cobb-Douglas production function provides an adequate representation of the production technology. The dependent variable used on a given set of resources, x, and other conditioning factors used in both production analyses is the total physical output in tonnes. Four main explanatory variables were used in the production frontiers in this study. They are land area under sugarcane, labour, fertilizer, and herbicides.

Model specification

The Cobb-Douglas is linear in logarithms, giving the following regression specification for the stochastic production frontier.

$$\ln Y_i = \beta_{0i} + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + V_i - U_i$$

Where: the subscript i indicates the i-th farmer in the sample (i = 1, 2, 3, .N) and ln represents the natural logarithm (that is logarithm to base e). The variables and their units of measurement are briefly explained below.

Output (Y) is the total quantity of sugarcane harvested in the study year and is measured in tonnes.
Land (X_1) is the area of the farm(s) devoted to the production of sugarcane. It is measured in hectares.
Labour (X_2) is the total hired worker days used in the sugarcane production.
Fertilizer (X_3) is the amount of fertilizer used in kilograms.
Herbicides (X_4) is the amount of herbicides used in litres
The V_i s are random errors associated with measurement errors in the yields of sugarcane reported or the combined effects of input variables not included in the production function. The U_{is} are assumed to be independent and are obtained by truncation (at zero) of the normal distribution with mean μ, and variance σ^2_u .

The inefficiency model based on Battese and Coelli (1995) was specified as:

$$\mu_i = \delta o + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i}$$

Where δ-coefficients are unknown parameters to be estimated, together with the variance parameters, which are expressed in terms of age (Z_{1i}), education (Z_{2i}), off-farm income (Z_{3i}), and land size (Z_{4i}). In the model Z_i are the values of explanatory variables for the technical inefficiency effects for the i-th farmer as defined below:

Z_1 = Age of the farmer (1 if <50 and 0 if >50 years).
Z_2 = Number of school years
Z_3 = Off-farm income (1 if yes, 0 if no).
Z_4 = the total number of hectares held by the farmer.

It is assumed that some farmers produce on the frontier and others do not produce on the frontier. Thus, the need arises for finding out factors causing technical inefficiency. The technical inefficiency model has been developed for this study to concentrate on this issue.

Ideally the Battese and Coelli (1995) model, which is estimated using computer programme, FRONTIER 4.1, written by Tim Coelli from the University of New England would have been used to analyze the data. The maximum likelihood (ML) estimates of the parameters of the frontier model are estimated, such that the variance parameters are expressed in terms of the parameterization of $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma_s^2$ where the γ-parameters have a value between zero and one. However, for this study the maximum-likelihood estimates of the parameters of the stochastic frontier production function model were obtained using the LIMDEP computer program. It should be, however, noted that both methods produce the same results.

RESULTS AND DISCUSSION

Productivity of farm inputs

As can be seen from Table 1, for the Vuvulane Farmers, production elasticities had the expected positive signs in the stochastic production frontier except for land, which is negative, whilst for the Big bend Farmers the production elasticities had the expected positive signs in the stochastic frontier. The production elasticity for land had a negative sign for the Vuvulane farmers, which was not expected. The negative land variable indicates that one percent increase in land size for sugarcane production for the Vuvulane farmers will cause reduction in the sugarcane output by 0.30%. This perhaps implies that sugarcane farmers in Vuvulane are over-utilizing land. This result is consistent with those of Shafiq and Rehman (2000) and Ahmad et al. (1999). However, the production elasticity for land size is not significantly different from zero at the 10% level of significance using the asymptotic t-test.

The positive land variable for the Big bend farmers indicates that one percent increase in land size for sugarcane production will cause an increase in the sugarcane yield by 0.264% but the production elasticity was statistically insignificant at 10% level of significance. The production elasticity for labour is positive, as expected for both Vuvulane and Big bend farmers. The positive elasticity of labour indicates that one percent increase in this variable will increase the yield of sugarcane by 0.796 and 0.236% in the Vuvulane and Big bend farmers respectively. This elasticity sign is consistent with those of Battesse et al. (1993), Hussain (1999) and Hussan (2004). However, the labour elasticity on the Vuvulane farmers is not significantly different from zero. For the Big bend farmers the elasticity of labour is statistically different from zero at 1% level. The derived production elasticity for the fertilizer variable is 0.536 for the Vuvulane farmers and is 0.431 for the Big bend farmers. The fertilizer variable had the expected positive sign and significantly different from zero at the 5 and 1% level of significance for the Vuvulane and Big bend farmers respectively. The positive sign of fertilizer elasticity indicates that one percent increase in the use of this variable will result in an increased yield of sugarcane by 0.536 and 0.431% in the Vuvulane and Big bend farmers respectively. The results are consistent with those of Battesse et al. (1993), Ahmad et al. (1999), Hussain (1999) and Hussan (2004). The derived production elasticity for herbicides variable is 0.214 for the Vuvulane farmers. This positive elasticity indicates that 1% increase in herbicides applied will increase the sugarcane yield by 0.214%. The derived production elasticity for herbicides variable is 0.332 for the Big bend farmers. This positive elasticity indicates that one percent increase in herbicides applied will increase the sugarcane yield by 0.332%. The herbicides elasticity for the sugarcane farmers for Big bend farmers is statistically different from zero at the 1% level. However, herbicides elasticity for the sugarcane farmers for Vuvulane farmers is not significantly different from zero at 10% level.

Technical efficiency

The estimated technical efficiency for the sugarcane growers at Vuvulane and Big bend are presented in Table 2 including their frequency distribution of the technical efficiency levels. The average predicted technical efficiency for the Vuvulane sugarcane farmers ranges from 37.5 to 99.9% with a mean of 73.6 % suggesting that there exist a great potential to increase per hectare yield of sugarcane. Whilst the average predicted tech-nical efficiency for the Big bend sugarcane farmers ranges from 71.0 to 94.4% with a mean of 86.7% suggesting that there exist some potential to increase per hectare yield of sugarcane.

It is also evident from Table 2 that 57.5% sugarcane farmers from Vuvulane and 74.3% sugarcane farmers from Big bend are operating at 80% level and below technical efficiency, while only 22.5% sugarcane farmers from Vuvulane and 25.7% from Big bend are operating above 90% technical efficiency level. This implies that a large number of sugarcane farms in the sampled Vuvulane farms faced some technical inefficiency problems.

Table 1. The maximum-likelihood estimates for parameters of the stochastic production functions for the Vuvulane and Big bend farmers.

	Vuvulane farmers		Big bend farmers	
Variable	**Coefficient**	**T-values**	**Coefficient**	**T-values**
Intercept	0.816	0.728	0.217	0.283
In Land	-0.301	-1.423	0.264	0.578
In Labour	0.796	0.283	0.236***	3.824
In Fert.	0.536**	2.261	0.431***	2.804
In Herb.	0.214	0.652	0.332***	2.308
Inefficiency model				
Constant	0.304**	1.961	-0.170***	-4.092
Age	-0.188*	-1.401	-0.356	-0.118
Schyrs	0.211	1.129	-0.817	-0.216
Off-farm	0.759	0.778	0.121	0.428
Land	-0.126	-0.522	-0.246	-0.157
Variance parameters				
Sigma square	0.339***	6.164	0.230**	1.890
Gamma (γ)	0.584	0.609		
Average technical efficiency		73.6%		86.65%
Log-likelihood		3.393		10.484

Notes: *** = significant at 0.01, ** = significant at 0.05 level, * = significant at 0.10 level.

Table 2. Frequency distribution of technical efficiency in the stochastic sugarcane production functions for the Vuvulane and Big bend farmers.

	Vuvulane farmers (N = 40)			Big bend farmers (N = 35)		
Level (%)	**No**	**%**	**Cumulative percentage**	**No**	**%**	**Cumulative percentage**
< 50	7	15	15	0	0	0
51- 60	5	12.5	27.5	0	0	0
61 – 70	5	10	37.5	0	0	0
71-80	8	20	57.5	6	17.1	17.1
81-90	8	20	77.5	20	57.2	74.3
90 – 100	7	22.5	100	9	25.7	100
	Mean = 73.6%	Minimum = 37.5	Maximum = 99.9	Mean = 86.7%	Minimum = 71.0	Maximum = 94.4

The Big bend sugarcane farmers are more technically efficient than the Vuvulane farmers with a mean technical efficiency of 86.7 compared to the 73.6 obtained from the Vuvulane farmers. But these levels of technical efficiency for the small sugarcane farmers are higher than the 58 - 59% efficiency of cotton and cassava farmers reported by Bravo-Ureta and Evenson (1994), the 63 percent efficiency for grain farmers in China reported by Yao and Liu (1998) and the 56.2% technical efficiency for rice farmers in Bangladesh by Coelli (2002). However, the small scale sugarcane growers had lower technical efficiency than that found by Hassan (2004) for wheat crop (93.6 %) in mixed farming system of Punjab.

The results discussed above reveal that, in general, small scale sugarcane growers of the selected areas have some problem in employing best production methods and achieving the maximum possible output from new and existing technologies. Mean technical efficiency over the small scale sugarcane farmers at Vuvulane is 73.6%, indicating that a 26.4% increase in the sugarcane yield is feasible with the current technology and unchanged input quantities in the Vuvulane farmers. Similarly, the Big bend small scale sugarcane farmers could obtain 13.3% higher yield by utilizing the available resources optimally.

Returns to scale

The returns-to-scale parameter for the Cobb-Douglas production frontier is estimated by the sum of elasticities of the four input variables and the returns-to-scale parameters for the Vuvulane and Big Bend farmers respectively are 1.245 and 1.263. For Vuvulane farmers, an increase in all inputs by one percent increases sugarcane output by more than one percent, indicating increasing returns to scale. Similarly for Big bend farmers an increase in all inputs by one percent increases sugarcane output by more than one percent, indicating increasing returns to scale.

Technical inefficiency effects model

Socioeconomic, demographic, institutional and non-physical factors are expected to affect technical efficiency. Using the inefficiency model equation, the study made an attempt to investigate determinants of technical inefficiency. The coefficients of the explanatory variables in the technical inefficiency model are of particular interest in terms of making policy options. The estimate for the variance parameter, γ, associated with the variance of the inefficiency effects is close to 1 for both the Vuvulane and Big bend farmers. Since it is significantly different from zero, it can be concluded that there are technical inefficiency effects associated with the production of sugarcane by the sampled farmers at Vuvulane and Big Bend. The parameter estimates from the inefficiency model in Table 1 had the relevant signs, indicating the impact of explanatory variables on technical (in) efficiency.

The age of the farmers was included to assess the effects of age on the level of technical inefficiency. It is commonly believed that age can serve as a proxy for farming experience. The older the farmer, the more experienced he/she is. It is estimated that the age variable for the Vuvulane farmers is -0.188, whilst for the Big bend farmers is -0.356. This means that age had a negative effect on the technical inefficiency in sugarcane production for both Vuvulane and Big bend farmers, showing that as the age of the sugarcane growers increases, technical inefficiency declines. Both the Vuvulane and Big bend older farmers tend to be less inefficient. This is possibly because they are more experienced in the production of sugarcane. One other possible reason is that the older farmers may have more resources at their disposal, which include cattle, capital. This variable was significantly different from zero at 1% significance level for the Vuvulane farmers whilst it is not significantly different from zero at 10% level for the Big bend farmers. This sign was expected, given the various effects that farmers' age may have on efficiency. The coefficient for years of schooling for the Vuvulane farmers is 0.211 which is positive, and it was expected to have a negative influence on technical inefficiency but the opposite was found. For the Big bend farmers the variable for years of schooling is -0.817. The reason for getting a positive variable from the Vuvulane farmers was possibly because there was not much difference between the educational levels of the sampled farmers at Vuvulane. Most farmers were found to be functionally literate at Vuvulane. It was also important to look at levels of informal education for such farmers. For Vuvulane, this variable was not significantly different from zero. For the Big bend farmers, the estimates for the variables are not significantly different from zero.

This result at Big bend indicates that the more educated sugarcane growers are more likely to be efficient as compared to their less educated counterparts, perhaps as a result of their better access to information and good farm planning (Dhungana et al., 2004). Similar results were also reported by Kumbhakar et al. (1991). However education is not correlated with technical efficiency in the cultivation of sugarcane at Big Bend, since the coefficient is not significantly different from zero. This result could be explained by the lower average education level of the sugarcane growers. Coelli (2002) was of the view that education had no effect on efficiency due to the average education level of less than four years. The coefficient of the off -farm income is 0.759 and 0.121 for Vuvulane and Big bend farmers respectively. The variable was positive for both Vuvulane and Big bend farmers, indicating that farmers engaged in off-farm income earning activities tend to exhibit higher levels of inefficiency. The positive relationship suggests that the involvement in non-farm work are accompanied by reallocation of time away from farm related activities, such as adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency. Other researchers that made similar findings are: Huffman (1980); Awudu and Eberlin (2001). This variable was not significantly different from zero by using the asymptotic t-test in both Vuvulane and Big bend Farmers. The coeffi-cient of the farm size is -0.126 and -0.246 for Vuvulane and Big bend farmers respectively. The variable was negative for both Vuvulane and Big bend farmers. It was found that the farm size had a negative effect on the technical inefficiency effects in sugarcane production for both the Vuvulane and Big bend farmers showing that as the farm size of the sugarcane growers increases, tech-nical inefficiency declines. The farm size variable is not significantly different from zero at 10% level using an asymptotic t-test on both the Vuvulane and Big bend farmers.

Conclusion

The results of the stochastic frontier production function and technical inefficiency model indicated that derived production elasticity for the fertilizer variable for the Vuvulane small scale sugarcane farmers was higher (0.536). The variable for labour and herbicides were positive and the variable for land was negative, but statistically non-significant according to an asymptotic t-test. Production elasticity for labour (0.236), fertilizer (0.431) and herbicides (0.332) were important in terms of contribution towards higher sugarcane yield for the Big bend Farmers. An attempt was made to ascertain the factors affecting technical efficiency in the small scale sugarcane production. Farm, and farmer related and socio-economic factors were included in the technical efficiency model. The effect of age had a negative signify-cant influence on technical efficiency for the managed scheme small scale sugarcane farmers.

The overall mean technical efficiency of 73.6 and 86.7% achieved by the small scale sugarcane farmers under a scheme (Vuvulane) and non scheme small scale sugarcane farmers (Big Bend) respectively showed that there was some scope to increase the small scale sugar-cane production. The more important contributors in the small scale sugarcane production were fertilizer, labour and herbicides. Thus an appropriate amount of fertilizer, herbicides and labour utilization could increase the sugarcane production. An analysis of the determinants of technical inefficiency was carried out and it showed that technical inefficiency in the small scale sugarcane production could be reduced by educating the small scale sugarcane farmers in improved techniques and proper use of available resources to boost their experience in the sugarcane production, hence policies designed to educate sugarcane farmers through proper agricultural extension services could have a great impact in increasing the level of technical efficiency and hence the increase in sugarcane productivity.

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