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ESTIMATING EFFICIENCY LEVELS AND THEIR DETERMINANTS AMONG SMALL-SCALE SUGARCANE GROWERS IN NORTHERN KWAZULU-NATAL, SOUTH AFRICA

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Abstract. South African small-scale sugarcane growers are faced with high production costs that may lead to agricultural inefficiency because of an inability to adopt newly available production technologies. This study employed the Data Envelope Analysis (DEA) approach and Truncated regression model to analyse data collected from 160 growers. The findings show technical, cost and allocative mean scores of 95.6,% 55.2%, and 57.5% in the Felixton region whereas 95.2%, 69.1% and 72.6% were achieved in the Amatikulu area, respectively. The age, extension support, and off-farm income variables had a negative effect on agricultural efficiency followed by positive effect of experience, education, access to credit and employment that showed positive relationships. The study proposes that the government should work jointly with mill owners to train and develop extension officers. Furthermore, it should subsidise inputs and equipment to address the poor allocation of resources because of financial constraints currently faced by small-scale sugarcane growers.

Keywords: data envelope analysis, small-scale grower, sugarcane production, technical efficiency, allocative efficiency, cost efficiency, truncated regression

INTRODUCTION

Driven by concerns of feeding a rapidly increasing world population and promoting the dwindling smallholder agricultural businesses to curb the tide of urban migration. The focus on promoting small-scale agriculture to create sustainable livelihoods has gained popularity among development specialists around the world. Small-scale agriculture in the impoverished rural communities remains a significant contributor to food security, sustainable livelihood and a vehicle for poverty reduction (Lefophane et al., 2013). The natural shocks such as drought, flooding and other externalities impact directly or indirectly on small-scale agriculture, which raises concerns about the issues of long-term food security and production. The 2015–2016 drought episode in South Africa has decimated the agricultural sector and posed a serious challenge to incomes of indigent farmers and to the promotion of food security among rural communities. In general, small-scale agriculture operates in dire circumstances and needs the government support to produce at optimum levels.

The improvement of agricultural productivity, in the face of various negative externalities, is the only effective strategy to address food security in rural communities compared to other solutions (Aye and Mungatana, 2011). Moreover, it will reduce overdependence on other sectors of the economy as well as alleviate poverty in rural areas through employment creation and improve farm income that results in access to food. Government thrust for small-scale agricultural development resulted

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in policy initiatives that were aimed at land reform, agricultural credit provision, infrastructure development and comprehensive support services for farmers. Empirical studies on the efficiency of small-scale farmers in developing countries utilised both DEA and Stochastic Frontier Analysis (SFA). However, Fried et al. (2008) merited the DEA based on its ability of making a non-prior assumption about the technology of the farm. Applying the DEA, Watto and Mugera (2015) found technical efficiency scores of tube-well and water buyers' sugarcane growers contrasting. In a different study, that sampled 198 households in India, the results showed that inefficiencies in sugarcane production affected the technical efficiency of growers (Murali and Prathap, 2017). On the other hand, Mahjoor (2013) focused on the technical, allocative and economic efficiencies of farms in Iran and concluded high levels of returns to scale and inefficiencies in terms of socio-economic factors. Moreover, economic efficiency estimation assumes homothetic technologies when benchmarking efficiency using technical and allocative criteria (Aparicio et al., 2015). This notion was further observed by the study of Khan et al. (2016) that applied both the constant returns to scale (CRS) and variable returns to scale (VRS) DEA models to estimate the technical, allocative and economic efficiency of rice farmers in Malaysia. This study reported efficiency mean scores of VRS technologies which showed higher performance compared to the CRS technologies using the DEA. However, Kelly et al. (2013) found that technical, allocative and economic scores applying the VRS DEA were not fully efficient. In South African empirical studies on small-scale sugarcane production, Thabethe et al. (2014) and Dlamini et al. (2010) have applied the SFA approach, which presented a gap for a detailed study that decomposes a DEA approach.

Socio-economics factors play a pivotal role in the performance of a farm business, and are used at the second stage of the DEA. Therefore, the determinants of technical efficiency influenced purely different agricultural practices and commodities. Traditional studies on determinants of farm production efficiency are mainly indecisive as regards the question of a positive or negative effect of socio-economic and policy related factors on the production, regardless of using a parametric or non-parametric approach. Studies, such as Mishra et al. (2017), Adelekan and Omotayo (2017), or Chang and Wen (2011) focused on the effect of gender, income, credit, labour, off-farm income and farm size on agricultural productive efficiency, and reported mixed results. Therefore, there is a need to explore the effect of socio-economic factors on agricultural efficiency of small-scale sugarcane growers in South Africa using a non-parametric approach.

MATERIAL AND METHODS

The total of 160 small-scale sugarcane growers selected via random sampling technique involving the selection of 80 growers from each of two lists. The list comprised the details of small-scale sugarcane growers located in close proximity to the Felixton and Amatikulu sugar mills. The input data comprised of labour, machinery, seeds, chemicals and fertilisers. The sugarcane yield served as the output for each grower and was obtained from the production estimates of extension officers for that particular season. The study used the secondary data because of poor record keeping by small-scale sugarcane growers. Information on prices was obtained from the local agro-retailer the growers indicated as the source of their production inputs, the prices of these inputs were recorded in South African Rands. Socioeconomic data of the small-scale grower were also solicited and variables such as age, area under cultivation, gender, education, off-farm income, access to credit, size of household, experience, extension support, and the employment status were applied at the second stage of the DEA analysis.

Estimation of DEA Method

The input-oriented technical efficiency approach under the VRS for a given decision making units (DMU_s) was computed by solving the following standard linear programming problem developed by Coelli et al. (2005) using R-Studio:

$$\mathrm{Min}(\lambda,\theta)\theta \tag{1}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} - \theta x_{ig} \le 0$$

$$\sum_{j=1}^{n} \lambda_j y_{kj} - y_{kg} \ge 0, \ \sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0$$

where: θ is a scalar and represents technical efficiency; λ_j is a vector of j elements which represents the influence of each farm on the determination of technical efficiency of the observed grower; s, x_{ig} and y_{kg} are the input and output vectors of grower g. The equation $[\Sigma_{j=1}^{n} \lambda_j = 1]$ is a convexity constraint which specifies VRS in the model.

In order to decompose the cost efficiency for a DMU_s, the cost minimisation objective equation for the DEA model was estimated, where x_g^* represents the cost minimisation vector of input qualities and w_g' is the vector of input prices:

$$\mathrm{Min}(\lambda, x_p')w_g' x_g^* \tag{2}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} - x_g^* \leq 0$$
$$\sum_{j=1}^{n} \lambda_j y_{kj} - y_g \geq 0, \sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0$$

The total cost efficiency for DMU_g was calculated as CE = $w_g' x_g^* / w_g' x_g$, therefore cost efficiency is the ratio of minimum cost to the actual cost for that particular *DMU*. In order to estimate allocative efficiency, the ratios of CE and TE were calculated.

$$AE = CE / TE \tag{3}$$

Estimation of Truncated regression Method

The truncated regression was applied at the second stage in order to investigate the determinants of DEA cost minimisation technique that was used by Watto and Mugera (2015). This study applied the single bootstrap truncated regression to identify determinants of technical efficiency in the following way:

$$Y_j = \alpha_j + \Sigma_{j=1}^{n} \beta_j z_j + \varepsilon_j \geq 0; j = 1, ..., N \text{ and } \varepsilon_j \rightarrow N(0,\sigma^2) \tag{4}$$

where Y_j is technical efficiency, Z_j is the set of explanatory variables for j = 1, ..., 9, and e_j is the error term.

RESULTS AND DISCUSSION

Descriptive statistics

As illustrated in Table 1 the descriptive statistics of the variables used in the DEA analysis, the variables included five inputs and one output. Overall, the average sugarcane yield for a Felixton grower is higher than that of an Amatikulu grower's yield, which is 170.49 and 153.21 tons/ha respectively. On average 10.27 and 5.26 litres of chemicals were used for the cultivation of a hectare in both the Felixton and Amatikulu growers' regions. The average costs of the applied chemicals were R2285.50 in the Felixton region and R3136.75 per hectare in Amatikulu. Fertiliser application for the Amatikulu growers was double the average of kilograms used in the Felixton region with 3.86 kg and 8.38 kg respectively, nonetheless, the Felixton growers spent on average R3036.75 on the purchase of fertiliser while their counterparts in Amatikulu spent R1268.00.

The average number of hours spent on sugarcane production in the Felixton region was 5.48 hours while the Amatikulu region growers devoted 3 hours per day, on average. As regards labour, the average wage in the amount of R94.12 was paid on the hourly basis to labourers in the Felixton region and in the amount of R100.43 in Amatikulu region. It is worth noting, that some small-scale sugarcane growers used on average 6.88 and 6.40 implements per hectare in the Felixton and Amatikulu

Table 1. Descriptive statistics for output and input variables

Variable	Felixton growers		Amatikulu growers	
	average	standard deviation	average	standard deviation
Sugarcane yield	170.49	141.24	153.21	198.21
Chemicals	10.27	9.13	5.26	2.46
Fertiliser	8.38	8.87	3.86	2.34
Labour	5.48	2.66	3.00	1.90
Machinery	6.88	5.70	6.40	5.36
Seeds	2.81	2.90	2.95	2.86
Cost of chemicals (Rands)	2 282.50	2 528.28	3 163.75	2 937.77
Cost of fertiliser (Rands)	3 036.75	6 152.21	1 268.00	792.78
Cost of labour (Rands)	94.12	42.56	100.43	2 937.77
Cost of machinery (Rands)	4 055.65	4 434.50	4 325.27	2 351.32
Cost of seeds (Rands)	1 980.00	227.78	2 545.00	2 692.13

Source: research survey, 2018.

Table 2. Descriptive statistics for socio-economic variables

Socio-economic determinants	Felixton region growers				Amatikulu region growers			
	mean	s.d.	min	max	mean	s.d.	min	max
Age of HH head	41.43	8.06	25	80	45.89	9.35	21	74
Extension support	1.73	1.88	0	12	1.31	0.58	1	3
Area under cultivation	3.14	2.35	0.2	15	2.60	3.09	0.2	18
Dummy variables (N = 160)	1	2	3	4	1	2	3	4
Access to Credit	5	75			2	78		
Education of HH head	32	27	21		44	27	9	
Employment status of HH	46	25	9		45	21	14	
Experience of HH head	13	35	32		8	48	24	
Off-farm income	41	39			55	25		
Gender of HH head	31	49			48	32		

s.d. – standard deviation.
Source: research survey, 2018.

regions, respectively. The total aggregate cost per hectare for the implements used was an average of R4055.65 for Felixton while the Amatikulu growers incurred a higher cost of R4325.27. The average amounts of seed cane planted were 2.81 and 2.95 tons per hectare in the Felixton and Amatikulu, respectively. Small-scale sugarcane growers in both regions receive sustainability subsidised in-kind loans in the form of mill certified seed cane, however, on average the amount of R1980.00 in Felixton and of R2545.00 in Amatikulu was spent on seed cane by growers per season.

Table 2 presents the socio-economic variables that affect TE, CE and AE in the Felixton and Amatikulu regions. On average, the age of small-scale sugarcane growers was 41 and 45 years in the respective regions. An average of 1.73 extension visits were reported in Felixton compared to 1.73 that was reported in the Amatikulu region. The average of 3.14 and 2.60 hectares respectively were cultivated for sugarcane production in the regions. The total number of growers who have access to credits was very small in both regions, with the 94% and 98% of the respondent reporting no access to credits in the Felixton and Amatikulu regions. Moreover, few respondents were employed compared to 42% that were unemployed in the Felixton region, and 41% of the unemployed growers in the Amatikulu region. The majority of the growers reported sugarcane production experience exceeding 10 years in both regions. Off-farm income, in any form of grants, business ventures and livestock sales showed many socio-economic variables. Lastly, a total of 49 (62%) respondents were female in the Felixton region compared to 48 (60%) male growers in Amatikulu.

DEA technical, cost and allocative efficiency scores

The DEA efficiency estimation in Table 3 was computed under variable returns to scale. The frequency distribution of technical, cost and allocative efficiency showed variation, bearing in mind that for a grower to be fully efficient the mean score must be the equal of 1 (Watto and Mugera, 2015). The mean TE, CE, and AE efficiencies were 95.6%, 55.2% and 57.5% for the Felixton growers and 95.2%, 69.1% and 72.6% for the Amatikulu growers, respectively.

Based on the mean technical score of 95.6% and 95.2% in both the Felixton and Amatikulu sub-regions, the small-scale sugarcane growers are operating at inefficiency levels of about 4.4% and 4.8%, respectively. However, out of the sample, the vast majority of growers were fully efficient, with 136 growers in both regions operating at optimal technical efficiency. Table 3 shows that in Felixton the number of small-scale sugarcane growers that exhibited full (100%) technical, cost

Table 3. Frequency distribution of technical, cost and allocative efficiencies

Percentage	Felixton region growers			Amatikulu region growers		
	TE	CE	AE	TE	CE	AE
<20	0	8	7	0	0	0
20–40	0	14	12	0	2	1
40–60	0	25	25	0	18	15
60–80	10	21	21	6	42	39
80–99	3	9	12	17	15	22
100	67	3	3	57	3	3
Mean	0.95	0.55	0.57	0.95	0.69	0.72
Standard deviation	0.11	0.23	0.23	0.84	0.15	0.14
Minimum	0.66	0.09	0.09	0.71	0.29	0.35
Maximum	1	1	1	1	1	1

Source: research survey, 2018.

and allocative efficiency where 67, 3 and 3 respectively compared to 57, 3 and 3 growers operating in Amatikulu. In Felixton, fully efficient growers were followed by ten respondents operating within the area of 60–80 percent, while in Amatikulu the growers in the 80–99 percent category included seventeen respondents. It is worth mentioning that none of the growers exhibited 0 to 60 percent in any of regions. The minimum and maximum mean technical efficiency scores were 66% and 100% for Felixton, while that of Amatikulu were 71% and 100%, respectively. The findings of this study are in contrast to the study by Murali and Prathap (2017) that showed lower technical inefficiency score of sugarcane growers above 15%. The study by Thabethe et al. (2014) conducted in the Mpumalanga province of South Africa showed fairly low technical efficiency scores of below 70%. Both studies applied the Stochastic Frontier Production Function approach and utilised different categories of input variables. Because of the higher technical efficiency of small-scale sugarcane growers, proper intervention targeted on the allocation of resources based on minimising cost needs to be introduced to trigger proper allocation of resources in order to improve the better livelihoods of poor small-scale sugar growers.

As regards CE, there is a lot one can draw from its parameters; it showed mean efficiency scores of 55.2% in Felixton and 69.1% in Amatikulu. This may imply that small-scale growers from Amatikulu were more cost efficient compared to their counterparts. These growers are 30.9% inefficient in their production, while growers in Felixton are 44.8% inefficient. Small-scale growers with less than 20% of CE were 8 and 0 for the Felixton and Amatikulu regions. Overall, 12 and 25 growers in the Felixton region operated between 20–60% of CE compared to only 2 and 18 in the other region. A little more than half of the sample, namely 53%, of the small-scale growers in the Amatikulu region exhibited cost efficiency between 60–80% compared to 26% of small-scale growers in the Felixton region, the total number of small-scale growers in the 80–99% were fifteen and nine for the respective regions.

Lastly, only three small-scale growers in both regions were fully efficient. For CE, 9 and 29 percentage points were the minimum scores for the Felixton and Amatikulu region respectively, and the maximum of 100% for fully efficient growers. As pointed in equation (3), AE was decomposed by taking the ratio between TE and CE. The minimum mean score for allocative efficiency was 9% and 35% for Felixton and Amatikulu region, respectively. However, the mean score of 72.6% in Amatikulu was higher than 57.5% obtained in the Felixton region. The mean AE scores constituted 27.4% and 42.5% inefficiencies, accompanied by only seven small–scale growers from the Felixton region operating in less than 20%, to zero in the Amatikulu growers. Twelve and twenty-five growers operated between 20–60% in the Felixton region compared to one and fifteen in the same category in the Amatikulu region. The majority of 61 growers in the Amatikulu region operated between 60–99% in comparison to only 33 in the Felixton region, with only three fully efficient growers in both regions. Therefore, there is a need to promote the proper allocation of resources in Felixton region to improve CE.

Determinants of technical, cost and allocative efficiency scores

Table 4 revealed that the grower's age was positively related to TE, CE and AE in the Felixton region. However, there was a negative relationship between age and CE in the Amatikulu region. This might be as a result of the older age of small-scale growers in Amatikulu region. Moreover, the reported extension support was negatively associated to TE in both regions, and was significant at 1% in relation to CE, AE and CE in the Felixton and Amatikulu regions, respectively. The positive relationship between the area under cultivation and TE, CE and AE was estimated in the respective regions. The relationship between access to credit and performance efficiency showed mixed results in both regions. In Felixton, a significant (5%) and positive relationship was estimated between credit and TE, however, CE and AE showed negative relationship as regards the access to credit. The opposite was the case in Amatikulu with all the estimates revealing a negative effect on TE, CE and AE.

The level of education, experience and the employment status had a positive impact on productive TE, CE and AE in all regions. Other, determinants such as experience and gender of the grower also showed positive impact on production efficiency. Furthermore, in both regions TE was significant at 5%. Lastly, off-farm income estimated a negative effect on TE, CE and AE in the Amatikulu region but had a positive relationship

Table 4. Estimation of determinants of technical, cost and allocative efficiencies in Felixton and Amatikulu regions

Socio-economic determinants	Felixton region growers						Amatikulu region growers					
	TE		CE		AE		TE		CE		AE	
Explanatory variables	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Age	0.005	0.006	0.003	0.001	0.003	0.001	0.062	0.024	–0.033	0.071	0.001	0.010
Extension support	–0.002	0.011	0.113***	0.015	0.113***	0.015	–0.007	0.004	0.151***	0.114	0.143	0.014
Area under cultivation	0.001	0.001	0.014	0.019	0.014	0.019	0.004	0.009	0.002	0.001	0.000	0.001
Access to Credit	0.041**	0.013	–0.026	0.018	–0.026	0.018	–0.001	0.011	–0.013	0.022	–0.012	0.012
Education of HH head	0.022	0.016	0.002	0.038	0.002	0.038	0.006	0.006	0.004	0.002	0.003	0.001
Employment status of	0.033	0.027	0.001	0.024	0.001	0.024	0.010	0.014	0.03	0.022	0.010	0.021
Experience of HH	0.034**	0.017	0.005	0.029	0.005	0.029	0.026**	0.011	0.003	0.013	0.031	0.013
Off-farm income	0.003	0.011	–0.002	0.029	–0.002	0.029	–0.009	0.012	–0.013	0.014	–0.020	0.013
Gender of HH head	0.035*	0.021	0.043	0.043	0.043	0.043	0.003	0.012	0.013	0.014	0.023	0.010

coef. – coefficient, s.e. – standard error.
*,**,*** indicate significance at 10%, 5% and 1% respectively.
Source: research survey, 2018.

with TE in the Felixton region followed by negative effect on CE and AE. Higher CE and low AE experienced by small-scale sugarcane growers in both regions indicate that inefficient growers pay higher prices for the inputs, taking the level of sugarcane yield into account. Consequently, growers ought to reduce their AE inefficiencies by purchasing appropriate combinations of inputs at the right price. The findings support previous studies by Murali and Prathap (2017) and Thabethe et al. (2014) that have attributed the negative effect on the reluctant and sceptical behaviour of older growers to extension support, innovative technology and adaptation of modern practises. These studies indicated the same results and attributed the negative effect on the reluctant and sceptical behaviour of older growers to extension support, innovative technology and adaptation of modern practises. The above indicates that the unwillingness and semi-traditional practices of small-scale sugarcane growers affect agricultural efficiency. The positive relationship of experience, education, access to credit and employment status contributes to the existing debate that has reported different results. This finding can be attributed to the fact that growers with education and extra income can afford more inputs in the production of sugarcane. The relationship between off-farm income and agricultural efficiency in the two regions may be explained by the allocation of time and resources to sugarcane farming by the growers. Furthermore, growers who generate off-farm income are likely to exhibit higher TE and CE due to much-needed capital resources that are generated from other sources.

CONCLUSION

Small-scale sugarcane growers exhibited very high TE mean scores in the production of sugarcane at different scales in the study area. Moreover, small-scale sugarcane growers in the Felixton region were more efficient compared to the Amatikulu region growers. In relation to the findings concerning cost and allocative efficiency, there is a need for small-scale sugarcane growers to minimise their production costs. In this quest, public and private initiatives aimed at financial management training as well as subsidies on machinery and equipment will contribute to the reduction of the cost burden related to the production. These subsidies are especially crucial since small-scale growers do not hold land title deeds, which prevents them from securing collateralised loans from commercial banks. Therefore, this study proposes policy reforms focused on training, inputs subsidies and production-related developmental initiatives channelled through extension advice aimed at improving cost and allocative efficiency. Moreover, a key policy line concerning the subsidisation of small-scale sugarcane growers may need to be introduced.

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