Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.5, No.16, 2014 

# Estimation of Technical, Economic and Allocative Efficiencies in Sugarcane Production in South Africa: A Case of Mpumalanga Growers

Londiwe. Thabethe[1*], Eric Mungatana[2] and Marlene Labuschagne[3]
1. Student, Department of Agricultural Economics and Rural Development, University of Pretoria.
2. Senior Lecturer, Centre for Environmental Economics and Policy Analysis, Department of Agricultural Economics and Rural Development, University of Pretoria.
3. Lecturer, Department of Agricultural Economics and Rural Development, University of Pretoria Email:
* Email of corresponding author: londiwethabethe@gmail.com or londiwe@namc.co.za

**Abstract**
This study measures the productive efficiency (technical, allocative and economic) levels of 231 small-scale sugarcane farmers in the Mpumalanga Province of South Africa using the stochastic frontier production function by Coelli (1995).The study uses sugarcane farm data collected in 2011 from a sample selected randomly. Labour, herbicides and fertilizer are identified as factors that contributed significantly to improved production. The results indicate that the sugarcane farmers lack technical, allocative and cost efficiencies. The mean technical, allocative and cost efficiency estimates are 68.5, 61.5 and 41.8 percent respectively. The study concludes that farmer education, land size, farming experience, and age contributed significantly and positively to productive efficiencies. The policy implication is that there is enough potential for farmers to increase sugarcane production and net profits. The study recommends that government needs to further invest in public education and strengthen farmer education as they constitute important determinants of productive efficiencies.
**Keywords:** stochastic frontier production, cost function, technical efficiency, allocative efficiency, economic efficiency, inefficiency determinants, South Africa.

The research was conducted in 2010/11 when Londiwe Thabethe was a student at the University of Pretoria in South Africa. The corresponding author is grateful to the Department of Agriculture, Forestry and Fisheries (Bursary Support), the National Agricultural Marketing Council (partly funding the research work), Bonani Nyhodo and Dr. Thulasizwe Mkhabela who assisted with content organization and data analysis respectively.

## 1. Background information

The rural areas of South Africa are characterized by high levels of poverty. Approximately 70 % of the poor reside in rural areas (Strategic Plan for South African Agriculture, 2001) and are dependent on agriculture for their livelihoods. Income for this group of people is constrained due to the fact that the rural economy is not vibrant enough to provide for self-employment opportunities. The major cause for this is the policies which were implemented in the past. On the other hand, natural risks such as climate variability, high production costs and uncoordinated policies have in the past contributed to sub-optimal growth and investment in the agricultural sector. Therefore, in order for rural areas to develop and expand opportunities for wages and self-employment, a foundation that would support greater earning and spending power is required (Strategic Plan for South African Agriculture, 2001).

Sugarcane is one of the important crops in South Africa, grown in KwaZulu-Natal (KZN) and Mpumalanga. The South African Sugar Association (SASA) indicates that the sugar industry generates an annual estimated income of R8 billion (SASA, 2010). The nominal Gross Domestic Product (GDP) estimate for the industry in 2009 stood at R2 400 billion (Stats SA, 2010). Therefore, the industry contributes between 0.5 % and 0.7 % percent to the national GDP. As a result if this, the industry makes an important contribution to the national economy. It also accounts for 6.88 percent of total agricultural exports (within the South African Customs Union-(SACU) – a decline from 11.7 percent in 1996 which could indicate that the exports declined because of a decline in production.

Furthermore, the industry directly employs about 77 000 workers, while indirectly employs about 350 000 workers, which represents a significant percentage of the total agricultural workforce in South Africa. The industry provides direct employment in the sugarcane production and processing, and indirect employment in numerous support industries (such as input suppliers). More than 2 percent of South Africa's population is dependent on the sugar industry.

It can therefore be argued that sugar mills and sugarcane farms play an important role in the economic survival of their surrounding rural communities and towns. A number of independent studies (Maloa, 2001), have found that milling towns and sugar farming areas have lower levels of unemployment and higher per capita income than the average small towns and farming areas in South Africa. These studies also found that the level of service in these areas is much better largely as a result of direct contributions by the industry or partnerships with government.

The land area under sugarcane production decreased from 429 thousand ha in 2000/2001 to 382 thousand ha in the year 2009/2010. Production also decreased from 23 million tons to 16 million tons during the same period (DAFF, 2011; SASA, 2011). The average yield of cane harvested also declined from 73.95 tons/ha in 2000/2001 to 67.67 tons/ha in 2009/2010 (SASA, 2011). In contrast to this, the producer price has been showing an increase year-on-year, which should serve as an incentive for the sugarcane farmers to increase their production.

According to Vink, Tregurtha and Kirsten (2008) a large number of small-scale agricultural producers have traditionally been involved in the sugar industry as cane growers. Records also show that the number has declined over the past 10 years with the result that the small-scale farmers' share of the industry declined from a high of 18.4% in 1997/98 to the current level of 10%. (Vink et. al., 2008). It is also indicated that the yield of the small-scale farmers, as a percentage of average industry yields, are declining. Other causes of the declining performance in the sugarcane production are inadequate use of available and recommended technologies, high input costs and an unstable global economy. Poor infrastructure inadequate and poor market information and high levels of technical inefficiencies on the farmers' side also account for low productivity.

The above evidence is in contrast with the sugar industry's impressive increase in the producer development initiatives (PDI) participation since 1999. According to the Cane Growers Association, the number of sugarcane farmers registered for the PDI has increase from 152 in 1999 to 358 in 2006 and the number is still increasing. Additional to the PDI, the industry has a variety of education and training initiatives that are geographically widespread across the sugarcane-growing areas (SASA, 2010). The industry is one of the industries where small-scale farmers are participating in the mainstream.

SASA (2010) indicates that there are more than 33 700 small-scale growers accounting for about 8.4 percent of the total annual crop. SASA (2010) further argues that the sugar industry has a long history of promoting and supporting small-scale farmers on tribal land (communal land).

Mentorship programmes focussing on business skills and grower support extension services are given to support sugarcane growing activities. The industry also provides technical skills training and accounts and financial management workshops for new and emerging sugarcane growers. Regional economic advisors, grower support service officers, special Value Added Tax (VAT) and diesel dispensation are also made available to the small-scale growers.

Through the South African Sugarcane Growers Association (SCGA), SASA has strengthened its regional economic service to provide local level support to new medium-scale black sugarcane growers who have entered the industry. Similar support is given to the beneficiaries of the government's land reform programme. The milling companies provide extension services in support of the sugarcane-growing operations of the small-medium and large-scale black farmers. SASA also provides in-field training to small-scale sugarcane farmers and offers certified courses in sugarcane agriculture and provides technology transfer and extension. Through the financial bodies established by the sugarcane mills, small-scale sugarcane farmers are able to access funds to purchase production inputs such as fertilizer, seed sugarcane, herbicides and ripeners.

The aim of these support measures was to encourage increased production in the sugarcane sub-sector. However, the production of sugarcane has been fluctuating over the past years, to some extent due to policy constraints and climate and weather conditions. Other causes of the declining performance in the sugarcane production are inadequate use of available and recommended technologies, high input costs and as mentioned before an unstable global economy. Poor infrastructure inadequate and poor market information and high levels of technical inefficiencies on the farmers' side also account for low productivity.

The high cost of production, attributable to high costs of inputs, can be reduced through increasing the farm outputs as a result of improving technical efficiency. This implies that the current levels of technical efficiency have to be quantified in order to approximate the production losses that could be caused by inefficiencies due to differences in farmers' management practices and socio-economic characteristics.

Other causes of the declining yields could be poor institutional arrangements. This could include poor policies governing the production and marketing of sugarcane. This could, in turn, lead to the farmers being reluctant to put more effort in the production of sugarcane. However, such causes are out of control of the small-scale sugarcane farmers. This, therefore, means that prominence will be given to the causes that are within the control of the small-scale sugarcane farmers which include the efficient use of production inputs to produce maximum output. It is therefore important to evaluate if the yields are declining because small-scale farmers are technically inefficient in their input use. There is a need to quantitatively evaluate the efficiency levels of the small-scale sugarcane farmers with the goal of finding ways to improve efficiency if inefficiencies are identified.

The main objective of the paper is to analyse the sugarcane production in the Mpumalanga Province of South Africa, with the aim of finding ways to increase production and productivity. Firstly, the technical, allocative and economic efficiency levels of the Nkomazi sugarcane farmers are estimated. Secondly an analysis of the determinants of inefficiency is done by investigating the relationship between the efficiency levels and the farm/farmer specific attributes. Lastly, policy recommendations are made on how efficiency can be improved.

The rest of the paper is organised as follows: The study area and data are given in section 2. In section 3 the theoretical framework to measure technical, allocative and economic efficiency using the production function and cost function frameworks. The analytical techniques and stochastic frontier models are described in section 4. The results and discussions are done in section 5. Lastly, section 6 draws the conclusion and policy recommendations from the findings of the study.

## 2. The study area and data variables

### *2.1. Study area*

The Nkomazi region was selected to undertake the study because it is the major sugarcane producing area in the Mpumalanga Province. The study area is situated in the Mpumalanga Province towards the North-East of South Africa. It is bordered by Mozambique and Swaziland to the east and Gauteng Province to the west. On the northern part, it is bordered by Limpopo. Sugarcane production mainly takes place from the areas in-between the Mananga border, Komati border and some areas towards Nelspruit (mainly in the Lowveld of the Mpumalanga Province).

The Nkomazi region covers an area of 3 500km². The area has been described to be amongst the areas with the highest agricultural potential in South Africa. Its resources constitute a unique combination of soil, climate and water. The climate is temperate in winter and hot and humid in summer. The soils are fertile and well suited for sugarcane farming.

### *2.2. Data collection and sampling procedure*

A random sampling procedure was employed in selecting the respondents for this study. A total of 231 farmers were interviewed. Data on input quantities and output were collected.

**Table 1: Description of variables used**

| Variables | Description |
|---|---|
| Production (PROD) | The quantity of sugarcane produced during the 2009/2010 season, expressed in tons |
| Land (LAND) | The amount of land in hectares planted with sugarcane by a farmer in the period under investigation |
| Labour (LABOUR) | The amount of hired and family labour used by the farmer, measured in man-days |
| Fertilizer (FERT) | The amount of chemical fertilizer, measured in kilograms. |
| Herbicides (HERB) | The quantity of herbicides used by the farmer, measured in litres. |
| $W_{LAND}$ | The price the farmer would pay to rent a hectare of land. |
| $W_{FERT}$ | The price of fertilizer per kilogram |
| $W_{HERB}$ | The price of herbicide per litre |
| $W_{LABOUR}$ | The price of labour per man-day |
| AGE | is equal to one for those age less than 40 and zero otherwise |
| EDUCATION | level is equal to one if small-scale farmer has five or more years of schooling and zero otherwise |
| OFF-FARM INCOME | is equal to one for farmers with sources of off-farm income and zero otherwise |
| EXPERIENCE | is one for farmers more than 10 years sugarcane farming experience and zero otherwise. |

### *2.3. Theoretical framework*

The discussion on the measurement of productivity and efficiency originated from papers by Koopmans (1951) and Debreu (1951). Farrell (1957) extended the works of Debreu and Koopmans to measure productivity and efficiency. The scalar ratio of outputs to inputs that are used in the production process can be defined as the productivity of an economic agent. Partial productivity such as yield per hectare (land productivity) or output per person (labour productivity) is measures of productivity. Also, total factor productivity (TFP), is defined as the ratio of aggregate outputs to aggregate inputs. The differences in production technology, in the efficiency of the production process, in the environment in which the production occurs and in the quality of inputs used by the agent may cause the variation in the productivity of an economic agent (Haghiri, 2003). The comparison between the observed and optimal values of the agent's outputs and inputs can be used to measure efficiency. There were other methods that were used to measure efficiency prior to Farrell's work. Nonetheless, economists and agricultural economists found these methods as unsatisfactory as they had some disadvantages. The estimation of the production function using the traditional least squares method was critiqued as being inconsistent with the definition of the production function (Schmidt, 1986). As a result, the frontier method was developed as a better theoretical method for measuring efficiency. According to Coelli (1995b) the frontiers can also be described as bounding functions.

The production technology is conventionally represented by the production function. Bravo-Ureta and Rieger (1991) developed a procedure or model for decomposing the cost efficiency into its technical and allocative components from the production frontiers. This helped to overcome the problem of solving for the cost function directly when there are little or no variations in the prices among the sampled firms. This methodology involves the use of the observed input ratio, the level of output for each firm adjusted for statistical noise and the parameters of the stochastic frontier production function (SFPF). The parameters of the SFPF are used to derive the cost function. To illustrate the approach, the stochastic frontier production function can be given as:

$$Y_i = f(X_i; \beta) + \varepsilon_i \quad (1)$$

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

where $\varepsilon_i$ is the composite error term. The components $v_i$ and $u_i$ are assumed to be independent of each other, where $v_i$ is the two-sided normally distributed random error and $u_i$ is the one-sided efficiency component with a half normal distribution. $Y_i$ is the observed output of the $i$th firm, $X_i$ is the input vector of the $i$th firm and $\beta$ is the unknown parameters to be estimated.

The composite error term ($\varepsilon_i$) is obtained by subtracting the predicted output from the observed output:

$$\varepsilon_i = Y_i - \hat{Y}_i \quad (3)$$

The maximum likelihood method is used to estimate the parameters of the SFPF. Subtracting $v_i$ from both sides of equation (2) gives:

$$Y_i^* = Y_i - v_i = f(X_i; \beta) - u_i \quad (4)$$

where $Y_i^*$ is the observed output of the $i$th firm adjusted for statistical noise captured by $v_i$. From equation (4), the technically efficient input vector, $X_i^T$, for a given level of $Y_i^*$ is derived by solving simultaneously equation (4) and the input rations, $X_1/X_t = \rho_k (k > 1)$, where $\rho_k$ is the ratio of the observed inputs.

Assuming that the production function is a self-dual function like the Cobb-Douglas production function, the corresponding dual cost frontier can be derived and written in a general form as:

$$C_i = h(W_i, Y_i^*; \delta) \quad (5)$$

where $C_i$ is the cost minimum cost of the $i$th firm associated with output $Y_i^*$, $W_i$ is a vector of input prices of the $i$th firm and $\delta$ is a vector of parameters which are functions of the parameters in the production function.

The economically efficient (cost minimising) input vector, $X_i^E$, is derived by using Shephard's Lemma and then substituting the firm's input prices and adjusted output quantity into the system of demand equations:

$$\frac{\partial C_i}{\partial W_i} = X_i^E (W_i, Y_i^*; \delta) \quad (6)$$

For a given level of output, the technically efficient, economically efficient and actual costs of production are given by $W_i X_i^T$, $W_i X_i^E$ and $W_i X_i$ respectively. The above cost measures are then used to do the bias calculation of the technical and economic (cost) efficient indices for the $i$th firm as follows:

$$TE_i = \frac{W_i X_i^T}{W_i X_i} \quad (7)$$

and

$$EE_i = \frac{W_i X_i^E}{W_i X_i} \quad (8)$$

The allocative efficiency can be calculated based on Farrell's methodology which states that the economic efficiency (EE) is divided by the technical efficiency (TE) to get allocative efficiency:

$$AE_i = \frac{W_i X_i^E}{W_i X_i^T} \quad (9)$$

The method of Bravo-Ureta (1991) was followed to avoid the problem of estimating the cost frontier directly. However, the method was criticised because the output-oriented approach are used to estimate the parameters of the frontier whereas, the input-oriented approach is used to derive the technical efficiency. The method gives technical efficiency scores that are different from those obtained from the maximum likelihood estimation of the SFPF in equation (1) which is output oriented unless firms are operating under constant returns to scale.

## 3. Empirical model

### *3.1. The parametric stochastic frontier production function (SFPF)*

The Cobb-Douglas model for this study is specified as follows:

$$\ln Y_i = \delta + \sum_{j=1}^{4} \beta_j \ln X_{ji} + v_i - u_i \qquad (10)$$

Where $Y_i$ is the observed sugarcane output for the $i$th farmer and $X_{ji}$ is the $j$th input quantity for the $i$th farmer, namely land, labour, fertilizer and herbicides. $ln$ represents the natural logarithm of the associated variables, and $\delta$ and $\beta$'s are parameters to be estimated.

Given the vector of input prices for the $i$th farm ($W_{ji}$), parameter estimates of the stochastic frontier production function ( $\hat{\beta}$) in equation (10), and the input oriented adjusted output level $Y_i^*$ in equation (4), the corresponding Cobb-Douglas dual cost frontier is derived and written as:

$$\ln C_i = b_0 + \sum_{j=1}^{4} b_j \ln W_{ji} + \emptyset \ln Y_i^* \qquad (11)$$

By using Shephard's Lemma, the cost minimising (economically efficient) input vector, $X_i^c$, is derived by substituting the firm's input prices and adjusted output quantity into the system of demand equations which is given as follows:

$$\frac{\partial C_i}{\partial W_i} = b_j W_j^{-1} C_i = X_i^C \qquad (12)$$

For a given level of output, the corresponding technical efficient, cost efficient and actual costs of production are equal to $W_i X_i^T$ , $W_i X_i^c$, and $W_i X_i$, respectively. These three cost measures are then used as the basis for calculating the technical and cost efficiency scores for the $i$th farm as follows:

$$TE_i = \frac{W_i X_i^T}{W_i X_i} \qquad (13)$$

and

$$CE_i = \frac{W_i X_i^C}{W_i X_i} \qquad (14)$$

The allocative efficiency can be calculated based on Farrell's methodology which states that the cost efficiency (CE) is divided by the technical efficiency (TE) to get allocative efficiency:

$$AE_i = \frac{W_i X_i^C}{W_i X_i^T} \qquad (15)$$

The computer program, FRONTIER version 4.1 (Coelli, 1996a) is used to estimate the model. The programme gives the maximum likelihood estimates for the parameters of the model as well as the technical efficiency scores whereas a the allocative and cost efficiency scores were computed using a programme that was written and implemented in STATA version 10.0.

### *3.2. Determinants of Efficiency*

For policy implications, the factors that cause these efficiencies need to be identified through investigation of the relation between the calculated TE, AE, EE and the farm/farmer specific variables. Thereafter, the association between the farm/farmer specific variables can then be established. The efficiency scores are regressed on the selected variables using a Tobit model. The model was specified as follows:

$$EFFICIENCY = f(AGE, GENDER, EDUCATION, OFFFARMINC, LANDSIZE, EXP) \qquad (16)$$

with variables as explained in Table 1.

## 4. Results and discussions

Table 2 presents the maximum likelihood (ML) and the ordinary least squares (OLS) estimates of the SFPF. Results show that the input coefficients in the two models are positive as expected and significant at the 1 percent level except for the intercept and the coefficient of land. This means that these inputs contribute to increased output. The sum of the coefficients is 1.652 indicating increasing returns to scale. The largest contributor to the small-scale sugarcane farmers' production is labour which has an elasticity of 0.365. This means that a 10 percent increase in labour supply will increase output by 3.65 percent. This is an expected result with the case of sugarcane because all the activities are done manually except for irrigation even though it does need labour for changing the sprinkler positions. On the contrary to Basnayake and Gunaratne (2002), land is not significant in the production of sugarcane which implies that the size of land does not matter. This implies that other factors are at play when it comes to land utilization, for example, proper management can help the farmer achieve more production even on a small piece of land.

 

**Table 2: The MLE and OLS estimates of the SFPF**

| Variable | OLS Estimates | | ML Estimates | |
|---|---|---|---|---|
| | Coefficient | Standard error | Coefficient | Standard error |
| lnIntercept | -0.895 | 0.571 | 0.606 | 0.562 |
| ln(LABOUR) | 0.391*** | 0.069 | 0.365*** | 0.056 |
| ln(HERB) | 0.286*** | 0.103 | 0.309*** | 0.088 |
| ln(FERT) | 0.286*** | 0.085 | 0.309*** | 0.078 |
| ln(LAND) | 0.084 | 0.087 | 0.063 | 0.082 |
| Adjusted $R^2$ | 0.841 | - | - | - |
| $\gamma$ | - | | 0.9893*** | 0.614 |
| $\sigma^2$ | | -279.72 | 0.897 | 0.790 |
| $\mu$ | | | -1.736 | 2.214 |
| Log-Likelihood | | | -259.67 | - |
| LR-Test | | | | 69.33 |

*****Significant at 1 percent probability level**

The dual cost frontier is given as:

$$lnCi = 0.677695 + 0.348948 \ln W_{LAND} + 0.295411 \ln W_{FERT} + 0.295411 \ln W_{HERB} + 0.0609229 \ln W_{LABOUR} + 0.9560229 \ln Y^*$$

where C is the cost of production for the $i$th farmer. $W_{LAND}$ is the average rental price of land per hectare estimated at R3218.79. $W_{FERT}$ is the average price of fertilizer per kg estimated at R44.14. $W_{HERB}$ is the price of herbicide per litre estimates at R23.98. $W_{LABOUR}$ is the average price of labour per day estimated at R49.15.

From the results, it is evident that the technical efficiency scores range from 55.4 to 80.3 with a mean of 68.3 percent. The presence of technical inefficiency indicates the potential output gains without increasing input use. This means that if the small-scale farmers were to operate on the frontier, they will achieve a cost saving of 24.8 percent. On the other hand, if the average small-scale farmer in the sample was to achieve the TE level of its most efficient fellow farmer, then the average small-scale farmer could realize a 14.9 percent cost saving, that is, ($1 - [68.3/80.3]$). A similar calculation for the most technically inefficient small-scale farmer shows that a cost saving of 31.0 percent (that is, $(1 - [55.4/80.3]$). None of the respondents had a technical efficiency of 100 percent. The implication of this is that there is room for improvement in the sugarcane production in the study area with the available technology and given sets or resources.

The average allocative efficiency is 61.5 percent with a minimum of 15.6 percent and a maximum of 83.2 percent. This indicates that there is still room to improve allocative efficiency of the small-scale sugarcane farmers by 38.5 percent if they operate on the frontier. This also suggests that if the average small-scale sugarcane farmer was to achieve the allocative efficiency level of its most efficient fellow farmer, the average household could achieve a cost saving of 26.1percent while the least efficient small-scale farmer could achieve a cost saving of 81.3 percent cost saving. On a similar not, none of the respondents had an allocative efficiency of 100 percent. This means that the small-scale farmers could assign the resources to their best alternative uses and prices as well as allow them to execute their allocative functions through input use.

The cost efficiency of the small-scale sugarcane farmers ranges from 11.4 to 53.6 with a mean of 41.8 percent. This gives room for cost efficiency improvement by 58.2 percent if the small-scale farmers were to operate on the frontier. This suggests that the average farmers can gain economic efficiency of 77.9 percent and the least efficient farmer can gain economic efficiency of 78.7 percent. This demonstrates the available potential that the small-scale sugarcane farmers in the study area can exploit to enhance the productivity and profitability through the use of available technology and resources.

According to the results obtained as presented in Table 3, all the variables have positive signs but some are not significant. *EDUCATION* level has a positive and significant impact on all three efficiencies (TE, AE and EE). Thus, as years spent in school increase, it results in increased technical, allocative and economic efficiency. Education's contribution to productivity has been attributed to worker and allocative effects (Welch-effect). The worker effect refers to technical efficiency which implies that a more educated farmer's ability to achieve higher output from a given bundle of inputs. The allocative effect refers to allocative efficiency which means the ability of the educated to obtain, analyze and understand economically useful information about inputs, production practices and commodity mix which enhances their ability to make optimal decisions with regard to input use and product mix. In short, the farmers' managerial capabilities are sharpened the higher the level of education.

 

**Table 3: Frequency distribution of technical (TE), economic (CE) and allocative efficiency measures from the SFA**

| Efficiency (percent) | Stochastic Frontier Approach | | |
|---|---|---|---|
| | TE(Frequency) | CE (Frequency) | AE (Frequency) |
| 100 | 0 | 0 | 0 |
| 90 – 100 | 0 | 0 | 0 |
| 80 – 90 | 0 | 0 | 3 |
| 70 – 80 | 51 | 0 | 51 |
| 60 – 70 | 179 | 0 | 86 |
| 50 – 60 | 1 | 20 | 54 |
| 40 – 60 | 0 | 135 | 23 |
| <40 | 0 | 76 | 14 |
| Mean (percent) | 68.3 | 41.8 | 61.5 |
| Minimum (percent) | 55.4 | 11.4 | 55.4 |
| Maximum (percent) | 80.3 | 53.6 | 83.2 |
| Std Deviation | 0.0299 | 0.0784 | 0.1252 |

**Source: Survey Results, 2011**

Amos (2007) also found that education has a positive relationship with the adoption of new technologies and advisory services which results to improved efficiency. This result is in line with other studies (Belbase and Grabowski, 1985; Kalirajan and Shand, 1986) which found a positive relationship between years of schooling and farm efficiency. Hyuha (2006) also supports the results on the level of education. Thus improving education level of farmers in the Nkomazi region can result in increased production efficiency. However, these findings disagree with the findings of Page and John (1984) and Wang et.al (1996) studies. The finding from these studies was that the relationship between technical efficiency and education is negative.

On the other hand, *LANDSIZE* has a positive and highly significant impact on AE and EE only. The significant relationship implies that the sugarcane farmer can achieve better optimal combination of factors of production is achieved on larger plots than on smaller plots. Increasing population pressure will continue to magnify the problem of land fragmentation with implications on efficient production and maximization of sugarcane production.

Likewise, *EXPERIENCE* has a positive and highly significant impact on EE and AE. This implies that an increase in the duration of the farmer's involvement in sugarcane production increases the productivity of his crop. The level of farming experience helps explain scale efficiency. This suggests that management skill aspects such as the optimal timing of operations are important. Extension education also become effective if targeted to experienced farmers than less-experienced ones. Padilla et al (2001) also discovered that experience is positively related to efficiency.

*AGE* has a positive and significant impact on the level of TE. The results suggest that farmers under the age of forty years have the highest levels of TE. Beniam *et al*. (2004) assume that the older a farmer gets, the more experienced he/she will be. It is argued that older farmers appear to be more efficient than younger farmers due to their good managerial skills, which they have learnt over time. On the contrary, Khan and Saeed (2011) argued that younger farmers are more technically efficient than older farmers, indicating that as younger farmers become more educated they become more efficient. Then again, whether the efficiency goes to the older or the younger farmers depend on the type of crop being cultivated and which age group is more interested in that crop.

Besides, given the importance and significance of land, labour, capital and other resources in farm production, it could be argued that young households are deficient in resources and might not be able to apply inputs or implement certain agronomic practices sufficiently quickly. As timely application of inputs and implementation of management is expected to enhance efficiency, young farmers may find this challenging. These results are in line with the findings obtained by Kalirajan and Shand, (1985), Kalirajan and Flinn (1983) and Belbase and Grabowski (1985). Hussain (1989) concluded that older farmers are more risk averse to new technologies than younger farmers.

In addition, the results indicated that the farmer's participation if *OFF-FARM* employment negatively and significantly affects allocative efficiency. As far as the impact of off-farm employment on technical efficiency is concerned, the literature offers mixed results. Some argue that off-farm labour supply curtails farming efficiency (Abdulai and Huffman, 2000). Others contend that the additional income generated by other household members, who engage in off-farm employment, can more than compensate for the constraints caused by reduced farm labour availability. For instance, Pascaul (2005) indicate that lack of finance from off-farm income to purchase seeds seriously hampers farmers' efficiency levels. Tesfay *et al.* (2005) also found out positive impact of off-farm employment on technical efficiency.

Table 4: Tobit model results for the impact of farm/farmer characteristics on efficiency.

| Variable | TE | AE | CE |
|---|---|---|---|
| Intercept | 4.326*** | 3.627*** | 2.364*** |
| Age | (0.024) | (0.313) | (0.318) |
| Education level | 0.0712** | -0.411 | -0.034 |
| Off-farm income | (0.063) | (0.0411) | (0.0121) |
| Land size | 0.602* | 0.659* | 0.801** |
| Years experience | (0.182) | (0.452) | (0.432) |
| Gender | 0.008 | -0.034* | -0.064 |
| Log-likelihood | (0.009) | (0.042) | (0.052) |
| | 0.051 | 0.543*** | 0.623*** |
| | (0.022) | (0.101) | (0.106) |
| | 0.030 | 0.321*** | 0.380** |
| | (0.025) | (0.211) | (0.217) |
| | 0.001*** | 0.002 | 0.002 |
| | (0.001) | (0.00) | (0.00) |
| | 38.5 | -26.5 | -33.8 |

**Source: Survey Results, 2011**

It may also be hypothesised that managerial input may be withdrawn from farming activities with increased participation of the educated in off-farm activities, which leads to lower efficiency. Abdulai and Eberlin (2001) found higher inefficiency of production with involvement of household in off-farm activities. In any case, the effect of off-farm occupation on production efficiency may not be determined beforehand. In this study, involvement in off-farm activity, though insignificant, was found to have positive sign in reducing inefficiency. This implies that the farmers does not spend the much needed time in his or her farm and thus production inputs may incorrectly used at times. Padilla et al (2001) also supports the result of off-farm employment by concluding that if the farmer spends more time in his off-farm duties, the more he becomes inefficient.

## 5. Conclusions and policy implications

This study estimated the stochastic production frontier function. The technical, allocative and economic efficiencies of 231 smallholder sugarcane farmers in the Nkomazi region of the Mpumalanga province were estimated. The maximum likelihood estimation method was used to estimate the Cobb Douglas stochastic frontier production and the cost functions. Various farm/farmer socio-economic characteristics explained the estimated technical, allocative and economic efficiencies. The results indicated that the average technical efficiency index of 68.3 percent. There was no individual farmer who attained a 100 percent technical efficiency. This is an indication that with all available resources farmers can still improve their efficiency. The average allocative efficiency is 61.5 percent with a minimum of 15.6 percent and a maximum of 83.2 percent. This indicates that there is still room to improve allocative efficiency of the small-scale sugarcane farmers by 38.5 percent if they operate on the frontier. This means that the small-scale farmers could assign the resources to their best alternative uses and prices as well as allow them to execute their allocative functions through input use. The cost efficiency of the small-scale sugarcane farmers ranges from 11.4 to 53.6 with a mean of 41.8 percent. This demonstrates the available potential that the small-scale sugarcane farmers in the study area can exploit to enhance the productivity and profitability through the use of available technology and resources. With regards to the sources of efficiency, the study concluded that age, level of education and gender are significant determinants of technical efficiency. On the other hand, level of education, off-farm income, land size and experience are significant determinants of allocative efficiency. In as far as cost efficiency is concerned; the significant determinants are level of education, land size and experience in sugarcane farming. The most important policy implications of this study is that there is enough potential for increased productivity among the small-scale sugarcane farmers of the Nkomazi region. The study recommends that policies to provide for adequate farmer education programs (Adult Based Education and Training-ABET) among the small-scale sugarcane farmers would reduce technical, allocative and economic inefficiencies. A review of agricultural policy with regards to renewed public and private support to refurbish agricultural extension system is needed. The quality and adequacy of extension services in South Africa needs to be upgraded.

## 6. References

*Abdulai, A. & Huffman, W.E. (2000). Structural adjustment and economic efficiency of rice farmers in Northern Ghana.* **,** *Economic Development and Cultural Change, 48(3), 503-520.*

Amos, T.T. (2007). An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria.

*Journal of Social Science,* 15(2): 127-133.
Andreu, M.L. (2008). *Studies on the economic efficiency of Kansas farms*. Unpublished PhD Thesis, Department of Agricultural Economics, Kansas State University.
http://krex.k-state.edu/dspace/bitstream/2097/952/1/MonicaLopezAndreu2008.pdf
Basnayake, B.M. & Gunaratne, L.H. (2002). Estimation of technical efficiency and its determinants in the tea small holding sector in the mid-country wet zone of Sri Lanka. *Sri Lanka Journal of Agricultural Economics,* 4: 137-150.
Belbase, K. & Grabowski, R. (1985). Technical efficiency in Nepalese agriculture. *Journal of Developing Areas, 19*: 515-525.
Beniam, N.J., Tonye J., Wandji, N., Nyambi, G, and Akoa, M. (2004). *Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon.*
Berry, R. & Cline, W.R. (1979). *Agrarian structure and productivity in developing countries.* Baltimore: The John Hopkins University Press.
Bhasin, V.K. (2002). *Agricultural productivity, efficiency and soil fertility management practices of vegetable growers in the upper east region of Ghana,* Sadoc Foundation Research Publication, Ghana.
Bravo-Ureta, B. & Rieger, L. (1991). Dairy farm efficiency measurement using Stochastic Frontiers and Neoclassical Duality. *American Journal of Agricultural Economics,* 73:421-428.
Coelli, T.J. (1995). Recent developments in frontier modelling and efficiency measurement, *Australian Journal of Agricultural Economics*, vol. 39: 219– 245.
Coelli, T. J. (1996). *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*, CEPA Working Paper 96/07
Debreu, G. (1951). The coefficient of resource utilization. *Econometrica,* 19: 273–92.
Department of Agriculture Forestry and Fisheries (DAFF) (2011). *The Strategic Plan of South African Agriculture 2001*. Available at: http://www.nda.agric.za
Department of Agriculture Forestry and Fisheries (DAFF) (2010). *The Strategic Plan of South African Agriculture 2001*. Available at: http://www.nda.agric.za
Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society Series A* , *120*, 351-381.
Haghiri, M. (2003. *Stochastic non-parametric frontier analysis in measuring technical efficiency: A case of the North American dairy industry*. An unpublished PhD thesis, Department of Agricultural Economics, University of Saskatchewan, Saskatoon.
Hussain, S. (1989). *Analysis of Economic Efficiency in Northern Pakistan: Estimation, Causes and Policy Implications*. Ph.D. diss., University of Illinois.
Hyuha, T. 2006. Profit efficiency among rice producers in Eastern and Northern Uganda. Unpublished PhD Thesis. Makerere University
Kalirajan, K.P. and Shand, R.T. (1985). Types of education and agricultural productivity: A quantitative analysis of Tamil Nadu rice farming. *Journal of International Development Studies*, 21: 232–43.sout
Kalirajan, K.P. (1981). A econometric analysis of yield variability in paddy production. *Canadian Journal of Agricultural Economics, 29* , 283-294.
Kalirajan, K.P. & Shand, R.T. (1989). A generalised measure of technical efficiency. *Applied Economics, 21* , 25-34.
Kalirajan, K.P. & Flinn, J.C. (1983). The measurement of farm-specific technical efficiency. *Pakistan Journal of Applied Economics, 2* , 167-180.
Kalirajan, K.P. (1991). The importance of efficient use in the adoption of technology: A micro panel data analysis. *Journal of Productivity Analysis, 2* , 113-126.
Khan, H. And Saeed, I. (2011). Measurement of technical, allocative and economic efficiency of tomatoe farmers in Northern Pakistan. *A paper presented at the International Conference on Management, Economics and Social Sciences (ICMESS), Bangkok, December 2011.*
Koopmans, T.C. (1951). An analysis of production as an efficient combination of activities. In T.C. Koopmans, (Ed) *Activity analysis of production and allocation,* Cowles commission for research in economics, Monograph No.13, New York: John Wiley & Sons.
Maloa, F. (200)1. *Employee perception of a performance management system*. Unpublished Masters Dissertation. Pretoria: University of South Africa
Padilla-Fernandez, M.D. & Nuthall, P.L. (2009). Technical efficiency in the production of sugarcane in Central Negros area, Philippines: An application of Data Envelop Analysis. *Journal of the International Society for Southeast Asian Agricultural Sciences,* 15(1):77-90.
Page, M.J. and John, M. (1984). Firm size and technical efficiency: applications of production frontiers to Indian survey data. *Journal of Development Economics*, 16:29–52.
Pascual, U. (2005). Land use intensification potential in slash-and-burn farming through improvements in

technical efficiency, *Ecological Economics*, 52, 497–511.
South African Sugar Association (SASA). (2011). *The South African Sugar industry: Facts and Figures.* Available at: http://www.sasa.org.za
South African Sugar Association (SASA). (2010). *The South African Sugar industry: Facts and Figures*. Available at: http://www.sasa.org.za
Tesfay G., Ruben. R., Pender, J. and Kuyvenhoven, A. (2005). *Resource use efficiency on own and sharecropped plots in Northern Ethiopia: determinants and implications for sustainability.*
Vink, N., Tregurtha, N., & Kirsten, J. (2008). Presidency fifteen year review report review of agricultural policies and support. Pretoria, South Africa: ComMark Trust.
Wang J., Crammer, G. C. and Wailes, E. J., (1996). Production efficiency of Chinese agriculture: Evidence from rural household survey data*. Agricultural Economics Journal* 15(1):17-28

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

## CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

**Prospective authors of journals can find the submission instruction on the following page:** http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

## MORE RESOURCES

Book publication information: http://www.iiste.org/book/

### IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar