Analysis of efficiency in sugarcane production: the case of men and women headed households in SONY sugar out -grower zone, Rongo and Trans-Mara districts, Kenya

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Abstract

About one quarter of cane producers in SONY Outgrower Zone are women headed households. However, a number of studies have suggested that women in rural areas are more disadvantaged in terms of accessing education, land, credit, and extension services. If this is the case, women cane farmers would be expected to be less efficient compared to men farmers. Before this can be concluded, there was need to establish whether differences in economic efficiency between men and women headed households exist in cane growing. The objectives of the research were; to characterize men and women headed cane growing households, to evaluate the relationship between institutional factors and gender, and to determine the differences in economic efficiency between men and women managed sugarcane farms. A multi stage sampling procedure was employed to select 205 active sugarcane farmers. A dual parametric stochastic decomposition technique was employed to disaggregate the components of economic efficiency. FRONTIER 4.1 program was used to derive maximum likelihood estimates and farm level technical efficiencies. A two limit Tobit model was then used to determine the influence of selected socio-economic and institutional variables on farm level technical, allocative and economic efficiency. Results showed that men headed households had a mean technical efficiency of 67.6%, a mean allocative efficiency of 82.48% and a mean economic efficiency of 58.0%. Women headed households had a mean technical efficiency of 72.0%, a mean allocative efficiency of 83.15% and a mean economic efficiency of 62.5%. Land under sugarcane cultivation was the single most important contributor to farmers' efficiency. Women managed farms were on average more technically, allocative and economically efficient than men managed farms. Membership to outgrower associations in addition to encouraging increase in human capital will be important in enhancing farmers' efficiency.

Key words: efficiency, Kenya, sugarcane productivity, stochastic frontier functions,

Introduction

The goal of increasing agricultural productivity and employment in Sub- Saharan African countries has received widespread attention in the literature on economic development and poverty alleviation (Abdulai, 2000). Typically, the backbone of Kenya's economy is agriculture. It directly contributes 26% of GDP and 60% of the country's export earnings. The sector also indirectly contributes a further 27% to the Gross Domestic Product (GDP) through links with the manufacturing, distribution and other service related sectors. (Sserunkuma, 2005).

Sugarcane is mostly grown in western Kenya, which also predominantly comprises of low income earners(KNBS,2005) By 2005, the Kenyan sugar sector was estimated to produce about 490,000 tonnes of processed sugar, against a domestic demand of 600,000 tonnes (Sserunkuma et al, 2005). The country therefore had a sugar deficit of about 110,000 tonnes, the bulk of which it imported from the Common Markets of Eastern and Southern Africa (COMESA) region.

The out grower schemes in Kenya are part of a production structure of the sector and were 19 in number by the end of 2005 (Sserunkuma 2005). The out grower schemes undertake the bulk of the production activities, and thus play a crucial role in the planning, production and allocation of resources to the communities in the production zones. Sugarcane is farmed under two modes: the outgrower and the plantation mode. The plantation is carried out by SONY Sugar Company in land surrounding the factory in what are referred to as nuclear estates. In addition, through its outgrower scheme, the company recruits, contracts and organizes men and women farmers in ploughing, harrowing, furrowing, seed cane, fertilizer and herbicide supply. The company recovers these costs once sugarcane is harvested and supplied to the company.

Despite policy reforms that have been undertaken in recent years, primarily aimed at the liberalization of the agricultural sector from government control, there has been a marked decline in crop productivity (Marinda *et al*, 2006).Among the reasons put forward for this decline include: area contraction, climatic factors, technological change, and price, both domestic and world market prices.

Between 1996 and 2005, the proportion of women headed rural households in Kenya rose from 30% in 1996 (World Bank, 1996) to about 37% in 2005(KNBS, 2005).This increase has been attributed to widowhood (arising from several factors, such as the AIDS pandemic), divorce or separation. It is therefore imperative that the release of women's collective productive potential is crucial in breaking the vicious cycle of poverty, as it will enable them to contribute more meaningfully to economic growth and prosperity (GoK, 2004). At the time of the research (2009), men headed households comprised 77.4% of cane growers in the two districts under study.

This study aimed to establish the current levels of economic efficiency of smallholder men and women sugarcane producers in Rongo and Trans Mara Districts in Kenya and to identify factors that are significant in influencing levels of economic efficiency differentials between men and women farmers.

The Study area

The study area covered Rongo and Trans-Mara Districts, situated in the south-western part of Kenya. Sugarcane is the main cash crop in both districts. The districts are characterized by reliable rainfall, with a mean annual rainfall of 1500 mm. Maximum temperatures range between 28° C and 34° C. Minimum temperatures range between 18° C to 22° C(Kenya Meteorological Services, 2010) The summed population of both Rongo and Trans Mara Districts was 685,488 persons (1999 census). The two districts have a mean altitude range of between 1,500 and 2,000 meters above sea level, with a few places in Trans Mara being above 2,000 meters above sea level.

Data

Out of the seven districts in SONY Sugar belt two districts were purposively selected for the study. Thereafter stratified random sampling technique was used to select 205 men and women headed households for the 31 sub locations comprising the study area. Data was collected with the use of a structured questionnaire on output levels and input use of sugarcane production, institutional factors, as well as socio-economic characteristics of men and women farmers. The questionnaire was pre tested in the field for its validity, in addition to ensuring that it was in line with study objectives. Additional data on five productive inputs namely: land area under sugarcane production (acres), family and hired labor (man-days), quantity of fertilizer (kg), quantity of seed cane (tonnes), and quantity of herbicides (litres) were collected. Labor was measured in man-days with one man-day being equal to 8 hours of labor. Further average district-wide input and output prices for input and output was collected as well.

Analytical framework

Cobb-Douglas stochastic frontier production function was employed to estimate the level of technical efficiency. Stochastic frontier models are based on econometric estimation procedures, augmented by an error term composed of two components. One is a symmetric random component, due to measurement error on output levels, random shocks (such as luck, unusual weather conditions) and omitted variables. The other is a non-symmetric component representing technical inefficiency. Battese and Coelli (1995) proposed a single stage approach where efficiency is a function of farm specific variables and the random error term. The major assumption made in this approach is that the farm specific variables and the input variables interact between them. It thus enables one to express technical inefficiency effects in terms of various farm-specific variables.

A parametric stochastic efficiency decomposition approach was employed to measure the economic efficiency indices of sugarcane production in SONY Outgrower zone. The approach, used by Bravo-Ureta and Pinheiro (1997) is an extension of the economic efficiency estimation procedure suggested by Kopp and Diewert in 1982. The advantage of employing this approach lies in the fact that the model's disturbance term specification captures white noise, measurement error and other exogenous shocks that lie beyond a firm's production unit.

Given the generic stochastic frontier production model as below:

$$\mathbf{Y_1 = \boldsymbol{f}(X_1; \boldsymbol{\beta}) + \boldsymbol{\xi}_i} \quad (1)$$

where,

Y_1 = Output quantity.

X_1= Input vector.

β = Vector of parameters to be estimated.

ξ_i =Composite error term.

Following the seminal work on parametric stochastic frontier models by Aigner, *et al* (1977) and Meeusen, *et al*(1977), the composite term is broken into two components.

Thus: $\xi_i = \nu_i - \mu_i$ (2)

where,

$\nu_i \sim N(0, \sigma_v^2)$ represents the random variability in production that is outside the control of producers.

$\mu_i \sim N(0, \sigma_v^2)$ is identically and independently distributed(iid) as half-normal, and measures the technical inefficiency in production.

The Cobb- Douglas functional specification, used to model for sugarcane production technology was also used to provide maximum likelihood estimators for $\sigma^2 = \sigma_v^2 + \sigma_u^2$, and $\gamma = \sigma_u^2 / \sigma^2$. Following Jondrow, *et al* (1982), the conditional mean of μ_i is measured using the formula below:

$$E(\mu_i/\xi_i) = \sigma \left\{ \frac{f*(\lambda \xi i/\sigma)}{1 - F*(\lambda \xi i/\sigma)} - \frac{\lambda \xi i}{\sigma} \right\} \quad (3)$$

where,

$\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$

F* = Distribution function

f* = Standard normal density function

From (3), estimates of both ν_i and μ_i can be found.

To adjust for noise and other stochastic disturbances, ν_i is subtracted from (1). This yields the adjusted output of the *ith* firm, Y_i^* as shown below:

$$Y_i^* = f(X_1; \beta) - \mu_i \quad (4)$$

The adjusted output is then used to derive the *ith* firm technically efficient input vector, X_{it} by the simultaneous solution of (4) and the observed input ratios, $X_1/X_i = k_i$.

Xu, *et al* (1998) utilize the assumption of duality, whereby the dual cost frontier is derived from the primal Cobb-Douglas production function, i.e. equation (1).

The generic dual cost frontier thus derived can be expressed as below:

$$C_i = h(P_i , Y_i^* , \Phi) \tag{5}$$

Where,

C_i = minimum cost of the *ith* firm due to Y_i^*.

P_i = Input price vector.

Φ = Vector of parameters to be estimated.

From (5), the economically efficient input vector for the *ith* firm, X_{ie} is derived by, firstly applying Shephard's Lemma, then secondly, substituting the firm's input price and the adjusted output levels into the derived system of input demand equations given by the formula below:

$$\delta C_i / \delta P_k = X_{ie} (P, Y_i^* , \Phi) \tag{6}$$

Given that the observed costs of production of the ith firm are calculated by $\sum X_i P_i$, and the economically efficient costs as $\sum X_{ie} P_i$, the economic efficiency index(EE) is thus computed by determining the ratio of the two, thus:

$$EE = \frac{\sum X_{ie} P_i}{\sum X_i P_i} \tag{7}$$

Since economic efficiency indices are the product of technical and efficiency indices, firm level allocative efficiency indices are calculated by dividing equation (7) by the respective farm technical efficiency indices earlier derived using the FRONTIER 4.1 computer program.

Results and Discussion

Means comparison for men and women headed households

Table 1: T- test results of selected variables for men and women headed households

	MHH		WHH			
Variables	Mean	Std. Error	Mean	Std.Error	T	
Level of education(No.of years)	11.906	0.247	10.893	0.484	-1.922	*
Sugarcane output(tonnes)	25.009	1.555	20.457	3.85	-1.282	
Men labour(man-days)	312.01	20.409	280.109	66.812	-0.612	
Women labour(man-days)	27.905	13.002	19.717	6.998	-0.335	
seed cane quantity(tones)	1.673	0.103	1.428	0.176	-1.142	
Urea(kilograms	148.11	11.161	116.304	10.773	-1.475	
DAP(kilograms)	134.28	10.32	101.087	10.011	-1.664	*
Herbicide(knapsack)	1.245	0.495	1.261	0.114	0.141	
Age(years)	45.79	0.656	45.609	0.936	-0.139	
Visits by extension officers	0.937	0.076	0.826	0.159	-0.675	
Distance from farm to factory(kilometers)	16.882	0.858	16.948	1.828	0.035	
Land size(acre)	2.02	0.102	1.789	0.227	-1.042	
Land under sugarcane(acre)	0.762	0.045	0.671	0.126	-1.175	
Amount of credit borrowed (KSh)	13000	1.718.88	12800	5,919.48	2.888	***
land hire rates(/acre)	7336.67	948.46	9000	1516.76	1.035	

* ** *** Significant at 1%, 5% and 10% respectively

Source: Field Survey (2011)

Table 1 shows the t test results for men and women headed household in the study area. At 1% level, men farmers had a higher level of formal education (11.906 years) compared to women farmers (10.983) years. At 1% level men farmers utilized significantly more of DAP fertilizer compared to their women counterparts. Men farmers applied on average 134.28 kilogrammes, while women farmers applied 101.9 kilogrammes. At the 10% level, Women farmers borrowed on average KSh 12,800, while men farmers KSh 13,000 to finance sugarcane production. All the other variables tested- output, men labour, women labour, Urea application, seed cane, herbicide, farmers' age, visits by extension workers, land size, and land hire rate- were found not to be significant with respect to men and women farmers.

Table. 2 shows pooled ordinary least square and maximum likelihood estimates of the Stochastic Production Frontier. The estimates were derived using FRONTIER 4.1 computer program developed by Coelli (1996).

Table 2: Pooled Maximum likelihood estimates for Men and women Sugarcane farmers

	Ordinary Least Squares			Maximum Likelihood Estimates		
Variable	Coefficient	Std. error	t-ratio	Coefficient	Std. error	t-ratio
Constant	1.388	0.345	4.025	4.133***	0.142	29.089
Land under sugar	0.130***	0.103	1.272	0.839***	0.025	34.193
Fertilizer	-0.025***	0.048	-0.525	-0.035**	0.002	-3.798
Labour	0.023***	0.043	0.559	0. 09	0.009	0.101
Seed-Cane	0.103	0.056	1.828	0.046	0.030	-1.520
Herbicide	0.633	0.097	6.545	0.059**	0.022	2.665
Function coefficient	0.864			1.069		
F-statistic model	44.9					
F-statistic CRTS						
σ_μ				0.881		
$\sigma_{\acute{v}}$				0.462		
$\lambda - \sigma\mu/\sigma\acute{v}$				1.909		
σ^2				0.694	0.086	8.082
$\Upsilon = \sigma_\mu^2/(\sigma_\mu^2 + \sigma_{\acute{v}}^2)$				0.874	0.771	12.963
Log likelihood	-18.527			9.89		
Adjusted R^2	0.9025					

Source: Field Survey (2011)

The value of the adjusted R^2 indicates that 90.25% of the variation in sugarcane yields can be explained by the variables included in the model (land under sugar, fertilizer, herbicide, seed cane and labour). The overall model was significant with an F-statistic of 44.9.The gamma (γ) parameter was used to test the randomness or otherwise of the observed variations in efficiency. At the 5% level of significance, the null hypothesis of random observations was rejected, implying inefficiency in sugarcane production amongst farmers in SONY Outgrower zone. The value (0.874) is closer to one, indicating inefficiency arising from farm practices and farm/household characteristics rather than random factors. The Likelihood ratio statistic used to test the validity of the Stochastic Frontier Production function returned a value of 9.89. This exceeded the critical value, i.e. $\chi^2_{1,0.95}$=3.84, implying that the Cobb-Douglas Stochastic Production Function provided a robust description to the observed data compared to the Ordinary Least Squares regression. Land under sugar, fertilizer and herbicide application were found to be significant in determining sugarcane yields. A 1% increase in land acreage under sugarcane increased output by 0.839%. At the same time, a 1% increase in fertilizer application decreased output by 0.035%. Herbicides application positively impacted sugarcane output, with a 1% increase in the same resulting in a 0.059% increase in output.

Table 3: Frequency Distribution for Men and Women Farmers Economic Efficiencies

Economic Efficiency(%)	All		Men Farmers		Women Farmers	
	No.	Percentage	No.	Percentage	No.	Percentage
more than 90	7	3.4	5	3.1	2	4.3
80 to 90	19	9.3	10	6.3	9	19.6
70 to 80	29	14.1	18	11.3	11	23.9
60 to 70	50	24.4	48	30.2	2	4.3
50 to 60	51	24.9	40	25.2	11	23.9
40 to 50	28	13.7	22	13.8	6	13.0
30 to 40	13	6.3	10	6.3	3	6.5
20 to 30	0	0	0	0	0	0
10 to 20	0	0	0	0	0	0
less than 10	8	3.9	6	3.8	2	4.3
Sample	205		159		46	
Mean(%)	59.0		58.0		62.50	
Minimum(%)	0.1		0.1		1.7	
Maximum(%)	99.1		99.1		95.2	

Source: Field Survey (2011)

The results on the distribution of economic efficiency indices are presented in Table. 3. A majority of farmers(63%) -had economic efficiency indices ranging between 40% and 70%. The predicted economic efficiencies ranged from 0.1% to 99.1%, with the typical average sugarcane farmer in SONY Outgrower Zone having an average of 59.0% economic efficiency. A larger number (47.8%) of women farmers had economic efficiency indices of 70% and above, compared to 20.7% for men farmers. A typical sugarcane farmer, were they to operate on the most economically efficient frontier would realize a cost saving of 40.46%. In addition, a typical man and woman sugarcane farmer would realize cost saving of 41.47% and 36.93% respectively were they to operate on the most economically efficient frontier.

A two limit Tobit model was used to derive technical, allocative and economic efficiency indices as a function of a vector of selected socioeconomic and institutional variables. Table 4 shows the results of the parameters and the computed t values.

Table 4: Two limit Tobit parameter estimates for determinants of efficiency

(Dependent variable= technical, allocative and economic efficiency)

Variable	TE		AE		EE	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Constant	0.8059**	2.83	0.8484***	2.83	0.7806***	2.42
Gender(*Gender*)(Men=1, 0 otherwise	-0.0354	0.266	0.0057	0.2	-0.03628	-1.18
Education(*Edlev*)	-0.0582	-1.25	-0.08443**	-2.02	-0.0663*	-1.47
Outgrower membership(*Socinc*) (Menber=1, 0 otherwise)	0.0625**	2.09	0.08827***	3.28	0.05275*	1.82
Extension access(*Extacc*)(Access=1, 0 otherwise)	0.0201*	0.515	0.0201*	-0.8	0.0159*	0.59
Credit access(*Creuse*) (Access=1, 0 otherwise)	0.0097	0.834	0.0187	0.45	0.0231	-0.52
Age(*Age*)	0.0474	0.06	0.06707	0.5	-0.00684	-0.09
Log-likelihood	53.33		75.322		60.87	

* ** *** represent significance at the 10%, 5% and 1% level, respectively

Membership to farmers' outgrower groups had a positive and significant impact on farmers' technical, allocative and economic efficiencies, suggesting the success of such associations in improving the overall efficiency in sugarcane production. These findings are consistent with those of Nchare (2007), Chirwa (2007) and Nyagaka, *et al* (2009) who found that the technical, allocative and economic efficiencies of smallholder Irish potato producers in Nyandarua North District, Kenya had a positive relationship between membership to farmers' association and economic efficiency. Seyoum, *et al* (1998) found that membership to a farmers association was responsible in a 14% reduction in farmers technical inefficiency. These studies emphasize the following benefits of farmers belonging to farmers' associations as: skills acquisition through common interest groups, access to informal credit, either through lending amongst themselves (merry-go rounds) and table banking, and securing of cheap labour during critical stages of sugarcane cultivation.

The inverse and significant relationship between farmers' level of education and their respective allocative and economic efficiency indices implies that farmers with relatively few years of formal schooling are on average more allocativelly and economically efficient compared to those with more years .Given the fact that farmers' level of education and farmers' age are negatively correlated-, it may imply that younger farmers are better placed to take advantage of new emerging information and improved farm technologies at a faster rate than older farmers. With better education, it may be argued that, *ceteris paribus,* farmers ability to perceive, interpret and assimilate new farming ideas and technologies is enhanced, leading to an increase in economic efficiency. The findings are consistent with Bravo –Ureta, *et al* (1997) who found a negative relationship between farmers' educational level and economic efficiency.

Access to credit facilities to sugarcane farmers contributes positively to farmers' economic efficiency. This is in line with a number of studies carried out on the influence of credit access and farmers economic efficiency (Nchare (2007), and Abdulai, *et al* (2001)). By enabling farmers to overcome liquidity constraints imposed by their limited income, access to credit enables the timely application of farm inputs, in addition to enabling them to effectively implement farm management decisions, leading, *ceteris paribus*, to an increase in respective farmers' productive efficiency. Despite this, credit access in the study area was low, with less than 10% of the farmers reporting having accessed credit for sugarcane cultivation.

The results also reveal an inverse, though insignificant relationship between the coefficient of gender and farmers' technical and economic efficiency. This suggests that women farmers are comparatively more technically and economically efficient compared to men farmers. However the positive coefficient with regard to allocative efficiency would seem to suggest that men farmers allocate their resources in a more efficient manner.

At 10% level of significance, farmers' access to extension services was found to have a positive effect on their technical, allocative and economic efficiency, implying that households with increased contacts with extension officers tend to be more efficient than those with less contact. Knowledge gained from contact with extension officers positively influence sugarcane producers in terms of adoption of modern technological and management practices. The findings are consistent with those of Xu and Jeffrey (1998) and Nyagaka, *et al* (2010) who found that increased farmers contact with extension officers tended to improve their managerial ability, resulting in efficient utilization of existing technology.

Lastly, farmers' age, used in this study as a proxy for experience, was positive, though insignificant in influencing farmers' technical, allocative and economic efficiency. This would have the implication that in term of the uptake of new technology/innovations, farmers would adopt the same regardless of their respective ages.

Conclusion and Policy Implications

Conclusions

There were significant differences between men and women farmers with respect to the following variables: Educational level (ρ=0.1)), DAP fertilizer application(ρ=0.1) and the amount of credit use to finance sugarcane growing (ρ=0.01). The relationship between farmers' gender and credit and extension access was significant. The relationship between farm ownership, land size, distance and farmers' contract status on the other hand were significant.

Pooled stochastic Cobb Douglas regression results showed land under sugar to be the single most important variable in positively influencing farmers' efficiency. Other significant variables are herbicide application and fertilizer use. Returns to Scale results showed women farmers were operating at the economically relevant Stage 2 of production. Men farmers were operating at Stage 1 of the same, suggesting underutilization of farm inputs in sugarcane cultivation by men farmers.

There was a wide variation in the technical and economic efficiency amongst farmers . Overall, though the difference in the technical, allocative and economic efficiency indices of men and women farmers was not significant, women farmers were more efficient compared to their men counterparts, both from a technical and efficiency perspective, implying that they ended up being more economically efficient.

Policy implications

The research findings that women farmers may be more efficient compared to men farmers has important policy implications, especially given the fact that a number of studies carried out have arrived at a conclusion that is contrary to this study. It will be useful if further investigations were to be carried out as to the socio-economic and institutional factors that appear to favor women sugarcane farmers at the expense of men sugarcane farmers.

Policies aimed at expanding the area, or acreage under sugarcane need to be encouraged so as to increase efficiency. This may be through the government, either through SONY Sugar Company formulating and implementing strategies aimed at incentivizing out growers in allocating more of their land to sugarcane production.

Significant potential exists insofar as enhancing sugarcane farmers' economic efficiency is concerned. With the average sugarcane farmer having an economic efficiency of 59.0%, the study concludes that cost savings of up to 40.95% would ensue were they to operate at their most economically efficient level.

The inverse relationship between farmers yield and the level of fertilizer application points to the possibility that sub optimal quantities of Urea and DAP are being used in sugarcane production, in particular, that more quantities of the two fertilizer are being applied than is necessary, to the extent that they result in decline in sugarcane yields. In addition, this would be indicative of the failure of extension systems to adequately advise farmers' on the optimal quantities of fertilizers to apply. There will thus be need for a rethink of extension strategies with particular focus on input use.

The positive and significant relationship between farmers' access to formal credit and economic efficiency suggests that, to the extent possible, policymakers should encourage the establishment of formal credit outlets. This can be achieved through the enactment and enforcement of requisite legal framework whose aim will be to facilitate farmers' access to cheaper credit facilities to finance sugarcane cultivation. In addition, farmers should be encouraged to mobilize their savings through the establishment of SACCOs and the strengthening of extant community based lending systems. In addition, the reasons for the low uptake of formal credit need to be investigated and appropriate strategies formulated so as to encourage more sugarcane farmers to take up loans as an effective way of financing sugarcane cultivation.

The positive impact on education on farmers' economic efficiency suggests its importance in increasing farmers overall efficiency. There is therefore need for policymakers to continue promoting formal schooling so as to enhance sugarcane productive efficiency. In addition, policies and strategies aimed at encouraging sugarcane farmers 'membership need to be encouraged. Such strategies would involve innovative institutional arrangements such as the use of the group approach, strengthening of mass media, and the employment of farmer led field schools.

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