Estimation of Technical Efficiency in Tanzanian Sugarcane Production: A Case Study of Mtibwa Sugar Estate Outgrowers Scheme

Msuya, Elibariki and Ashimogo, Gasper
Sokoine University of Agriculture

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Elibariki Msuya and Gasper Ashimogo

Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania

Summary

This study describes the technical efficiency of sugarcane production and the factors affecting this efficiency. The study was conducted in Turiani Division, Mvomero District, Morogoro Region, Tanzania. Specifically, the study determined and compared the level of technical efficiency of outgrower and non-outgrower farmers, and examined the relationship between levels of efficiency and various specific factors. A cross sectional single-visit survey that included randomly selected representative samples of 140 outgrower and non-outgrower farmers was conducted. To estimate technical efficiency analysis was done using a (FRONTIER Version 4.1) computer program for stochastic frontier production and cost function estimation developed by Coelli, (1996). Technical efficiency was estimated using the Cobb-Douglas production frontier assumed to have a truncated normal distribution. The results of the estimation showed that there were significant positive relationships between age, education, and experience with technical efficiency.

Key words

Technical efficiency, Outgrowers, Sugarcane, Tanzania

1. Introduction

The plantation as a system of large-scale farming, still occupies a central role in the agricultural sector of Tanzania, particularly in the cultivation, processing and export of cash crops. Plantations play a major role in foreign exchange earnings. The plantation sector contributes more than 55 % of the national foreign earnings (Msambichaka and Bagachwa, 1986). In Tanzania, plantation agriculture is mainly identified with five important export crops, namely, sisal, sugar, tea, coffee and tobacco in order of increasing importance (Maganya, 1990).

At present, the sugar industry is one of the largest agro-processing industries in Tanzania. It contributes approximately 35 percent of the gross output of the food-manufacturing sector and some 7 to 10 percent of total manufacturing value added, (National Development Cooperation [NDC], 1992). The sugar industry is also a major employer with a labour force of about 20 000 including casual labour for cane cutting. The industry also plays a major role in foreign exchange earnings in the country. The sugarcane plantations are categorised into two major production sectors, the estate sector and the outgrowers sector.

The outgrowers were able to produce 245 274 metric tonnes which is about 28 percent of total production of sugarcane in 2000/2001 season (Economic and Social Research Foundation [ESRF], 2002). There are signs that the estates can increase production. The Tanganyika Planting Company Limited (TPC) and Mtibwa Sugar Estate (MSE) have doubled sugar production after privatisation in 1994 (Daily News, 2002).

Although the sugar industry has grown since the privatisation of the estates, the industry has been facing severe problems during the last decade. Some of these problems are; declining production and productivity, increasing cost of production due to increase in input prices for fertiliser, pesticides, farm implement etc., fall in export prices and increased competition from cheap, imported sugar (Senkondo, 1988; Rawlins, 1989; Senkondo and Ashimogo, 1991; Sprenger, 1991; Mbilinyi and Semakafu 1995; and ESRF, 2002).

The management of MSE and Mtibwa Outgrowers Association (MOA), with the help of the Ministry of Agriculture through its extension workers, have tried to solve these problems in order to improve its' performance. Some of the efforts included provision of education to outgrowers (through extension services), advocating higher tax on imported sugar, provision of improved planting materials and replanting and gap filling.

Despite these efforts, the performance of the outgrowers was has remained below its potential. As a result the percentage contribution of the outgrowers has been fluctuating in the past decade and dropping since 1998/99 season. Although the national average yield of sugarcane is some 32.2 tons per hectare (Mbilinyi and Semakafu, 1995), yields on individual farms tend to vary enormously among outgrowers. For example, in Mtibwa division the yield varied from 12 tons to 70 tons per hectare.

In addition, the relatively high growth rate of production in both outgrowers' farms and the estates witnessed after privatisation was mainly achieved through expansion of the cultivated area rather than through increase in productivity of factors of production. This pattern of growth can no longer continue because of the declining land frontier and intolerance to any further environmental degradation especially, deforestation. Therefore, a new strategy for developing this industry should put emphasis on increasing sugarcane productivity.

In view of the declining competitiveness of the domestic sugar industry due to increasing imports, and high production costs, production efficiency will become an important determinant of the future of the industry in Tanzania. Developing and adopting new production technologies can improve productive efficiency. This is difficult at present due to limited income and credit to the outgrowers.

Therefore, the industry can maintain its economic viability by improving the efficiency of the existing operations given currently available technology.

So far little rigorous work has been undertaken to quantitatively study the efficiency levels of existing sugarcane technologies with a purpose of identifying ways of improving efficiency. The estimation of efficiency will enhance identification of the sources where improvement can be made. The relationship between efficiency and specific factors can also provide useful policy information. This study attempts to fill this gap by examining the technical efficiencies of outgrower farmers and non-outgrower farmers. The main objective of the study is to estimate the technical efficiency of the sugarcane farmers and determinants of technical inefficiency in Turiani division. The specific objectives of the study are: - (i) To determine and compare the levels of technical efficiency of outgrower and non-outgrower farmers; (ii) To identify the factors causing technical inefficiency of the outgrower and non-outgrower farmers by examining the relationship between efficiency level and various specific factors; (iii) To consider implications for policy and strategies for improving sugarcane production efficiency.

2. Methodology

2.1 The stochastic frontier model with technical efficiency effect

The stochastic frontier production function has two error terms one to account for random effects (e.g., measurement errors in the output variable, weather conditions, diseases, etc. and the combined effects of unobserved/uncontrollable inputs on production) and another to account for technical inefficiency in production.

The stochastic frontier production function can be written as

$$Y_i = f(X_i\,; \beta) \exp(V_i - U_i). \quad (1)$$

Where Y_i is the production of the i^{th} farm, X_i is a vector of inputs used by the i^{th} farm; β is a vector of unknown parameters, V_i is a random variable which is assumed to be independently and identically distributed (iid) N $(0,\sigma_V^2)$ and independent of U_i and U_i is a random variable that is assumed to account for technical inefficiency in production. Following Battese and Coelli (1995), U_i is assumed to be independently distributed as truncation (at zero) of the normal distribution with mean, μ_i and variance, σ_U^2 ($|N(\mu_i, \sigma_U^2)|$)[1], where

$$\mu_i = Z_i\,\delta \quad (2)$$

Where, Z_i is a 1 x c vector of farm-specific variables that may cause inefficiency and δ is a c x 1 vector of parameters to be estimated. The farm-specific stochastic production frontier representing the maximum possible output (Y^*) can be expressed as

$$Y_i^* = f(X_i;\beta) \exp(V_i). \quad (3)$$

Equation (1) may be rewritten using equation (3) as

$$Y_i = Y_i^* \exp(-U_i). \quad (4)$$

Thus, technical efficiency of the I^{th} farm, denoted by TE_i, is given by

$$TE_i = Y_i / Y_i^* = \exp(-U_i). \quad (5)$$

This means the difference between Y and Y^* is embedded in the U_i. If $U_i = 0$, then Y is equal to Y^*. This means production lies on the stochastic frontier and hence technically efficient and the farm obtains its maximum possible output given the level of inputs. If $U_i > 0$, production lies below the frontier and the farm/firm is technically inefficient (Dey *et-al.*, 2000).

[1] The original specification of U to be half-normal (N $(0,\sigma_U^2)$) (Aigner et al. 1977) has been applied over the past decades (Coelli, 1994). If it will not follow a half-normal distribution it will follow either exponential or truncated normal at zero. The study of Parikh et al. (1995); Greene, (1990) and Kirkley et al. (1995) concluded that efficiency levels were essentially the same for half-normal, truncated-normal and exponential distribution.

2.2 Data collection and sampling

Data for the study was obtained from both secondary and primary sources during a field survey carried out between September and November 2002. Turiani division was selected for the study because there are a large number of outgrower farmers in the area. Turiani division is found in Mvomero District about 100 kilometres from Morogoro town along the Kilosa – Handeni road. The altitude of Turiani division is between 380 meters and 520 meters above sea level. With an average monthly rainfall of about 106mm making up a total annual rainfall of about 1270mm, the division provides a suitable climate for tropical and subtropical varieties of crops. Turiani has a total population of about 90 129 with an average of 4.6 people per household and an average population density of 22.3 persons per square km. The division is comprised of five wards namely, Mtibwa, Sungaji, Mhonda, Diongoya and Kanga. The division headquarter is in Sungaji ward. A random sample of 140 farmers (69 outgrower farmers and 71 non-outgrower farmers) was selected for this study. Sugarcane outgrower farmers were sampled from a registry kept by the Mtibwa Sugar Company. A cohort of non-outgrower farmers was selected from register of residents in the respective villages[2].

2.3 Model specification

Since stochastic frontier production models were proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), there has been a vast range of their applications in literature. Battese and Coelli (1995) proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given our research objectives, the generalized stochastic frontier model can be expressed for two groups of farmers as:

[2] The efficiency of sugarcane non-Outgrowers was based on paddy rice production, the second best alternative crop that competes for resources with sugarcane in the division.

$$\text{Ln } Y_{io} = \beta_{0o} + \beta_{1o} \ln L_{io} + \beta_{2o} \ln Fl_{io} + \beta_{3o} \ln Hl_{io} + \beta_{4o} \ln R_{io} + \beta_{5o} \ln C_{io} + \in_I \quad (6)$$

and

$$\text{Ln} Y_{in} = \beta_{0n} + \beta_{1n} \ln L_{in} + \beta_{2n} \ln Fl_{in} + \beta_{3n} \ln Hl_{in} + \beta_{4n} \ln R_{in} + \beta_{5n} \ln C_{in} + \in_I \quad (7)$$

Ln = denotes logarithms to base e

Y = the maximum attainable output for a given level of all inputs, measured in kg.

L = Land area cultivated, measured in hectares.

Fl = Family labour utilized, measured in man-days.

Hl = Hired labour utilized, measured in man-days.

R = Total variable inputs (seeds, fertilizer, pesticides, harvesting bags) used and measured in Tanzanian shillings.

C = the value of total capital equipment (hand hoe, machete, bicycle, axe, forked hoe, and sickle) measured in Tanzanian shillings.

β_i's = are unknown parameters to be estimated.

According to Aigner, Chu and Lovell (1977), the error term is really a composite of two terms:

$$\in_i = V_i - U_i\ ; \qquad i = 1,\ldots,N \qquad (8)$$

where

V_i = represents independently and identically distributed random errors N $(0,\sigma_v^2)$. These are factors outside the control of the firm.

U_i = represents non-negative random variables which are independently and identically distributed as N $(0, \sigma_u^2)$ i.e. the distribution of U_i is half normal. $|U_i| > 0$ reflects the technical efficiency relative to the frontier production function. $|U_i| = 0$ for a firm whose production lies on the frontier and $|U_i| > 0$ for a firm whose production lies below the frontier.

Knowing that firms are technically inefficient might not be useful unless the sources of the inefficiency are identified (Admassie and Matambalya, 2002). Thus, the second stage of this analysis investigates the sources of the firm-level technical inefficiency for the sampled outgrower and non-outgrower farmers. The model specification was[3]:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + W_i \quad (9)$$

Where

Z_1 = age of the farmer in years

Z_2 = level of education of the farmer in years

Z_3 = Mtibwa ward dummy (1 for Mtibwa and 0 otherwise)

Z_4 = Diongoya ward dummy (1 for Diongoya and 0 other wise)

Z_5 = Kanga ward dummy (1 for Kanga and 0 otherwise)

Z_6 = originality of the farmer (1 for farmer from Mtibwa division and 0 for migrants)

Z_7 = number of years the farmer has been an outgrower (apply only for outgrower farmers)

Z_8 = total farm area measured in hectares

W_i = an error term that follows a truncated normal distribution

δ_I's = inefficiency parameters to be estimated

[3] With exception of Z_7, the inefficiency model and variables for non-outgrower farmers are the same as those for Outgrowers farmers

3. Results and discussion

The summary statistics related to variables used for analysis for both outgrowers and non-outgrowers are depicted in Table 1. The means of inputs presented in Table 1, suggest that at the time of the survey, non-outgrower farmers lagged on both counts.

Table 1: Summary statistics for variables in the stochastic frontier production function

Variable	Measure	Outgrowers				Non-outgrowers			
		Min.	Max.	Mean	Std. Deviation	Min.	Max.	Mean	Std. Deviation
Output	ton	5.00	600.00	89.10	109.55	.20	65.00	3.08	7.81
Farm area	Hectare	1.00	20.00	3.57	4.10	.50	50.00	2.86	6.03
Family labour	manday	.00	5400.00	801.58	1326.79	.00	5716.00	693.11	927.56
Hired labour	manday	280.00	12,800.00	1491.72	1982.98	.00	2796.00	476.18	627.33
Variable inputs	TShs.	1200.00	558,200.00	86,694.12	128,933.31	.00	550,000.00	26,505.63	66,304.89
Equipments	TShs.	500.00	349,000.00	59,681.88	56,028.82	.00	385,000.00	51,698.59	60,534.59

3.1 Production frontier and technical efficiency estimates

The OLS as well as maximum likelihood (ML) estimates of the Cobb-Douglas model are presented in Table 2 and Table 3 respectively. Separate estimates are shown for the outgrowers and non-outgrowers. The estimate of γ is 0.62 and 0.87 for outgrowers and non-outgrowers respectively. This indicates that for both groups of farmers, by far the largest portion of error variation is due to the inefficiency error u_i (and not due to the random error v_i) implying that the random component of the inefficiency effects does make a significant contribution in the analysis. The one sided LR test of $\gamma = 0$ provide a statistic of 21.2679 and 20.3892 for outgrowers and non-outgrowers respectively which both exceed the chi-square five percent critical value of 15.51. Hence the stochastic frontier model appears to give a significant improvement over the average (OLS) production function.

Table 2: OLS estimates for parameters of the Cobb-Douglas production function

Variable	Parameter	Outgrowers			Non-outgrowers		
		Coefficient	S. E.	t ratio	Coefficient	S. E.	t ratio
Constant	B_0	3.9666	1.2447	3.187***	-0.5133	0.5136	-0.999
Farm area	B_1	1.2321	0.2000	6.161***	0.9204	0.1011	9.098***
Family labour	B_2	0.0019	0.0258	0.075	-0.0058	0.0335	-0.174
Hired labour	B_3	-0.2774	0.1882	-1.474	0.0269	0.0228	1.182
Variable inputs	B_4	0.0618	0.0153	4.034***	0.0445	0.0495	0.899
Equipments	B_5	0.0259	0.0391	0.664	-0.0027	0.0317	-0.085

*Note: Significance levels of 1%, 5%, and 10% are indicated by ***, **, and * respectively.*

The estimated ML coefficient of the extent of land under cultivation showed positive values of 1.0157 and 0.9545 for outgrowers and non-outgrowers respectively, which were significant. Therefore, an increment of land (farm area) under cultivation by one percent will increase output of outgrowers and non-outgrowers by 1.0157 and 0.9545 percent respectively. Similar results were recorded by Basnayake and Gunaratne, (2002); and Rawlins, (1989).

The estimated coefficients for family labour, and hired labour showed negative values of 0.0229 and 0.2614 respectively for outgrowers. The hired labour coefficient value was significant ($P < 0.10$). This indicates that an increment of one percent of family labour and hired labour will reduce output by 0.0229 and 0.2614 percent respectively. This indicates that outgrowers currently over utilise both family and hired labour. For non-outgrowers the estimated coefficient for family labour was a negative value of 0.0288, indicating excess use of family labour. This can be due to the fact that nearly a whole month is devoted for scaring birds in rice paddy farms. Due to high labour costs bird scaring is often done by family members. The estimated coefficient value for hired labour was positive (0.0127). However, it is not significant hence no conclusive statement can be made regarding the effect of hired labour on non-outgrowers output.

Table 3: Maximum likelihood estimates for the parameters of the Cobb-Douglas stochastic frontier production function

Variable	Parameter	Outgrowers			Non-outgrowers		
		Coefficient	S. E.	t ratio	Coefficient	S. E.	t ratio
Constant	B_0	4.5384	0.9659	4.698***	-0.0152	0.3922	-0.038
Farm area	B_1	1.0157	0.1691	6.003***	0.9545	0.0901	10.587***
Family labour	B_2	-0.0229	0.0216	-1.061	-0.0288	0.0290	-0.991
Hired labour	B_3	-0.2614	0.1412	-1.851*	0.0127	0.0189	0.675
Variable inputs	B_4	0.0581	0.0131	4.456***	0.0479	0.0176	2.721**
Equipments	B_5	0.0217	0.0314	0.692	-0.0143	0.0249	-0.578
σ^2		0.3370	0.1663	2.026**	0.7988	0.3492	2.287**
γ		0.6221	0.2419	2.571**	0.8763	0.0414	21.158***
Log likelihood		-38.8130			-32.3790		
LR test		21.2679			20.3892		

*Note: Significance levels of 1%, 5%, and 10% are indicated by ***, **, and * respectively.*

The estimated ML coefficients for variable inputs showed positive values of 0.0581 and 0.0179 for outgrowers and non-outgrowers respectively, which are highly significant. This indicates that an increment of the variable inputs for both outgrowers and non-outgrowers by one percent will increase output by 0.0581 and 0.0179 percent respectively. As the increase in output is small this may indicate that variable inputs are nearly fully utilized.

The estimated ML coefficient of capital equipment used showed an insignificant positive value of 0.0217. Thus, an increment on capital equipment by one percent will increase output by 0.0217 percent. However, contrary to expectations, the coefficient of capital equipment for non-outgrowers showed a negative value of 0.0143. This indicates that an increment in capital equipment will decrease the non-outgrowers output.

3.2 Sources of technical inefficiency of outgrower and non-outgrower farmers

The mean technical efficiency of outgrower farmers was found to be 76.43 % and 80.65% for outgrowers and non-outgrowers respectively. This indicates that the output could be increased (using existing resources and technology) by 23.57 % and 19.35 % if all outgrowers and non-outgrowers achieved the efficiency level of the best outgrower and the best non-outgrower respectively. Table 4 shows the distribution of technical efficiencies of outgrowers and non-outgrowers in Turiani division. It can be observed that most of the farmers (81.43%) are efficient because they have technical efficiency levels of above 70%. A t-test showed that there is no significant difference between the technical efficiency of outgrowers and non-outgrowers at the 0.05 significant level. This could be due to the similar socio-economic situation facing both farmers in the division. It could also be due to the fact that some of the sugarcane outgrowers also have rice farms and thus resources available are used for both crops.

The estimated coefficients in the inefficiency models are of particular interest to this study and are depicted in Table 5. A wide variation of technical efficiencies among the outgrowers and non-outgrowers justifies the need for analysing the causes of technical inefficiencies. It should be noted that since the explained variable in the inefficiency function is the mode of inefficiency, a positive sign on a parameter in Table 5 indicates that the associated variable has a negative effect on efficiency and a negative sign indicates a positive efficiency effect.

Table 4: Distribution of technical efficiencies based on Cobb-Douglas specification

Technical efficiency %	Outgrowers	Non-outgrowers
	Number of farmers	Number of farmers
10 – 20	0	1
20 – 30	4	0
30 – 40	0	0
40 – 50	2	0
50 – 60	3	7
60 – 70	7	2
70 – 80	10	13
80 – 90	32	36
90 – 100	11	12
Total	69	71

The age coefficients appeared to be positive and significant ($P < 0.10$) for outgrowers and negative and insignificant for non-outgrowers. This indicates that older outgrowers were less efficient than younger ones. This could be due to the fact that sugarcane cultivation is very strenuous giving the younger farmers an advantage. On the other hand rice cultivation may require a more sophisticated physical skill giving the older farmers an advantage. It could also be due to the fact that most of the younger outgrower's farms are new and more fertile hence have the potential for higher yields. But the case is different for non-outgrowers where older farmers were found to be more efficient than younger ones. This observation finds support from other literature, which showed age to have a negative relationship with inefficiency and positive with efficiency (Admassie and Matambalya, 2002; Dey, *et al.*, 2000; and Jaume, 2000).

Table 5: Determinants of technical inefficiency

		Outgrowers			Non-outgrowers		
Variable	Parameter	Coefficient	S. E.	t ratio	Coefficient	S. E.	t ratio
Constant	δ_0	0.3723	0.8355	0.445	3.1647	1.9209	1.647*
Age	δ_1	0.0274	0.0159	1.723*	-0.1310	0.0893	-1.465
Education	δ_2	-0.1281	0.0500	-2.561**	-0.1683	0.1456	-1.155
Mtibwa	δ_3	0.3871	0.6595	0.586	0.9467	0.7875	1.202
Diongoya	δ_4	-0.0362	0.6844	-0.052	0.8695	0.7543	1.152
Kanga	δ_5	0.0214	0.9935	0.021	1.3484	1.0255	1.314
Origin of the farmer	δ_6	-0.6437	0.4011	-1.604*	-1.6413	1.1371	-1.443
Experience	δ_7	-0.0665	0.0487	-1.365	-0.1206	0.1102	-1.093
Farm area	δ_8	-0.1667	0.0763	-2.184**	0.0280	0.0462	0.607

*Note: Significance levels of 1%, 5%, and 10% are indicated by ***, **, and * respectively.*

Coefficients of education showed negative values for both outgrowers and non-outgrowers. The negative significant ($P < 0.05$) coefficient value for education suggested that more educated farmers are more efficient than the less educated. This result is consistent with the idea that schooling increases information and together with long-term experience leads to higher production efficiency (Seyoum, Battese and Fleming, 1998; Basnayake and Gunaratne (2002); Dey, *et al*. 2000; Pagán 2001). A dummy variable for Mtibwa had a positive sign for both outgrowers and non-outgrowers. This indicated that efficiency levels are greater outside Mtibwa ward. This could be due to the fact that as the ward has grown into a small town, farmers in the ward are more inclined to engage themselves in alternative commercially oriented income generating activities other than agricultural.

The negative coefficient for origin of the farmer for both outgrowers and non-outgrowers indicated that migrants to the division appeared less efficient. This could be due to limited access to resources such as land. The coefficient for farm area had a negative value and was significant for outgrowers. This suggests that farmers with larger land area are relatively more efficient.

4. Conclusion and policy implications

The results obtained from the stochastic frontier estimation indicate that the technical efficiency of outgrowers and non-outgrowers given the Cobb-Douglas model were 76.43 percent and 80.65 percent respectively. This indicates that there is a scope of further increasing the output of outgrowers and non-outgrowers by 23.57 percent and 19.35 percent respectively without increasing the levels of inputs used.

Several factors affect technical efficiency. For outgrowers these include; age, origin of the farmer, educational level, and farm area. All these were significant at the 10% and 5% levels of significance. For the non-outgrowers none of these were significantly related though all had expected signs. According to the results, older farmers are more efficient for non-outgrowers than younger farmers. This could be due to good managerial skills, which they have learnt over time. Therefore, younger farmers should be encouraged to work with older farmers. Better-educated farmers were found to be more efficient than the less educated. This may be because their knowledge, gained from education, has provided them with a background to take correct decisions. For example it would be easier for them to grasp information provided to them by the extension officers. Therefore, it is necessary to increase educational facilities in the area.

Experience showed a positive relationship with efficiency. This may be due to lessons learnt over the years. Therefore farmers with little experience should be encouraged to work with the experienced ones. Farmers from Mtibwa and Kanga wards were found to be relatively less efficient.

This could be because of distance for Kanga farmers and the smallholdings in Mtibwa ward. The farmers in Kanga should be encouraged to join efforts so as to reduce the costs of transportation. Farmers residing in Mtibwa should find more farming areas outside the ward especially in Diongoya ward. Age and experience are generally related. However, they are not necessarily the same. Therefore more importance should be given to experience, or the length of the farming career ("farming age"). Possibilities of some kind of apprentice system to pair the more experienced farmers with the less experienced, should be explored. Some kind of incentive might be devised to reward younger farmers to serve a period of apprenticeship, for example making more land available only after such a period.

Migrant farmers were also found to be relatively less efficient. This could be due to farm area problems as it is not easy for newcomers to secure land easily because it is expensive. Migrants should be encouraged to seek land in areas, where they could acquire larger traits of land and increase their efficiency. The possibility of cooperative transport among outgrowers, especially those located further from the factory, would reduce their dependency on the estates. In the future outgrowers may even own cooperative processing plants, further reducing their dependency on the long established estates. Some might argue that this would further liberalize the market and lead to more competition, improving efficiency and lowering costs.

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