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Full Length Research Paper

Technical efficiency in Ghana's cocoa industry: Evidence from Bibiani-Anhwiaso-Bekwai District

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This study empirically examined the production efficiency of cocoa farmers in Bibiani-Anhwiaso-Bekwai District in Ghana using farm level data. Results presented were based on data collected from a random sample of 300 cocoa farmers in fifteen (15) communities/villages using standardized structured questionnaires. The productivity and technical efficiency in cocoa production were estimated through stochastic frontier production function analysis. Empirical results showed that cocoa farms in the study area exhibited increasing returns-to-scale (RTS=1.26), indicating reducing average costs (AC) of production. This implies that cocoa farmers were operating in the irrational zone of production (stage I), an indication of inefficiency in production. The technical efficiency levels in cocoa production were estimated to range between 3 and 93% with a mean technical efficiency of 49%. The main factors that significantly affected technical efficiency in cocoa production were found to be farmer's experience in cocoa production, farmer's participation in the Cocoa Disease and Pest Control (CODAPEC) programme, and household size. The study recommended subsidies on chemical inputs for disease and pest control to improve resource use efficiency in cocoa production.

Key words: Cocoa, technical efficiency, stochastic production frontier, returns to scale.

INTRODUCTION

In West Africa, agriculture has continued to play a dominant role in the provision of food, raw material for industries, employment for the majority, and foreign exchange earnings, which are used in financing development activities. Industrial tree crops, notably cocoa, coffee, oil palm, and rubber, have dominated agricultural exports. Among the perennial tree crops, cocoa is of particular interest for some parts of West Africa, and for the global chocolate industry. West African countries, including Ghana, together accounted for more than 70% of total world cocoa production in 2006 (ICCO, 2007). Cocoa has historically been a key economic sector and a major source of export and fiscal earnings in Ghana (Bulir, 1998; McKay and Arytee, 2005). The share of cocoa in Ghana's GDP rose from 4.9% in 2000 to 2004, to 8.1% in 2005/2006. There was an increase of cocoa's share in agricultural GDP from 13.7% in 2000 to 2004 to 18.9% in 2005/2006 (Breisinger et al., 2008). Cocoa's share of agricultural GDP has been increasing rapidly and existing yield gaps and the prospects of continued high world commodity prices suggest further growth potential. Cocoa exports, the second most important export good for Ghana, have more than doubled between 2002 and 2006. In 2005, cocoa beans and cocoa products (processed) accounted for about 28% of total exports, slightly behind gold (Bo G, 2007). The value of processed cocoa-based exports in Ghana has gone up from US$ 83.6 million in 2004 to US$ 152.9 million in 2006 (CEPS, 2006). Ghana continues to levy an export tax on cocoa that contributes directly to government incomes even though the importance of this

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income source has declined (ISSER, 2001; Bo, 2007). Even with complimentary growth in other sectors, cocoa will continue to dominate agricultural exports over the medium term (Breisinger et al., 2008). Cocoa contributes about 70% of annual income of small-scale farmers, and stakeholders like Licensed cocoa Buying Companies (LBC's) also depend largely on cocoa beans for their trading and marketing activities, employment and income generation (Asamoah and Baah, 2003).

In Ghana, growth in the cocoa sector has been achieved by increasing the area cultivated rather than by improving yield (MOFA, 2006; COCOBOD, 2007). Cocoa yields in Ghana are well below international averages, suggesting potential for productivity driven growth (FAO, 2005; ICCO, 2007). Achievable yields for cocoa are around 1 to 1.5 tons per hectare, more than double the average yields in 2005 (FAO, 2005; MOFA, 2007). Whilst the average cocoa yield in Malaysia is 1800 kg/ha and 800 kg/ha in Cote d'voire, it is only 360 kg/ha in Ghana (Abekoe et al., 2002). Reasons for the low productivity include poor farm maintenance practices, planting low-yielding varieties, and the incidence of pests and diseases (Abekoe et al., 2002). Binam et al. (2008) also reported that Ghana appears to be the least efficient in cocoa production compared to other cocoa producing countries in West Africa like Nigeria, Cote d'voire and Cameroun. Cocoa productivity levels can be enhanced either by improving technical efficiency and/or by improving technological application (Nkamleu et al., 2010). Nkamleu (2004) noted that the relevant question for agricultural policymakers is whether to pursue a strategy directed towards technological change (bringing new technologies) or a strategy towards efficiency (improving the use of existing technologies). Cross country studies by Heady and Dillon (1988) and location specific studies like Audibert (1997) in Mali, and Tian and Guang (2000) in China have shown that there is room for increasing agricultural productivity in developing countries by improving technical efficiency of agricultural production. This means that every factor of production should be efficiently and effectively mobilized in cocoa production to reduce the gap between actual and potential outputs.

One of the major objectives of stakeholders in the Ghanaian cocoa industry is to increase production on a sustainable basis at the farm level. Proper farm maintenance through weeding and increased use of inputs like pesticides and fertilizers is considered to be the most effective way to increase production. This is because a greater part of cocoa produce is lost through diseases, pests and weeds on the farm (Binam et al., 2008; Dzene, 2010). For these reasons, efficiency has remained an important subject of empirical investigation particularly in developing economies where majority of farmers are resource-poor (Amos, 2007; Binam et al., 2008; Nkamleu et al., 2010). Cocoa yields are dependent on how farmers combine their resources optimally to maximize output. For cocoa to continue to play its key role in the economy, producers ought to optimize resource use in the industry.

There have been a few studies on technical efficiency in the Ghanaian cocoa industry (Aneani et al., 2011; Binam et al., 2008; Dzene, 2010; Kyei et al., 2011). However, findings from these studies are quite limited in terms of applicability in specific farmer locations due to their broad geographic scope. Farmers in different agroecological zones have different socio-economic backgrounds and resource endowments which might impact their resource use efficiency. Therefore, an empirical study to investigate technical efficiency in different cocoa agro-ecologies is a necessary first step in our national effort to improve resource use efficiency in specific production areas/zones, boost production, and improve the overall contribution of the cocoa sector to local economic development and overall national development.

Objectives

The main objectives addressed in the study were to:

i. Estimate the level of technical efficiency in cocoa production in Ghana, and
ii. Examine the factors that influence the level of efficiency in cocoa production in Ghana.

RESEARCH METHODOLOGY

Sampling and data collection

The data for this study were collected through a cross sectional survey of cocoa farmers in the Bibiani-Anhwiaso-Bekwai District, Ghana. A stratified random sampling technique was followed to collect primary data for analysis. The district was divided into three zones/strata (Bibiani, Anhwiaso and Bekwai) and a total of 100 cocoa producing households were selected from each stratum/zone. The sample size per zone/stratum was the same because the three zones had similar population strengths in terms of cocoa farmers. Simple random sampling method was employed to select five communities from each stratum (zone). In each selected community, cocoa producing households were selected using simple random sampling technique. Data was then obtained from 20 cocoa farmers from each of the five communities in each zone, giving a total sample size of 300 cocoa farmers. Data was collected through personal interviews with the use of standardized structured questionnaire. Interviews were conducted in local language in order to break any communication barrier.

Method of data analysis

Descriptive statistics were used to summarize and organize the socio-economic data collected during the field survey. In addition, stochastic frontier production function analysis was employed to examine the productivity and technical efficiency of cocoa farmers.

Technical efficiency is defined as the ability to achieve a higher level of output given similar levels of inputs (Farrell, 1957). The stochastic frontier production function independently proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) is defined by:

$$Y_i = f(x_i, \beta) + \varepsilon_i \text{ where } i = 1, 2, 3..., n$$

Where Y_i represents the output level of the i^{th} sample farm; $f(x_i; \beta)$ is a suitable function such as Cobb-Douglas or translog production functions of vector x_i of inputs for the i^{th} farm and a vector, β, of unknown parameters, and ε_i is an error term (defined later).

Technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm. Technical inefficiency is, therefore, defined as the amount by which the level of production for the farm is less than the frontier output:

$$\hat{TE} = \frac{Y_i}{Y_i^*}, \text{ whrer } Y_i^* = f(x_i; \beta), \textit{ highest predicted for the ith farm}$$

$$\hat{TE} = Exp(-u_i)$$

$$Technical\ inefficiency = 1 - \hat{TE}_i$$

Where Y_i is the observed output and Y^*_i is the frontier output. This is such that 0 < TE< 1. The stochastic frontier production function model is estimated using the maximum likelihood estimation (MLE) procedure.

Following the approach of Aigner et al. (1977) and Meeusen and Broeck (1977) in estimating a stochastic frontier production function, a Cobb-Douglas function was fitted to the field data. This functional form has been employed consistently in related efficiency studies (Chirwa, 2007; Donkor et al., 2008; Ogundari, 2008; and Aneani et al., 2011). The Cobb-Douglas function is employed because it is commonly used in the literature, making estimates comparable with previous studies. The specified multiplicative production function was:

$$Y = AX_1^{\beta_1}.X_2^{\beta_2}.X_3^{\beta_3}.X_4^{\beta_4}.X_5^{\beta_5}.X_6^{\beta_6}.X_7^{\beta_7}.X_8^{\beta_8}.X_9^{\beta_9}.\varepsilon \quad (1)$$

The linear transformation of (1) is achieved by taking the natural logarithm of both sides of the equation to obtain (2):

$$\ln Y = \ln A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + \varepsilon_i \quad (2)$$

Where: Y = output of cocoa beans in Kg; X_1 = Land input in hectare (ha) (+); X_2 = Labour input in man days (+); X_3 = Mean age of cocoa trees (+/-); X_4 = Farm management (Frequency of weeding and pruning per year) (+); X_5 = Frequency of insecticides application (that is, number of applications per year) (+); X_6 = Frequency of fungicides application (i.e. number of applications per year) (+); X_7 = Intensity of insecticides application (quantity applied per hectare in litres) (+); X_8 = Intensity of fungicides application (quantity applied per hectare in litres) (+); X_9 = Intensity of fertilizer application (quantity applied per hectare in Kg) (+); *Ln* is the natural logarithm, β_j's are the parameters to be estimated and ε_i is the disturbance term.

The error/disturbance term $\varepsilon_i = u_i - v_i$ is composed of two components, a symmetric error term accounting for deviation because of factors which are out of the farmer's control (v_i) and error term accounting for the deviation because of inefficiency effects (u_i), and *i*= 1, 2,….n farmers; v_i - is *independently and identically distributed (i.i.d)* $N(0; \sigma_V^2)$; u_i - is non-negative and is assumed to be *i.i.d.* $N(0; \sigma_u^2)$ truncated at zero or exponential distribution independent of v_i.

The positive and negative signs (+ and -) indicate the direction of influence of the variables based on *a priori* expectations. Positive (+) indicates movement in the same direction (that is, positive influence on production) and negative sign (-) indicates movement in opposite direction (that is, negative influence on production).

For this study, the parameters of equation (1) were estimated using the maximum likelihood (ML) method, following estimation by Battese and Corra (1977):

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \ and \ \lambda = \sigma_u^2 / \sigma^2$$

Where σ_u^2 is the variance of U_i and σ_v^2 is variance of V_i, σ^2 is the sum of the error variance and λ is defined as the total variation of output from frontier which can be attributed to technical (in)efficiency. It is the λ that is used in the estimation of the technical efficiency level and the frontier function by the FRONTIER 4.1 software or STATA 11.0 (Coelli, 1996). If λ=0, inefficiency is not present, hence deviation from the frontier is entirely due to random noise and if, λ=1, it indicates that the deviation is due entirely to inefficiency (Battese and Coelli, 1995).

A two-stage estimation procedure was followed in this study. After the Cobb-Douglas production function was estimated, the inefficiency model was also estimated in the second stage by using the residuals in the first model and socio-economic variables. Following the model of Battese and Coelli (1995), after the technical efficiency (TE) level at which cocoa bean is produced was calculated, the TE level was explained based on some farm level factors. This model specifies technical inefficiency effects in the stochastic frontier model that are assumed to be independently (but not identically) distributed non-negative random variables as truncations at zero of the normal distribution (Coelli et al., 1998). Specifically,

$$U_i = Z_i \varphi + W_i \quad (3)$$

Where Z_i is a (1 × M) vector of explanatory variables, and in this study they include age of the cocoa farmer, number of years spent in school, years of experience in cocoa farming, marital status (1 if married and 0 if otherwise), gender (1 if male and 0 if female), participation in cocoa disease and pest control project (CODAPEC) (1 if farmer participated and 0 if otherwise) and household size. φ is an M × 1 vector of unknown parameters to be estimated; W_i are unobservable random variables, which are assumed to be independently distributed, obtained by truncation of the normal distribution with zero mean and unknown variance, σ^2, such that U_i is non-negative (that is, $W_i \geq U_i$).

These socioeconomic variables were included in the equation because they impact on the efficiency with which farmers produce cocoa beans. Many past studies on technical efficiency in agricultural production (Chirwa, 2007; Donkor et al., 2008; Ogundari, 2008; and Aneani et al., 2011) have tested the effects of these variables on technical inefficiency. Considering them in this study was not only appropriate from theoretical stand point; it also

Table 1. Socio-economic characteristics of respondents.

Socio-economic variable	Frequency	Percentage (%)
Sex		
Male	273	91
Female	27	9
Total	300	100
Marital status		
Married	260	87
Single	31	10
Widow/Widower	9	3
Total	300	100
Age (years)		
20-30	36	12
31-40	65	22
41-50	81	27
51-60	86	29
61-70	27	9
>70	5	2
Total	300	100
Educational level		
No formal education	34	11
Basic education	207	69
Secondary education	46	15
Technical/Vocational	3	1
Tertiary education	10	3
Total	300	100
Farm experience (years)		
< 10	63	21
10-20	71	24
21-30	101	34
31-40	45	15
>40	20	7
Total	300	100

Source: Field survey (2010).

afforded the opportunity for comparison of the study results with previous findings.

In this study, the sample size was increased to correct for any endogeneity problem resulting from measurement error. Also, Spearman's correlation test was conducted to test for the presence of serial correlation or multicollinearity between any two of the explanatory variables.

RESULTS AND DISCUSSION

Characteristics of the respondents

Table 1 provides a summary of the characteristics of cocoa farmers interviewed for the study. Majority of cocoa farmers interviewed were males (91%), married (87%), and were in the middle and active age bracket (31 to 50 years). Majority of them (80%) had either basic or no formal education. However, about 22% of the farmers had been in cocoa production for more than 30 years.

Table 2 provides the distribution of cocoa farmers according to farm size and cocoa output. About 12% of the respondents had cocoa farm sizes that were less than one (1) hectare while about 2% had just a little above 10 ha of cocoa farm. A high proportion of the farmers (70%) had between 1 and 5 ha of cocoa farm. This indicates that cocoa farming in the study area is

Table 2. Distributions of respondents by farm size and output.

Variable	Frequency	Percentages (%)
Farm size (ha)		
< 1	36	12
1-5	211	70
5.5-10	48	16
> 10	5	2
Total	300	100
Output (in metric tons)		
<0.6	124	42
0.6 - 1.3	84	28
1.4 -1.9	36	12
2 - 2.6	26	9
2.7 -3.2	13	4
>3.20	16	5
Total	300	100

Source: Field survey (2010).

dominated by small-scale producers.

This observation is consistent with the general assertion that cocoa, the golden tree, is mainly produced by several small-scale farmers in the rural areas (Clay, 2004; Donald, 2004). COCOBOD (2002) indicated that cocoa farm sizes in Ghana are relatively small, ranging from 0.4 to 4.0 ha.

In terms of cocoa output, about 42% of the respondents produced less than 0.6 metric tons of cocoa beans per season and 28% produced between 0.6 and 1.3 metric tons of cocoa beans in the 2009/2010 cropping season (Table 2). However, the average yield per hectare was estimated at about 378.81 kg (0.38 metric tons) compared with 250 kg/ha (0.25 metric tons/ha) and 360 kg/ha (0.36 metric tons/ha) estimated by Ghana COCOBOD (1998) and ICCO (2003), respectively. This result shows that cocoa farmers in the district had average productivity which is a little higher than the national average.

Cocoa production function analysis

As indicated in Table 3, the inefficiency component of the disturbance term (u) is significantly different from zero as indicated by the log likelihood ratio test (chi-square of 36.69 with associate probability of 0.000). Therefore, the null hypothesis of technical inefficiency (H_0: Sigma u=0) is rejected. The estimated sigma squared (σ^2) shows a "good fit" and the correctness of the specified distributional assumptions of the composite error term. On top of that, the value of gamma (γ) indicates that there is 55.28% variation in output due to technical inefficiency. This means that technical inefficiency has an important role in explaining output levels among cocoa farmers in the study area. Apart from age of cocoa trees, there was positive relationship between cocoa output and the explanatory variables considered in the model.

The observed signs of the explanatory variables were consistent with a-priori expectation as the level of production depends largely on the application of agrochemical inputs on the farm. However, these chemicals can only be applied up to a level that is considered optimal after which farmers will be operating at sub-optimal level. Results from the model show that farm size, frequency of weeding and pruning, frequency of insecticides application, intensity of insecticides application, labour and mean age of cocoa tree have significant effects on cocoa output. Estimates of the independent variables of the stochastic frontier model presented in Table 3 show that all explanatory variables, except mean age of cocoa tree, exhibit positive relationship with cocoa output. These findings are consistent with results of similar studies conducted in the past (Gockowski et al., 2000; Helfand, 2004; Kyei et al., 2011; Tadesse and Krishnamoorthy, 1997). Nkamleu and Ndoye (2003) reported that in Africa, cocoa output has been achieved by increasing the area cultivated rather than by improving yield. For example, in a study on technical efficiency in cocoa production in the Offinso District of Ghana, Kyei et al. (2011) estimated 1.05 as the coefficient of land area cultivated and -0.249 as coefficient for age of cocoa trees.

Return to scale (RTS) was estimated to be 1.26, signifying a positive increasing-returns-to-scale. The implication is that cocoa farmers in the study area are operating in the irrational zone of production (stage I) where decreasing average costs (AC) of production is

Table 3. Maximum likelihood estimates of stochastic cocoa production frontier.

Variable	Estimates	Std. error	t-statics
Constant	3.4868	0.9246	3.7700***
Farm size (ha)	1.4296	0.1760	8.1200***
Farm management	0.0748	0.0329	2.2700**
Frequency of insecticides application	0.2252	0.1022	2.2000**
Frequency of fungicides application	0.0077	0.0747	0.1000
Intensity of insecticides	0.2451	0.0588	4.1700***
Intensity of fungicides application	0.0158	0.0707	0.2200
Intensity of fertilizer application	0.0266	0.0631	0.4200
Labour (family and hired)	0.1724	0.0772	2.2300**
Mean age of cocoa tree	-0.9343	0.2764	-3.380***
Return to scale	1.2629		
Variance parameters			
Sigma U-squared (σ_u^2) 0.2186			
Sigma V-squared (σ_v^2) 0.1768			
Lamda (λ) 1.1119			
Sigma-squared(σ^2) 0.3954*			
Gamma(γ) 0.5528**			
Log likelihood Function -264.369			
Log likelihood ratio test 36.69***			

Source: Field survey (2010).*** = 1% significance level, ** = 5% significance level, * = 10% significance level.

being experienced. This shows that there is more room for improvement in terms of cost reduction and efficiency improvement in cocoa production.

Results in Table 4 show considerable variation of efficiency indices across cocoa farms. The fact that technical efficiencies of all sampled cocoa farmers were less than one (1) implies that no farm reached the cocoa production possibility frontier.

The predicted farm specific technical efficiencies (TE) ranged between 3 and 93%. The mean efficiency of cocoa farmers was estimated to be 49%, indicating that the average farmer in the study area produced on the average, only 49% of potential output, given the current technology available to cocoa farmers. Thus, in the short run, there is a scope for increasing cocoa production by about 51% by adopting new technologies, practices and efficient combination/allocation of production factors. This finding is quite consistent with findings from other studies. Binam et al. (2008) estimated the mean efficiency of cocoa farmers in Ghana to be 44%. Dzene (2010) used a balanced panel data for three years to show that mean technical efficiencies for cocoa farmers in the Western region of Ghana were 48.6, 48.3 and 47.2% in 20002, 2004 and 2006 respectively. However, all the empirical estimates of technical efficiency for Ghanaian cocoa farmers are lower than those estimated for cocoa farmers in other West African countries. For instance, Amos (2007) showed that cocoa farmers in Nigeria are 72% technically efficient while Binam et al. (2008) estimated 74, 65 and 58% as technical efficiency figures for cocoa farmers in Nigeria, Cameroun and Côte d'Ivoire respectively.

Determinants of technical efficiency in cocoa production

Table 5 provides the results of the inefficiency model. Farming experience (years of experience in cocoa farming), household size and farmer's participation in CODAPEC programme were found to be significant determinants of technical efficiency in cocoa production. While household size was found to reduce the efficiency level of cocoa farmers, cocoa farming experience and participation in CODAPEC programme were found to increase technical efficiency level in cocoa production. Cocoa farmers with larger household sizes were less technically efficient in cocoa production compared to those with smaller household sizes. Amos (2007) also found household size to be a significant determinant of efficiency in cocoa production. Consistent with a-priori expectation, farmers' participation in CODAPEC programme was found to have a positive relationship with technical efficiency in cocoa production. The CODAPEC

Table 4. Frequency distribution of technical efficiency effects.

Technical efficiency (%)	Frequency	Percentage (%)	Cumulative
0-9	7	2.33	2.33
10-19	18	6.00	8.33
20-29	35	11.67	20.00
30-39	30	10.00	30.00
40-49	23	7.67	37.66
50-59	45	15.00	52.66
60-69	46	15.33	68.00
70-79	41	13.67	81.66
80-89	47	15.67	97.33
90-99	8	2.67	100.00
Efficiency summary			
Mean	0.49		
Minimum	0.03		
Maximum	0.93		

Source: Field survey (2010).

Table 5. Factors affecting technical (in)-efficiency.

Inefficiency variable	Estimates	Std. error	t-statistics
Constant	4.2608	0.9696	4.3900***
Age of farmer	0.0017	0.0044	0.4000
Gender	-0.2394	0.1953	-1.2300
Marital status	-0.1129	0.1413	-0.8000
Years in school	0.0102	0.0157	0.6500
Years of experience	-0.0122	0.0063	-1.9500**
Household size	0.1768	0.0911	1.9400**
CODAPEC	-0.8529	-0.1114	-7.6500***

Source: Field survey (2010).*** = 1% significant, ** = 5% significant.

programme provided opportunity for farms to be sprayed periodically at little or no cost to the farmer.

Conclusion

The study has demonstrated that cocoa farmers in the Bibiani-Anhwiaso-Bekwai district were technically inefficient in production. Based on the maximum likelihood stochastic results, 55.28% of the variations in cocoa output were due to technical inefficiency. The study has shown that age of cocoa trees, labour, frequency of weeding and pruning, frequency of insecticide usage and intensity of insecticide application were the main factors that significantly influenced cocoa production in the study area. The study further showed that cocoa farmers in Bibiani-Anhwiaso-Bekwai district exhibited positive increasing returns to scale, indicating that cocoa production was in the irrational zone (that is, stage I of the production function). Experience in cocoa farming, household size and farmers' participation in the CODAPEC programme were found to be the main determinants of technical efficiency among cocoa farmers in the district. Government should strive to make cocoa agrochemicals available at the right time during the cocoa season and at subsidized prices. This would make it possible for farmers to have access to inputs at the right time to improve productivity and technical efficiency. Also, Cocoa Diseases and Pest Control (CODAPEC) programme should be expanded to cover all cocoa farmers, and strengthened to meet the recommended fungicide application frequency per season to boost cocoa productivity and improve technical efficiency.

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