A multi-output production efficiency analysis of commercial banana farms in the Volta region of Ghana: A stochastic distance function approach

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Abstract

The banana sector makes a significant contribution to the Ghanaian economy in terms of employment, fiscal revenue and foreign exchange. However, decreasing productivity in the sector, coupled with price volatility, has led to a sharp decline in output. The strong export-oriented nature of the sector requires continuous improvement in productivity to enhance the sector's competitiveness. The efficient use of production resources through the improvement of farmers' production efficiency could enhance the competitiveness of the sector in international trade. By means of a stochastic frontier approach, an output distance function estimation technique was used to analyse and explore factors driving productivity in Ghana's banana sector. The results of the study show that sources of decreasing productivity are closely linked to the effect of current farm production techniques, poor agronomic practices and household-specific attributes.

Key words: stochastic multi-output distance function; determinants of technical efficiency; commercial banana production; Ghana

1. Introduction

The importance of the banana sector for Ghana's national development has increased over the past decade. An increasing export orientation towards higher value markets (mainly the EU[1] market) has led to significant export growth. Due to the growing consumer demand for healthy banana fruits across the EU, the sector's contribution has been visible in the national economy. The sector's foreign exchange contribution to the economy from 2000 to 2013 amounted to €172 million (Eurostat 2013), making it the second most important foreign exchange contributor in the fruit industry. Traditionally, banana exports in Ghana have been dominated by a few multinational companies (e.g. Dole, Chiquita, Del Monte, etc.). However, the increasing use of refrigerated containers (i.e. reefer containers) in ships and the increased number of direct cargo plane flights from Ghana have enabled the frequent delivery of high-quality bananas to retailers in the European fruit market (Agritrade 2012). This has opened up opportunities for local exporters to supply bananas directly to traders in the EU. Furthermore, the recent EU banana trade liberalisation, coupled with growing consumer willingness to pay premium prices for quality organic bananas, presents a great opportunity in terms of capital

[1] EU–Ghana trade measures are primarily discussed here because the EU is the main export destination for the Ghanaian fruit industry.

accumulation by and livelihood improvement for actors in the sector. However, decreasing productivity is hampering the ability of the sector to meet the rapidly increasing export demand (Jaeger 2003). This, in turn, denies the country urgently needed foreign exchange. Harnessing the full economic potential of the sector will depend on enhancing the competitiveness of the sector in international trade (i.e. the efficient conversion of inputs into output along the entire production process). Given the important contribution of the sector to the economy (through job creation and foreign exchange contribution), as well as Ghana's excellent agro-ecological conditions for banana production, more could be done to enhance the sector's competitiveness by improving farmers' productivity.

The strong export orientation of the sector necessitates enhancing the productivity of farmers to help sustain its competitiveness. This study therefore assessed the productivity performance of farmers using survey data from Ghana. By identifying and analysing the factors that influence banana production in the region, the findings of the study could assist policy makers in designing effective future intervention programmes to help the sector to exploit its full economic potential. The paper is organised as follows: Section 2 provides the theoretical concepts underpinning the empirical estimation model. Section 3 gives a brief overview of the study area and the data. Section 4 presents our results and discusses the findings, and section 5 concludes by highlighting selected practical intervention policy measures.

2. Analytical framework

2.1 Theoretical concept

The analysis of production efficiency under a multi-output production strategy (i.e. production diversification) requires detailed modelling of the underlying production technology. In order to capture the distinct effects of different outputs, the modelling approach should allow for multiple outputs (Brümmer *et al*. 2006). In many parts of rural Ghana, a multiple-output production setting is often a common feature of rural farming activities. This is largely driven by the farmers' strategy of spreading or reducing risk, as well as achieving self-sufficiency. Price volatility in the international banana market, coupled with erratic and unreliable rainfall patterns, has increased production risk and uncertainty for banana farmers in Ghana. The use of a single output production function framework to analyse the performance of farmers in situations where farmers produce several outputs (diversified production) imposes a number of restrictive assumptions, which may bias the performance estimates (i.e. ignoring the allocative effects regarding the outputs and inputs (Brümmer *et al*. 2002)). According to Färe and Primont (1990), if a farmer only produces one output using the various inputs at his/her disposal, then the production technology may be represented by a simple production function to capture performance. However, if two or more outputs are produced, an alternative representation of the technology must be considered (Färe & Primont 1990). An alternative to a single-output specification to capture performance is the use of a multi-output, multi-input distance function specification,[2] which helps us to overcome the problems associated with the implicit assumptions imposed on the structure of a single output production function (Zhang & Brümmer 2011). Another advantage of a distance function is that estimation is possible without price information or the need to impose any behavioural assumptions (e.g. profit or revenue maximisation, cost minimisation) to provide a valid representation of the underlying production technology (Brummer *et al*. 2002). According to Coelli *et al*. (2005), the output-oriented distance function

[2] This estimation technique has been used by many authors, for example Brümmer *et al*. (2002), Coelli *et al*. (1999), Färe *et al*. (1989) and Grosskopf *et al*. (1993).

measures how much an output vector can be radially expanded (holding inputs fixed) while still remaining in the feasible production region, as specified in equation 1 below:

$$D_o\,(\boldsymbol{x}, \boldsymbol{y}) = \inf\,\{\theta\colon \boldsymbol{y}/\theta \in P(\boldsymbol{x})\} \tag{1}$$

where **y** (outputs) in the output distance function ($D_o\,(\boldsymbol{x}, \boldsymbol{y})$) is non-decreasing, linearly homogeneous and convex, while $\boldsymbol{x}$ (inputs) is non-increasing and quasi-convex. $P(\boldsymbol{x})$ represents the set of feasible output vectors ($\boldsymbol{y}$) that can be produced using the input vector ($\boldsymbol{x}$). $D_o\,(\boldsymbol{x}, \boldsymbol{y})$ is the distance from the farm's output set to the efficient frontier, and θ is the corresponding level of efficiency (i.e. θ is a scalar parameter that denotes how much the output vector should be radially expanded to the feasible efficient frontier). $D_o(\boldsymbol{x}, \boldsymbol{y})$ takes a value of 1 whenever the output vector (**y**) lies on the outer boundary of the output set (i.e. $D_o\,(\mathbf{x}, \mathbf{y}) = \theta = 1$). Figure 1 graphically illustrates the concept of the output distance function.

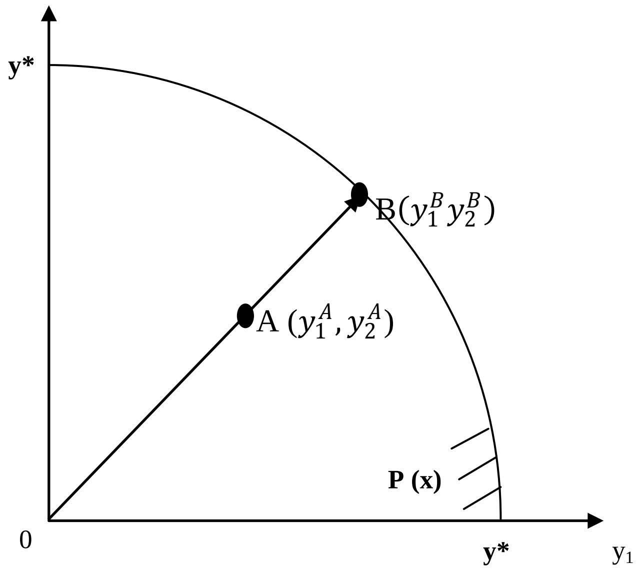

Figure 1: Output distance function with two outputs (y_1, y_2)
Source: Authors' own depiction

Assume a farmer produces two outputs, (y_1^A, y_2^A), using input vector (x), while **y*** represents the production possibility frontier (PPF). From production theory, the PPF curve describes all the possible combinations of technically efficient production points of the outputs (y_1, y_2) that could be produced using the input vector (x) and still remain in the feasible production region P(x). The P(x) is therefore bounded by the PPF. Based on principles derived from frontier production theory, production at any point other than on the frontier (e.g. B) represents sub-optimal performance (e.g. point A in Figure 1). Output point A represents a departure from the feasible, technically efficient production points (located on the PPF); hence the distance from point A to point B signifies the level of inefficiency in the production process. As suggested by Coelli *et al*. (2005), proportional expansion of output A towards the efficient production point B requires upward scaling of point A by a scalar θ, which needs to be minimised.

$$D_0(x, y) = 0A/0B \leq 1 \qquad \text{i.e. } D_0(x, y) \leq 1; \tag{2}$$

$$D_0(x, y) = 1/TE_0 \qquad \text{i.e. } TE_0 \geq 1 \tag{3}$$

The output distance $D_0(x, y)$ gives the reciprocal of the maximum proportional expansion of the output vector (y), given the input vector (x) and characterised the technology completely. The reciprocal of the distance function, according to Brümmer *et al*. (2002; 2006), can be viewed as a performance measure, which is in line with the Debreu (1959) and Farrell (1975) measures of output-oriented technical efficiency (TE_0).

2.2 Translog output distance function

In order to estimate the distance function in a parametric setting, a *translog* functional form is assumed[3] (Coelli *et al*. 1999). The inclusion of square and interaction terms presents a high degree of flexibility. The *translog* distance function specification for the case of K inputs and M outputs could be depicted in equation form as follows:

$$\ln D_{0i}(x, y) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mi} + 1/2\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mn} \ln y_{mi} \ln y_{ni} + \sum_{k=1}^{K} \beta_k \ln x_{ki} + 1/2\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} \ln x_{ki} \ln y_{mi}, \quad (4)$$

where $i = 1, 2\ldots, N$ denotes the i^{th} farmer in the sample. In order to obtain the production frontier surface, we set $D_0(x, y) = 1$, which implies that $\ln D_0 (x, y) = 0$. According to O'Donnel and Coelli (2005) and Coelli and Perelman (2000), the parameters of the distance function in equation 4 must theoretically satisfy linear homogeneity in outputs and regularity conditions (i.e. monotonicity[4] and curvature[5]). Symmetry is imposed as:

$\alpha_{mn} = \alpha_{nm}$; $m, n = 1, 2, \ldots, M,$ and $\beta_{kl} = \beta_{lk}$; $k, l = 1, 2, \ldots, K$.

According to Lovell *et al.* (1994) and Coelli *et al.* (1999), normalising the output distance function by one of the outputs[6] enables the imposition of homogeneity of degree +1 as follows: by setting $\theta = 1/y_M$ and substituting it in equation (1) $\Rightarrow D_0(x, y/y_M) = D_0(x, y)/y_M$. Therefore, for the i^{th} farmer, the above expression can be rewritten in translog form as:

$$\ln(D_{0i}(x, y)/y_{Mi}) = TL(x_i, y_i/y_{Mi}, \alpha, \beta, \delta), \; i = 1, 2, \ldots, N, \quad (5)$$

where the *translog (TL)* equation is written in full as:

$$TL(x_i, y_i/y_{Mi}, \alpha, \beta, \delta) = \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln(y_{mi}/y_{Mi}) + 1/2\sum_{m=1}^{M-1}\sum_{n=1}^{M-1} \alpha_{mn} \ln(y_{mi}/y_{Mi}) \ln(y_{ni}/y_{Mi}) + \sum_{k=1}^{K} \beta_k \ln x_{ki} + 1/2\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{ki} \ln x_{li} + 1/2\sum_{k=1}^{K}\sum_{m=1}^{M-1} \delta_{km} \ln x_{ki} \ln(y_{mi}/y_{Mi}). \quad (6)$$

By rearranging the terms in equation (6), the above function can be rewritten as follows:

$$-\ln(y_{Mi}) = TL(x_i, y_i / y_{Mi}, \alpha, \beta, \delta) - \ln D_{0i}(x, y), \; i = 1, 2, \ldots, N,$$

where $- \ln D_{0i}(x, y)$ corresponds to the radial distance function from the boundary. Consequently, if we set $u = - \ln D_{0i}(x, y)$ and add the term v_i to capture noise, we end up obtaining the Battese and Coelli (1988) version of the traditional stochastic frontier model proposed by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977), as follows:

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[3] Since the Cobb Douglas functional form has the wrong curvature in the y_1/y_2 space.
[4] Non-increasing inputs, non-decreasing outputs.
[5] Convexity in outputs
[6] According to Coelli and Perelman (1999), the transformed output variables in a ratio form are measures of output mix, which are more likely to be exogenous. Also, Schmidt (1988) and Mundlak (1996) emphasise that the ratio of two output variables does not suffer from endogeneity.

$$-\ln(y_{Mi}) = TL(x_i, y_i / y_{Mi}, \alpha, \beta, \delta) + \varepsilon_i, \text{ where } \varepsilon_i = v_i + u_i \quad (7)$$

where ε_i is the composed error term and $u = -\ln D_{0i}(x, y)$ captures the farmer's inefficiency, as it represents the distance to the efficient frontier. It is a non-negative random term assumed to be independently distributed and truncation at zero of the $N(0,\sigma^2_{ui})$ distribution, in line with Wang and Schmidt (2002). The v_i captures random noise, assumed to be iid $N(0,\sigma^2_v)$. Both terms are assumed to be independently distributed (i.e. $\sigma_{uv} = 0$).

2.3 Empirical specification

A translog stochastic output distance function with two outputs, (y_1, y_2), and four inputs, $x = (x_1, x_2, x_3, x_4)$, was specified as follows:

$$-\ln(y_{1i}) = \alpha_0 + \alpha_1 \ln(y_{2i}/y_{1i}) + 1/2\alpha_{11} \ln(y_{2i}/y_{1i})\ln(y_{2i}/y_{1i}) + \sum_{k=1}^{K=4} \beta_k \ln x_{ki} + 1/2\sum_{k=1}^{K=4} \sum_{l=1}^{K=4} \beta_{kl} \ln x_{ki}\ln x_{li} + 1/2\sum_{k=1}^{K=4} \delta_k \ln x_{ki} \ln(y_{2i}/y_{1i}) + v_i + u_i \quad (8)$$

where y_{1i} represents the value of banana produced in cedis (i.e. new Ghana cedis) by the i^{th} farmer for the 2012 production year. y_{2i} is the normalised output, which is equal to the "output ratio" of the value of other crops (i.e. value of maize + cassava + cocoyam + yam) relative to the value of banana produced by the i^{th} farmer in the 2012 production year. The inputs (x) included in the model are land (x_1), labour (x_2) maintenance cost (x_3) and cost of planting material (sucker (x_4)), while α, β and δ are the parameters to be estimated.

To examine how farm management and specific household socioeconomic characteristics influence the performance of farmers, we employed a heteroskedasticity corrected inefficiency model, as proposed by Wang and Schmidt (2002) and specified as follows:

$$\sigma_{u_i} = \exp\{z_{ij}\delta_j\} \quad (9)$$

Model 9 is based on the assumption that hypothesised explanatory variables Z_{ij} (i.e. education level, farm experience, contact with extension workers, household size and age of household head) affect the degree of technical efficiency and so produce technical efficiency estimates (δ) that incorporate these factors.

3. Study area and dataset

The Volta region is located in the south-eastern part of Ghana and represents one of the most important banana-producing regions in the country. It is regarded as a pioneer region for both large- and small-scale commercial banana production for the export market. The climate and soil conditions in this region are considered particularly suitable for banana production. The non-seasonal bearing characteristics of bananas, together with the suitable agro-ecological conditions, enable year-round production in this region. Ghana's competitive advantage in banana production therefore stems from the types of suitable growing conditions that prevail in this region. Commercial banana producers often employ a monoculture system of production; however, due to declining revenue and unstable farmgate prices as a result of volatility in the international market, all the sampled farmers in the study area cultivate a mixture of crops (such as cassava, cocoyam, yam and/or maize) beside their banana plantations. This is done partly as a means to offset risk, but also to supplement household income and nutritional needs. In situations where banana is cultivated as pure monoculture, farmers often allocate portions of the same or adjacent land to producing these other crops. Banana is mostly cultivated for the export market, while the other crops are cultivated for the local market or household consumption.

The farm diversification strategies observed in our sample justify the use of the multi-output distance function approach to analyse the performance of farmers. This study used an integrated approach that draws on both quantitative and qualitative methods of primary data collection. Based on information from district extension officers in the study region, a list of villages where households produce banana commercially for export was obtained and farmers were sampled randomly. Using structured questionnaires, detailed production information (viz. production practices, farm attributes, input usage and outputs produced), as well as important socioeconomic and demographic characteristics, was obtained for the sampled farmers. In total our sample comprised 120 commercial banana producers.

3.1 Summary statistics

Table 1 below presents a summary overview of all the variables used in the estimation model. Before estimating the model, outputs were aggregated into two categories (i.e. value of banana and other crops produced). The dataset contains information on the quantity of banana and other crops produced and sold, as well as the farmgate price received by farmers from exporters and local traders. The farmgate price received by a farmer and the quantity he/she sold were used to calculate the value of the two outputs (i.e. quantity sold × price received). The farmgate price depends on the quality of the products, as well as the location of the farm with respect to urban centres. However, we could not obtain any information on quality grading standards, since this is a purely subjective assertion by buyers used to justify farmgate prices. Hence, the value of crops as calculated here does not take into account direct quality differences; these are extrapolated indirectly through the price received. The labour input consists of the total number of people who work on a plantation (i.e. family plus hired labour). The land input is measured in hectares. All monetary values use the 2012 value of the new Ghanaian cedi.

Table 1: Summary characteristics of the sample data (Number of observation = 120)

Variable	Units	Mean	Std. dev.	Min.	Max.
Banana	100 cedis (2012 value)	337.38	132.37	120	620
Other crops	100 cedis (2012 value)	18.73	8.90	5	38
Land	Hectares	7.08	2.71	4	14
Labour	Number of on-farm workers	5.31	2.18	2	10
Maintenance cost	Cedis (2012 value)	278.63	151.97	100	800
Education	Years	13.10	5.98	1	24
Planting material cost	Cedis (2012)	132.48	74.50	35	600
Experience	Years	23.07	14.18	2	60
Crop density	Number of plants per hectare	781.57	147.09	200	970
Distance to market	Km	6.75	4.50	2	24
Extension	Number of extension contacts	4.74	5.34	1	41
Fertiliser	Dummy	0.56	0.50	0	1
ITC (mobile phone)	Dummy	0.79	0.41	0	1
Land status	Dummy	0.63	0.49	0	1
Manure	Dummy	0.47	0.50	0	1

Source: Study findings based on 2012 survey.

4. Results and discussion

4.1 Distance elasticities

Table 2 presents the result of the maximum likelihood estimates (i.e. the first-order estimates) of the translog output distance function as specified in equation 8. The data was normalised at the sample mean; hence, after taking logs, the first-order distance coefficients can be interpreted as partial elasticities. All the first-order inputs' distance elasticities possess the expected sign,[7] and therefore satisfy the monotonicity condition at the sample mean. In line with the way equation 8 is specified, a negative sign in front of the input distance elasticities is interpreted as a positive contribution of the inputs (x) to the production of banana. Similarly, a positive sign in front of other crops' distance elasticity implies a negative shadow share contribution of other crops relative to the banana output in the overall production (i.e. reflecting the degree of substitution). All the inputs contribute positively and significantly to the production of banana. The elasticity effect on other crops is simply the opposite because of the homogeneity constraint in outputs, in line with Brümmer *et al*. (2002). The low partial productivity effect for land may be an indication of deteriorating soil quality in the production area, while that of labour may be an indication of increasing labour cost as a result of rural urban youth migration.

Table 2: Average distance elasticities

Variables	Coefficient	(Standard error)
Banana	0.90	-
Other Crops	0.10***	0.02
Land	-0.07 **	0.03
Labour	-0.06**	0.03
Maintenance cost	-0.21***	0.03
Planting material cost	-0.04*	0.02
Fertilizer (dummy)	-0.03*	0.01
Manure (dummy)	-0.18***	0.02
RTS	0.50	

Source: Study findings based on 2012 field survey data. *, ** and *** indicate significance at the 10%, 5% and 1% level respectively.
Note: square and interaction terms are omitted for simplification.

In terms of policy, this result shows that the outflow of young farmers and youth labour from the region could lead to a decline in production efficiency in the sector. Consequently, specific intervention measures to enhance technological progress (especially labour-saving technologies) and policy measures that make agriculture more attractive to the youth should be given priority to counter the possible impact of labour shortages in the sector. The input maintenance cost had the biggest partial productivity impact on banana output. This reflects the importance of capital in keeping up with the high agronomic requirements of banana production. The distance elasticities for the two outputs reflect the changes in the output composition. The shadow share of banana in the total farm output is computed as 0.90 (i.e. 90%), while that of other crops is 0.10 (i.e. 10%). These estimates suggest that a one per cent increase in the production share of other crops using the specified inputs reduces the shadow share value of banana output by 10%, and vice versa. All the farmers in our data cultivate banana (as a cash crop) mainly for the export market, and therefore its large shadow share to total revenue with respect to other crops is consistent with the data and our expectations. The relatively low estimate of other crops' output elasticities reflects the low shadow share of other crops in the multi-output production setup.

[7] The distance elasticities for a "well-behaved" input must be negative, according to Brümmer *et al*. (2006) and Brümmer and Glauben (2004).

Overall, the magnitudes of the estimates (a reflection of economic gain) as shown by the partial elasticity estimates of the production inputs are very small. Summing up the production inputs' distance elasticities gives a measure of the scale elasticity. At the sample mean, the production systems exhibit decreasing returns to scale (i.e. RTS = 0.50, implying that doubling the amount of inputs employed in production will result in less than double the output). This means that, given the current technology available to the industry, as more inputs of this type are employed in production, proportionately less outputs are obtained. This increases the average cost per unit produced. Normally, firms experiencing such decreasing returns to scale are viewed in the economic literature as being too big; as a result, a need arises for such farms to be restructured into a more manageable size. However, the average farm size of 7.1 ha is far too small to justify the argument that farm sizes are overstretched. It should be admitted that the RTS result is probably due to incomplete data. If, for example, only half of the important inputs have been quantified, summing the elasticities is highly likely to give this result. Further research is needed before this possibility can be dismissed. However, outdated production technologies are less efficient in extracting the full biological potential of the crops under cultivation. Accordingly, the introduction of modern production technologies could greatly improve farmers' productivity, and thus the overall output level in the sector.

4.3 Technical efficiency

Table 3 and Figure 2 present summary information on the production efficiency of the sampled farmers in the Volta region. Table 3 reveals that the farmers in this region produce, on average, 85% of the potential output given the current technology available to them. This implies an average increase of 15% in output margins is possible if production inefficiency is eliminated.

Table 3: Summary overview of technical efficiency (TE)

Number of observations	Mean	Standard deviation	Minimum	Maximum
120	0.85	0.07	0.66	0.97

Source: Study findings based on 2012 field survey.

Figure 2 shows the distribution of the efficiency scores of the farmers. The performance scores are distributed over a range from 0.66% to a maximum of 0.97%. Nevertheless, most scores are located around the mean efficiency score (Figure 2). This narrow spread of efficiency scores around the sample mean, with a standard deviation of 0.07, implies low performance variation in the set of sampled farmers. The tails of the boxplot give an indication of the level of variability for the upper and lower 25% quartiles. The long tail toward the lower 25% indicates that there is much more variability in performance scores for low-performing farmers located in that quartile in comparison to the upper 25% quartile.

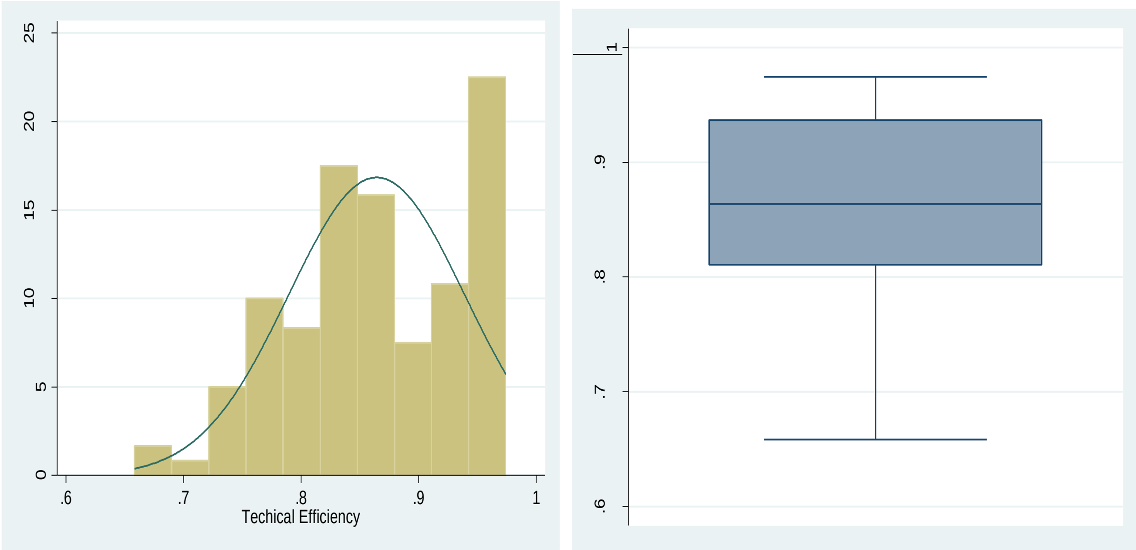

Figure 2: Bar and boxplot distribution of technical efficiency scores
Source: Study findings based on 2012 field survey data.

4.4 Determinants of inefficiency

The results of the inefficiency model are presented in Table 4. The parameter estimates for the included variables measure the direct impact of these variables on the level of farmers' technical efficiency. Farmers' education levels have a positive effect on reducing inefficiency. The significant effect of education in reducing inefficiency may suggest that educated farmers are more capable of sourcing new information on input and output prices, as well as being more willing to experiment with new production technologies to improve their farm operations. Inefficiency increases significantly as distance to market increases. This observation may suggest that farmers located in remote areas have less access to technical inputs and support services, which would have a negative effect on their production performance. Increasing crop density reduces production efficiency. This may be due to the dense canopy effect as a result of a high number of banana plants per hectare, which prevents efficient light penetration and distribution on plots and subsequently affects photosynthesis. As a result, farmers in the sector should be assisted through the extension services to keep to the recommended density requirements. Land ownership has a positive and significant effect on reducing inefficiency. This observation may be an indication that farmers with secured land tenure (i.e. secured property rights) have more incentives to improve their land quality, especially with regard to long-term investment decision making and production strategies. Secured land property right is therefore one of the major factors that has a positive effect on production efficiency in this region of Ghana. The low magnitude of technical efficiency scores may be a consequence of the imposition of the necessary conditions for curvature in the estimated model. Hence, the result should not be over-interpreted.

Table 4: Drivers of inefficiency

Variables	Coefficient	Standard error
Constant	0.19*	0 .11
Education	-0.02***	0.01
Distance to market	0.12**	0.01
Crop density	0.03**	0.01
Experience	-0.01	0.01
Extension	-0.02	0.03
Contract (dummy)	-0.03	0.04
Land status (dummy)	-0.23***	0.04

Source: Study findings based on 2012 field survey data.
*, ** and *** represent significance at the 10%, 5% and 1% level respectively.

5. Conclusions

This study contributes to the ongoing quest to maximise the contribution of the agricultural sector to the national developmental goals of Ghana. Clearly, enhancing farmers' productivity can influence not only the sector's survival, but also how much it benefits from participating in international trade. This paper explores ways of improving the production efficiency of commercial banana producers using survey data of 120 randomly sampled farmers in the Volta region of Ghana. By means of a stochastic frontier approach, an output distance function estimation technique was used to analyse and explore factors driving production inefficiency in this region of Ghana. Farmers in our survey produced a mixture of crops (i.e. production diversification). Hence, an output distance function was deemed appropriate as it allowed us to explore changes in the levels of outputs in relation to the frontier output mix (PPF). The empirical results show that the changes in the output composition are significantly different from zero. The result of the first-order input elasticities also reveals that all inputs monotonicitly increased banana production in the region. However, evidence of a decreasing return to scale (RTS = 0.50) could not be attributed to farm size, as prescribed by economic theory. The obsolete nature of the production techniques[8] (the sector is dominated by traditional production practices) currently being employed in the region is an impediment to growth in the sector. Measures to improve production practices using modern production tools therefore will help to boost overall output.

The results of the efficiency model show an average performance score of 85%, which implies that a potential 15% increase in output through improvements in technical efficiency would be plausible, given the current production technology in the region. Household socioeconomic characteristics such as farmers' education level, experience, land tenure and regular contact with extension workers were found to improve production efficiency (i.e. reduce inefficiency). However, the low economic magnitudes of the estimate are deemed to be insufficient in sustaining the sector's competitiveness in the highly competitive environment of international trade. Hence, policy measures that facilitate a transition from the current traditional production practices to the use of modern production techniques, in conjunction with improvements in technical support and logistics services (e.g. better facilities for ensuring proper postharvest handling, packaging and storage), will enhance productivity gains on a sustainable basis. In practical terms, the traditional production practice of transplanting part of an underground pseudostem or whole sucker with contaminated soil and roots intact facilitates the transmission of devastating banana wilt diseases from farm to farm, making the control of these diseases very difficult. The introduction of modern production methods – where planting materials

[8] An obsolete production technique, such as the "slash and burn" land preparation technique, destroys certain important species (flora and fauna) in the ecosystem. This has a negative effect on soil micro-organisms necessary for fertility and crop yield.

(i.e. banana suckers) are propagated by means of tissue culture techniques to ensure disease-free planting material – could ensure high farm output with minimum production cost.

Finally, the results of the study show that sources of production inefficiency across the farmers sampled in the region are closely linked to the effect of current farm production techniques, poor agronomic practices and household-specific attributes. Practical intervention measures that improve the capacity of farmers to make efficient use of the available resources (i.e. improving the technical efficiency of farmers), in addition to measures that facilitate the transfer of modern production technologies to all farmers in the sector, will enhance the competitiveness of the sector in response to increasing international market pressure in terms of quality and quantity standards. Even though our analysis sheds some light on the problems facing the banana sector and recommends some remedies, it should be stressed that these recommendations are not in any way a panacea to all the problems facing the sector. The use of cross-sectional survey data limited our ability to explore potential time-linked (i.e. trends) sources of productivity growth in the sector. To explore such sources of productivity growth (i.e. TFP) and the determinants in detail, a panel or time-series data will be needed; hence, a follow-up study using such datasets is strongly recommended. Nevertheless, we are optimistic that the implication of this study is relevant for policymakers in enhancing the sector's economic performance and competitiveness. Furthermore, policy makers in neighbouring countries (i.e. Togo and Benin) could draw lessons from this study in addressing banana productivity due to the similarity in farm-household socioeconomic and production structures, as well as similarities in soil and climatic conditions.

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