Drivers of technical efficiency and technology gaps in Ghana's mango production sector: A stochastic metafrontier approach

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Abstract

Mango production and exports in Ghana have been increasingly volatile over the past years. After the successful take-off of the sector in the early 2000s, output and international market share decreased. In this study, the reasons for the lacklustre performance on the production side are considered using cross-country survey data from Ghana. In particular, technical inefficiencies and technology gaps of smallholder mango producers are analysed. A metafrontier framework allows for separating production inefficiencies caused by bad agronomic and management practices from technology gaps. The results show that each production zone requires (a) specific targeting programme(s) in order to improve technical efficiency.

Key words: international trade; productivity; technology gaps; Ghana mango sector

1. Introduction

The mango sector plays an important role in Ghana's economy in terms of employment and foreign exchange (Afari-Sefa 2007). Ghana is one of the few countries in the world with two major mango seasons; this opens the possibility to supply high volumes of quality fruit to the international mango market all year round (Ganry 2007). Both local and multinational agro-processing companies thus have established production plants in many parts of Ghana, processing high volumes of tropical fruits into specialised products (i.e. fresh cuts, dried, juice and concentrates) for export. The steady expansion of cultivation throughout the country has increased employment opportunities for many through its forward and backward linkages (i.e. supply of fruit to exporters/agro-industries and demand for inputs/services) to other sectors of the economy (Jaeger 2008).

A lack of public and private investment in facilitating innovative technological advancement to enhance productivity in the sector may have undermined the performance of the sector. However, output growth is determined not by technological advancement alone, but also by the efficiency with which the available technologies and local resources are used (Nishimizu & Page 1982). Thus, in a country in which opportunities for developing modern, new production technologies are lacking, efficiency and productivity studies could be significant in assessing how output in the mango sector could be increased with the available production technologies or resources. The efficient use of the available resources through improvements in farmers' production efficiency could drastically enhance the competitiveness of the sector in international trade. This study therefore aimed to identify and analyse the factors that influence mango farmers' production levels and efficiency. Our findings are useful in highlighting selected policy measures that could be useful in assisting policy makers to design effective future programmes for helping the sector exploit its full economic potential.

Efficiency estimation using stochastic frontier analysis (SFA) and/or data envelopment analysis (DEA) often assumes homogeneous production technology for all decision-making units in that industry. However, for a variety of reasons, farmers in the same sector may be forced to operate under different production technologies, e.g. because of differences in climate, soil type and financial resources. Battese *et al*. (2004) emphasise that "technical efficiencies of firms that operate under a given production technology are not comparable with those of firms operating under different technologies". Thus, failure to account for these technological differences risks attributing production shortfalls due to technological gaps to the technical inefficiency of farmers in that industry, hence the need to employ an analytical method that allows the effect of technology gaps on production output to be distinguished from that of technical inefficiency effect.

In many instances, farmers in the same industry are not constrained by such physical factors in making use of the available production technology, but are constrained by a lack of required infrastructure and/or investment constraints. Such a situation typically arises with perennial fruit crops such as mangoes, where the production cycles span many decades. Often it is not feasible for farmers to replant their trees in the short or medium term, even though a more productive variety may have become available since the initial planting (Villano *et al*. 2010). Farmers in the northern savannah zone of Ghana face different climatic and soil conditions, as well as lower infrastructural development, compared to those in the middle and southern zones. We therefore adopted the metafrontier approach to study the technical inefficiency and technological gaps of mango farmers in the different production zones of Ghana. The model enables us to separate causes of technical inefficiencies due to poor agronomic practice from those due to technological differences between the zones. This distinction is important, since both sources of production shortfalls have different policy implications:

1. Technical inefficiency (i.e. estimates of the distance from an input-output point to the zonal frontier) should be addressed by designing performance-enhancing programmes involving changes to the agronomic practices and/or management capabilities and effectiveness of how farmers use the available resources in that zone to achieve higher yields.
2. Technology gaps (i.e. estimates of the distance between the zonal frontier and the industrial frontier) could be addressed by programmes to improve the production environment in order to enable farmers to access the best production techniques available in the industry.

Naturally, policy measures cannot affect certain bio-physical conditions such as temperature, humidity and rainfall patterns in the production environment. Thus, further empirical analysis is necessary to distinguish bio-physical reasons for technology gaps from other sources of these gaps. Nevertheless, generating knowledge on the role of such bio-physical differences could be useful in highlighting the suitability of a zone for producing mangoes. Such empirical insights could shape future agricultural development policies towards such regions. The structure of the paper in the subsequent sections is as follows: In section 2 we highlight the theory underpinning the metafrontier approach and show how distances between observed data points and the metafrontier can be decomposed into meta-technology ratios and technical efficiency. Section 3 describes the research area and data. Section 4 discusses the results and Section 5 concludes by highlighting selected policy measures.

2. Analytical framework

2.1 The stochastic metafrontier model

Building on the work of Hayami (1969) and Hayami and Ruttan (1970; 1971), Battese and Rao (2002) and Battese *et al*. (2004) proposed the stochastic metafrontier estimation technique as an improved estimation approach over the classic stochastic frontier approach (SFA) and data envelopment analysis (DEA) to investigate the technical efficiencies of firms in the same industry that may not have the same technology.

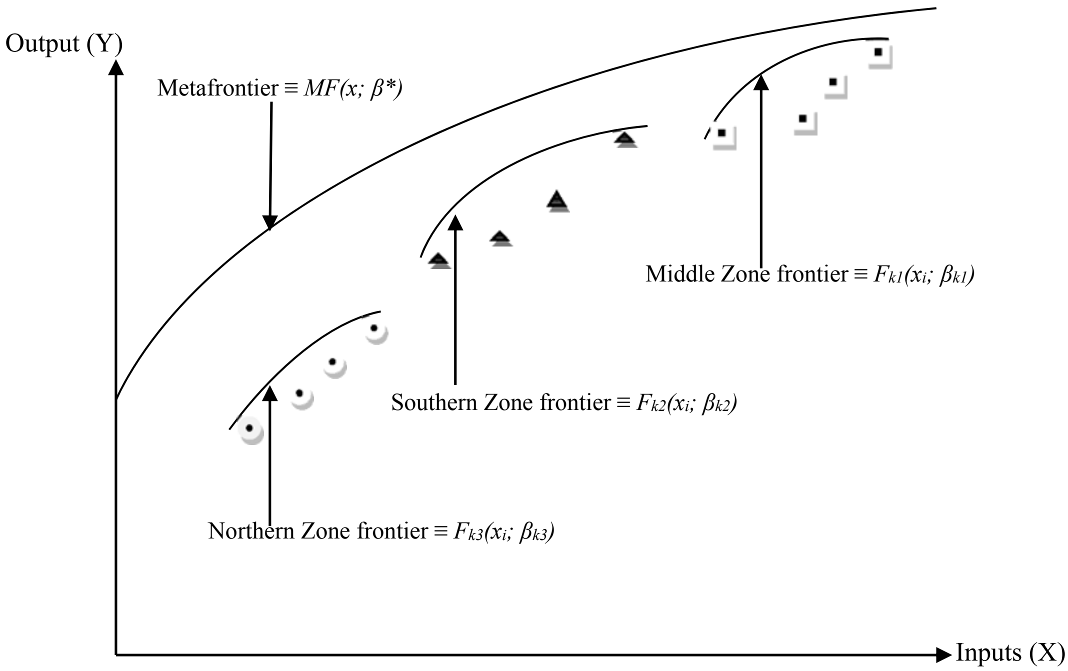

Figure 1: Metafrontier function model
Source: author's owned conceptual depiction

The metafrontier represents a boundary of an unrestricted technology set potentially available to the industry as a whole, while the group/zonal frontiers represent the boundaries of restricted technology sets where the restrictions may be due to constraints prevailing in the production environment, which limit farmers in these zones from using the full range of technologies potentially available to the industry (O'Donnell *et al*. 2008). In line with (Battese *et al*. 2004), the metafrontier is assumed to be a smooth function (not a segmented envelope) that envelopes all the frontiers of the individual groups (zones) in the industry (see Figure 1). For the k^{th} zone, a stochastic frontier model can be written as:

$$\ln Y_{i(k)} = f(x_{i(k)}, \beta_{(k)})e^{v_{i(k)}-u_{i(k)}} \quad (1)$$

We assume that the frontier production function is linear in logarithms, so $x_{i(k)}$ denotes the input vector for the i^{th} farmer in zone k, and $Y_{i(k)}$ is the output for the ith farmer for the kth zone; $\beta_{(k)}$ is a vector of parameters specific for each zone; the $v_{i(k)}$s are random error terms identically and independently distributed as $N(0, \sigma^2_{v(k)})$ (Aigner *et al*. 1977). Finally, the $u_{i(k)}$ s are non-negative random variables that account for technical inefficiency. In order to incorporate determinants of technical inefficiency, $z_{ij(k)}$, we assume a heteroscedastic specification based on a half-normal distribution $N^+(0, \sigma^2_{u_{i(k)}})$ (Wang & Schmidt 2002):

$$\sigma_{u_{i(k)}} = \exp\{z_{ij(k)}\delta_j\} \quad (2)$$

where δ is a vector of parameters to be estimated, reflecting the impact of the variables $z_{ij(k)}$ on technical inefficiency. The metafrontier production function model for farmers in the whole mango production sector could be expressed as:

$$\ln Y_i^* = (x_i; \beta^*) = e^{x_i\beta^*}, \quad i = 1, 2, \ldots N, \quad (3)$$

where Y_i^* is the metafrontier output and β^* denotes the vector of parameters for the metafrontier function satisfying the constraints:

$$x_i\beta^* \geq x_i\beta_{(k)} \quad \text{for all } k = 1,2,3. \quad (4)$$

Equation (4) specifies that the metafrontier dominates all the zone frontiers. The metafrontier production function as specified by equation (3) is a log linear production functional form, and the constraint imposed in equation (4) does not allow the metafrontier function to fall below the deterministic functions for the three zones involved in the sector (Battese *et al*. 2004). The model is underpinned by a single data-generating process (O'Donnell *et al*. 2008). The observed output for the ith farmer defined by the stochastic frontier for the kth zone in equation (1) is alternatively expressed in terms of the metafrontier function of equation (3) by:

$$Y_i = e^{-u_{i(k)}} \times \frac{e^{x_i\beta_{(k)}}}{e^{x_i\beta^*}} \times e^{x_i\beta^* + v_{i(k)}} \quad (5)$$

The first term on the right-hand side of equation (5) is the technical efficiency of the *ith* farmer relative to the stochastic frontier for the kth zone. Equation (6), which is the same as the first term on the right-hand side of equation (5), allows us to examine the performance of the *ith* farmer relative to his/her zonal frontier.

$$TE_{i(k)} = \frac{Y_i}{e^{x_i\beta_{(k)} + v_{i(k)}}} = e^{-u_{i(k)}} \quad (6)$$

The second term on the right-hand side of equation (5) is what O'Donnell *et al*. (2008) call the meta technology ratio (MTR) for the observation of the sample farms involved in the sector. This is expressed as:

$$MTR_{i(k)} = \frac{e^{x_i\beta_{(k)}}}{e^{x_i\beta^*}} \quad (7)$$

This measures the ratio of the output for the frontier production function for the kth production zone relative to the potential output that is defined by the metafrontier function, given the observed inputs. This ratio provides an estimate of the technology gap between the zones and the sector as a whole. The MTR plays an important part in explaining the ability of farmers in one zone to compete with farmers from different zones in the sector. The technology gap ratio has values between zero and one because of equation (4). Values close to one imply that the zone is producing on or nearer to the maximum potential output, given the technology available to the sector as a whole. The technical efficiency of the *ith* farmer, compared to the metafrontier, is denoted by TE_i^* and is defined in a similar way to equation (6). It is the ratio of the observed output of the *ith* farmer relative to the metafrontier output (i.e. the last term on the right-hand side of equation (5)), adjusted for the corresponding random error, such that:

$$TE_i^* = \frac{Y_i}{e^{x_i\beta^* + v_{i(k)}}} \quad (8)$$

Following equations (5), (6) and (7), the TE_i^* can alternatively be expressed as

$$TE_i^* = TE_{i(k)} \times MTR_{i(k)} \quad (9)$$

Because both $TE_{i(k)}$ and $MTR_{i(k)}$ are measures between zero and one, the value of TE_i^* is also between zero and one. In line with Battese *et al*. (2004) and O'Donnel *et al*. (2008), we estimated the parameters and measures associated with the metafrontier model as described in their work.

2.2 Empirical specification

The empirical result for this study was obtained using the translog stochastic frontier production function model. A translog model of equation (1), which is assumed to represent the production technology for mango farmers in a particular zone, could be defined as:

$$\ln y_i^k = \beta_0^k + \sum_{j=1}^{J} \beta_j^k \ln x_{ji}^k + 1/2 \sum_{j=1}^{J} \sum_{m=1}^{J} \beta_{jm}^k (\ln x_{ji}^k)(\ln x_{mi}^k) + \sum_{s=1}^{S} \beta D_s + v_i^k - u_i^k \quad (10)$$

where $\ln x_{ji}^k$ represents the jth input ($j = 1,2,....J$) of the ith farmer ($i = 1,2,...N$) in the kth zone ($k = 1,2,...K$). $\beta_{jm}^k = \beta_{mj}^k$ for all j and m. $\ln y_i^k$ denotes the natural logarithm of the total fruit output (measured in kg) for the *ith* farmer in the *kth* zone. The X_s represents the various continuous/discrete production inputs variables (viz. land, labour, fertiliser cost and plant age). D_s are dummy variables (viz. extension, irrigation, credit access, gender and farmer association) intended to capture unique regional and household socioeconomic characteristics that may influence the production output(s) levels of farmers (see Table 10 for variable units and definitions). The discrete variables in the model were scaled to have unit means so that the first-order coefficients of the translog function can be interpreted as elasticities of output with respect to inputs evaluated at the sample means (Coelli *et al*. 2005). For appropriate policy interventions it is not enough to only have estimates of technology gaps between zones and the industrial frontier, but information on what might have contributed to the formation of these gaps is also needed. We therefore specify an average response function to capture the determinants of the technology gap ratio, as follows:

$$MTR_i = \beta_0 + \sum_{j=1}^{J} \beta_j q_{ij} + \varepsilon_i \quad (11)$$

Equation (11) specifies climatic, soil, infrastructural and government programme variables outside the control of farmers hypothesised to influence the production environment of the mango production sector. The ε_i captures any statistical noise and is assumed to be identically and independently distributed as $N(0, \sigma_v^2)$ random variables.

3. Research area and data

Ghana is divided into ten administrative regions. These regions are characterised by huge differences in infrastructure access and quality (i.e. roads and access to input and output markets, etc.). Based on climatic conditions, the country is divided into six agro-ecological zones (Table 1). Mangoes are tolerant to a wide range of soil and weather condition, making them possible to be grown commercially in many regions in the country. The growing areas extend from the coastal savannah through the deciduous forest in the middle zone to the Guinea savannah in the north.

Table 1: Agro-ecological zones of Ghana (from north to south)

Agro-ecological zone	Area (km^2)	Average annual rainfall (mm)	Range (mm)	Major rainy season	Minor rainy season
Sudan savannah	2 200	1 000	600–1 200	May–Sept	-
Guinea savannah	14 7900	1 000	800–1 200	May–Sept	-
Transition zone	8 400	1 300	1 100–1 400	March–July	Sept–Oct
Deciduous forest	66 000	1 500	1 200–1 600	March–July	Sept–Nov
Rain forest	9 500	2 200	800–2 800	March–July	Sept–Nov
Coastal savannah	4 500	800	600–1 200	March–July	Sept–Oct

Source: Ghana meteorological department, Accra-Legon

A distinct dry season is required to assist with the initiation of fruit set. However, the intensity and extent of rainfall or dry season causes tree yields to fluctuate from year to year, depending on the variety. This seasonal variation in climatic factors therefore may affect the type of production technology employed in a particular region. In the light of the high possibility of non-homogeneous production technology across the country, this study uses a metafrontier estimation technique to assess the factors affecting the production performance of farmers in the mango production sector. In 2012, a field survey was carried out to gather data on production inputs and output by farmers in the Ghanaian mango sector. The study used an integrated approach that draws upon both quantitative and qualitative[1] methods of primary data collection. Based on information from district extension offices in each region, villages in each district with commercial mango producers were selected. In total, our sample comprises 365 mango farmers. Due to some plantations stretching between administrative regions, no significant difference in terms of soil and weather conditions could be observed. Hence, we decided to group the data into three zones, as presented in Table 2 below. Using a structured questionnaire, detailed information on mango production activities (e.g. input use, farm output, etc.) as well as some socioeconomic characteristics of the sampled farmers were obtained.

Table 2: Grouping of regions into zones

Zone	Region(s)	Number of observations
Northern Zone	Northern	93
Middle Zone	Brong-Ahafo and Ashanti	91
Southern Zone	Eastern and Volta	181

Source: study findings base on 2012 field survey

A lack of systematic book-keeping of all production activities by most farmers means that most of the information obtained is recall information.[2] Ideally, all ten administrative regions in Ghana should have been included in the survey; however, due to financial and other resource constraints, only the abovementioned regions, which reflect a fair representation of mango-producing areas in Ghana, were surveyed for the study.

3.1 Summary statistics

The descriptive results in Table 3 show considerable differences between the three zones. On average, farmers in the southern zone had higher farm output, allocated more land area to mango production and had higher expenditure on agrochemical inputs. These variations might suggest differences in production practices between these zones. However, the descriptive analysis does not tell us how these differences affect farmers' efficiency of production, hence we proceeded with a metafrontier

[1] Qualitative information was obtained during on-farm interaction with farmers, extension officers, village heads etc., while quantitative information was obtained using a structured survey questionnaire.

[2] Ideally, systematically well-documented farming information would have been preferred rather than recall information, since recall information could aggravate the problems of outliers in statistical estimation. This could be a drawback and should be borne in mind in the interpretation.

estimation technique to explore how this heterogeneity in production practices affects farmers' technical efficiency across the zones.

Table 3: Summary statistics (continuous variables)

Variable	Northern Zone (n = 93)			Middle Zone (n = 91)			Southern Zone (n = 181)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Farm output (kg)	404.00	100.00	4 400.00	2 555.28	190.00	17 500	5 819.49	150.00	20 000
Labour (hours)	3.54	3.00	5.00	4.21	3.00	8.00	5.34	3.00	8.00
Land (ha)	0.69	0.40	4.00	2.88	0.40	15.40	5.17	0.40	20.00
Crop density (plants/ha)	56.42	40.00	100.00	92.46	35.00	105.00	94.11	40.00	110.00
Education (years)	8.61	4.00	28.00	12.04	0.00	25.00	12.74	4.00	24.00
Plant age (years)	8.30	6.00	12.00	7.76	6.00	18.00	10.60	6.00	25.00
Experience (years)	9.23	6.00	14.00	8.79	6.00	18.00	11.59	6.00	26.00
Age of farmer (years)	52.16	30.00	75.00	51.80	30.00	74.00	55.27	30.00	76.00
Household size	8.37	2.00	13.00	5.77	2.00	10.00	5.95	2.00	14.00
Distance to market (km)	7.42	5.00	17.00	10.67	4.00	26.00	12.16	4.00	32.00
Agrochemical cost (cedis)	53.01	0.00	106.40	56.74	0.00	175.00	82.67	0.00	195.00
Fertiliser cost (cedis)	2.45	0.00	40.00	34.89	0.00	210.00	59.45	0.00	230.00
Fruit traders	3.10	1.00	5.00	7.00	3.00	12.00	8.00	1.00	13.00
Input stores	2.00	1.00	3.00	5.00	3.00	9.00	5.00	0.00	10.00

Source: study findings based on 2012 field survey data. Note: Coefficients and standard errors have been rounded off to two decimal places

3.2 Test for model specification

Table 4 presents information on the various hypotheses tested in this study (these hypotheses are tested using the generalised likelihood-ratio statistic; $LR = -2[\ln\{L(\text{H0})\} - \ln\{L(\text{H1})\}]$, where $L(H0)$ and $L(H1)$ are values of the likelihood function under the null ($H0$) and alternative ($H1$) hypotheses respectively. LR has approximately a Chi-square (or mixed Chi-square) distribution if the given null hypothesis is true, with a degree of freedom equal to the number of parameters assumed to be zero in ($H0$). Coelli (1995) proposes that all critical values can be obtained from the appropriate Chi-square distribution. However, if the test of hypothesis involves $\gamma = 0$, then the asymptotic distribution necessitates the mixed Chi-square distribution (Kodde & Palm 1986; Table 1).

The use of metafrontier is meaningful and justified only if a statistical test confirms the presence of differences in the underlying technology between groups in the same industry (O'Donnell *et al.* 2008). Using the maximum likelihood estimation procedure, the value of the log-likelihood function for the stochastic frontier estimated by pooling the data for all zones and the sum of the values of the log-likelihood functions from the individual zonal production frontiers was computed to verify if the various zones used different technologies, and hence the necessity to adopt a metafrontier as an appropriate estimation framework. As presented in Table 4 below, the null hypothesis of homogeneous technology among all zones was strongly rejected, hence the metafrontier framework adopted for the analysis was appropriate and justified. The null hypothesis that the Cobb-Douglas frontier is an adequate representation of the data for all zones was strongly rejected, indicating that the translog model represents the data better. The null hypothesis that technical inefficiency is not present in all zones was also rejected, implying that the majority of farmers operated below the production frontier.

Table 4: Hypothesis testing for stochastic production frontier model

Null hypothesis (Ho)	χ^2 statistics	Degrees of freedom	χ^2 critical	P-value
Homogenous technology across all regions	118.02	53	70.99	0.00
Cobb-Douglas functional form is appropriate: $\beta_{ij} = 0$				
Northern Zone (Northern region)	26.12	6	12.59	0.01
Middle Zone (Brong-Ahafo and Ashanti regions)	33.46	6	12.59	0.00
Southern Zone (Eastern and Volta regions)	1.96	6	12.59	0.01
No technical inefficiency effects: $\gamma = \gamma\ 1 = ... = \gamma\ 9 = 0$				
Northern Zone (Northern region)	27.13	9	14.067	0.01
Middle Zone (Brong-Ahafo and Ashanti regions)	10.07	9	14.067	0.01
Southern Zone (Eastern and Volta regions)	14.68	9	14.067	0.01

Source: Study findings based on 2012 field survey data.

4. Results and discussion

4.1 Parameter estimates of the translog stochastic production frontier

Table 5 presents the estimated first-order coefficients of the translog zonal stochastic frontier production function (see Table 11 in the Appendix for the full table). Table 5 shows that total farm output is positively and significantly influenced by the share of land allocated to mango production in all three zones. This reflects the importance of access to land in the production zones. The Northern Zone experienced the highest output elasticity with respect to the input variable land. The positive and significant coefficient of land (i.e. 1.05) implies an increasing marginal productivity with respect to land access in the Northern Zone, while the opposite effect of decreasing return is experienced in the Southern and Middle Zones. Increasing population pressure, due mainly to rural-urban migration – particularly from the Northern Zone to the Southern and Middle Zones (viz. Accra and Kumasi) – coupled with rapidly increasing urbanisation in these two zones relative to the Northern Zone, puts pressure on potential agricultural land for mango cultivation. Hence, farmers in the Northern Zone can expand their plantation size with relative ease compared to farmers in the Middle and Southern Zones.

Increasing labour input has a positive and significant effect on output in the Southern and Middle Zones, but surprisingly not in the Northern Zone. Increasing labour participation in farm maintenance and other agronomic practices was expected to have a positive effect on output, hence the non-significant effect of labour input in the Northern Zone contradicted our expectation. However, this observation could be explained by the decreasing labour availability due to constant youth migration from the Northern Zone to the Southern and Middle Zones, which limits farmers in the Northern Zone because of a lack of access to youth labour. As revealed during data collection, farmers in the Northern Zone often rely more on animal draft power and farm machinery (e.g. donkeys, tractors, knapsack sprayers, etc.) in performing most farm operations compared to their counterparts in the Middle and Southern Zones, who rely on the abundant, cheap influx of youth labour from the north in performing most farm operations. Fertiliser use has significant positive effects only in the Northern Zone, while plantation age has the same effect except in the Middle Zone.

Table 5: First-order estimates of the translog stochastic frontier models

Variable	All zones pooled		Northern Zone		Middle Zone		Southern Zone	
Name	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Constant	-0.310**	0.125	-0.137	0.286	-0.252	0.162	-0.367*	0.205
log land	0.597***	0.062	1.050*	0.577	0.861***	0.102	0.469***	0.133
log labour	0.450**	0.203	-0.801	2.622	0.975***	0.319	0.696*	0.365
log fertiliser cost	0.220***	0.055	1.894***	0.616	0.175	0.117	0.230**	0.115
log plant age	0.310***	0.108	0.970***	0.165	-0.074	0.219	0.415***	0.135
Extension (dummy)	0.093*	0.059	0.409***	0.122	0.203**	0.089	-0.072	0.102
Irrigation (dummy)	0.226***	0.080	0.343***	0.082	-0.069	0.109	0.448***	0.153
Credit access (dummy)	0.090*	0.056	-0.144	0.138	0.090	0.105	0.019	0.071
Gender (dummy)	0.087	0.064	-0.203**	0.098	0.311***	0.100	0.139	0.096
Farmer assoc. (dummy)	0.074	0.089	0.516***	0.120	-0.016	0.125	0.079	0.097

Source: Study findings based on 2012 field survey data. *, **, *** indicate significance at the 10%, 5% and 1% levels respectively.
Note: Coefficients and standard errors have been rounded off to three decimal places. Square and interaction terms have been omitted in this table (see Table 11 in the Appendix for the full table).

A set of dummy variables which are assumed to capture regional and household socio-economic characteristics had positive and significant effects on total farm output. However, the effect of these variables differed remarkably on how they influenced the production possibility frontier between the three zones. For instance, extension had a positive and significant effect in the Northern and Middle Zones, while irrigation had the same effect except in the Northern and Southern Zones. Male farmers had a significantly positive effect on output in the Middle and Southern Zones, while being a member of a farm association had the same effect only in the Northern Zone.

4.2 Determinants of inefficiency

The result of the inefficiency analysis in Table 6 shows that increasing access to land reduces inefficiency in all zones; however, this effect is significant only in the pooled model. This observation could imply that farmers with a large farm size have more resources, which enables them to employ efficiency-enhancing technologies during production compared to farmers with smallholdings. Increasing agrochemical costs to control diseases and pests (e.g. fruit flies) reduce inefficiency in the Southern Zone. In contrast to our expectations, farmer's education, experience and land status had a significant effect on increasing inefficiency in the Northern and Middle Zones. Irrigation practice significantly reduced inefficiency in the Northern Zone, compared to the insignificant and opposite effect in the Middle and Southern Zones.

Table 6: Determinants of inefficiency

Variable	All zones pooled		Northern Zone		Middle Zone		Southern Zone	
Name	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-1.326***	0.391	-43.355***	0.694	-0.788*	0.468	-3.116*	1.963
log land	-0.414**	0.208	-3.637	3.722	-0.248	0.265	-0.322	0.339
log Labour	-0.784	0.697	-1.236	2.803	0.787	0.845	-0.415	0.898
log fertiliser cost	0.202*	0.106	-7.351***	2.540	0.050	0.126	0.189	0.375
log agrochemical cost	-0.011	0.043	-0.083	0.159	0.090	0.082	-0.508**	0.247
log experience	0.096	0.419	11.640**	5.305	-0.042	0.479	0.371	0.654
Irrigation (*dummy*)	0.322	0.277	-3.886*	2.114	0.121	0.352	1.989	1.814
Education (*years*)	0.014	0.014	0.337**	0.160	0.008	0.021	0.016	0.022
Farmer assoc. (*dummy*)	-0.264	0.316	1.815	1.228	-0.244	0.309	-0.159	0.351
Land status (*dummy*)	-0.037	0.128	4.306**	1.753	0.318*	0.189	-0.007	0.185

Source: Study findings based on 2012 field survey data. *, **, *** indicate significance at the 10%, 5% and 1% levels respectively.
Note: Coefficients and standard errors have been rounded off to three decimal places.

The value of gamma, which provides an indication of how much of the deviation in the observed output from the production frontier can be associated with inefficiency, was estimated to be 51%, 95% and 77% respectively. This suggests that the combined effect of the hypothesised variables included in the inefficiency model contribute collectively in explaining how inefficiency affects farm output in these zones.

4.3 Parameter estimates of the metafrontier

The rejection of homogeneous production technology for all zones suggests that the performance estimates obtained using the zonal stochastic frontiers are not comparable, since farmers in each zone operate using different technology. Hence, the metafrontier technique that enables comparisons of farmers' performance in each zone relative to the potential sectoral technology (i.e. the meta-technology) was employed. Table 7 presents the two metafrontier parameters.

In line with Battese *et al*. (2004) and O'Donnell *et al*. (2008), statistical simulations were used to obtain estimates of standard errors of the two metafrontier parameters. Both the LP and QP gave similar estimates, hence the QP estimates were used for computation of the MTR and are used for the discussion in the subsequent sections.

Table 7: Parameter estimate of the metafrontier

Variable	LP (sum of absolute deviation)		QP (sum of square deviation)	
Name	Coefficient	SE	Coefficient	SE
Constant	-0.088	0.181	-0.102	0.173
log land	0.756***	0.111	0.708***	0.103
log labour	0.495*	0.307	0.575*	0.332
log fertiliser cost	0.268**	0.122	0.304***	0.098
log plant age	0.123	0.177	0.065	0.179
Extension (dummy)	0.062	0.108	0.079	0.112
Irrigation (dummy)	0.139	0.134	0.135	0.112
Credit access (dummy)	0.100	0.081	0.113	0.081
Gender (dummy)	0.264***	0.092	0.269***	0.095
Farmer assoc. (dummy)	0.022	0.124	0.029	0.117
.5*log land^2	0.015	0.215	-0.068	0.193
.5*log Labour^2	0.172	1.985	-0.084	1.716
.5*log fertcost^2	-0.053	0.069	-0.043	0.067
log land*log labour	-0.211	0.390	-0.159	0.348
log land*log fertiliser cost	0.167**	0.085	0.181**	0.073
log Labour*log fertiliser cost	-0.071	0.189	-0.049	0.164
Number of observations	365		365	

Source: study findings based on 2012 field survey data. *, **, *** indicate significance at the 10%, 5% and 1% levels respectively

Note: Coefficients and standard errors have been rounded off to three decimal places

4.4 Average performance scores

Table 8 and Figure 2 presents the summary distribution of the meta-technology ratio (MTR), metafrontier technical efficiency (MFTE), and group-specific technical efficiency (TE) as defined in equation (5). The MTR values in Table 8 reveal that mango farmers across the three zones produce, on average, 48%, 79% and 70% respectively of the potential output given the technology available to the Ghanaian mango industry as a whole. The MTR values capture the average performance shortfall as a result of the technology gap facing each zone when their performance is compared with the metafrontier. Consequently, on average, the Middle Zone is more productive (31% and 9% percentage points) than the Northern and Southern Zones respectively. Even though farmers in the

Northern Zone achieved a high average output performance of 94% with respect to their zonal frontier, their output performance still lags behind the sectoral performance, with a technology gap of 48%.

The mean values of the efficiency performance (TE) with respect to each zone frontier vary from a low of 72% (Middle Zone) to a high of 94% (Northern Zone). However, zone-specific performance scores cannot be compared with each other since they are estimated with respect to different frontiers. Comparisons of efficiency performance across zones are therefore made using the metafrontier technical efficiency (MFTE) scores. The performance of farmers in the Middle and Southern Zones were identical when their average technical efficiency scores were compared to the metafrontier. The average technical efficiency score of the Northern Zone relative to the metafrontier was substantially smaller compare with that of the other two zones. These differences in performance scores with respect to the MTR, TE and MFTE have consequences for policy design. They provide information on the specific type of intervention measures needed to be put in place in each zone to enhance productivity in the sector.

Table 8: Summary statistics of technical efficiency (TE), meta-technology ratio (MTR) and meta-frontier technical efficiency (MFTE)

	Northern Zone			Middle Zone			Southern Zone		
	TE	MTR	MFTE	TE	MTR	MFTE	TE	MTR	MFTE
Mean	0.94***	0.48***	0.45***	0.72***	0.79***	0.56***	0.80***	0.70***	0.56***
Minimum	0.44	0.29	0.19	0.32	0.44	0.25	0.38	0.44	0.28
Maximum	1.00	0.95	0.86	0.95	1.00	0.92	0.98	1.00	0.86
Std. dev.	0.13	0.15	0.15	0.17	0.12	0.15	0.13	0.13	0.12
No. of obs.	93			91			181		

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

Note: Coefficients and standard errors have been rounded off to three decimal places

For instance, in the Northern Zones, where the majority of farmers have already been observed to be operating on or near the zonal frontier (viz. 94% TE), but with a huge technology gap (viz. 48% MTR) to the sectoral frontier, measures of raising technology levels (such as the introduction of new mango varieties better suited to this zone and an improvement in agricultural infrastructure, etc.) to help bridge the technology gap will be appropriate, while in the Middle and Southern Zones, where there is much scope for output improvement using the available technologies (viz. TE of 72% and 80% respectively), measures such as enhancing access and improving the quality of the delivery of extension services to enable farmers to improve their agronomic and management capabilities (i.e. better use of available resources) will be a prudent and cost-effective intervention policy.

Figure 2: Distribution of TE, MTR and MFTE for the three zones
Source: Study findings from 2012 field survey data

4.5 Determinants of variations in the meta-technology ratio (MTR)

The value of the MTR gives an idea of the potential improvement in performance that could be achieved through improvements in the production environment. Policy makers can improve the production environment using various instruments, such as reforms in labour laws, input subsidy regulations and infrastructural improvement, for example rural road networks to facilitate the transportation of outputs to urban buying centres and technical inputs to such rural areas. The R-square values of the analysis reveal that 59%, 68% and 69% of variation in the MTR could be explain by such factors embodied in government programmes, private and public participation in input and output markets, and infrastructural, soil and climatic variables in the three zones respectively. For example, access to better roads, connection to the electric grid, access to more fruit buyers and the availability of input stores positively and significantly improve the MTR value (i.e. improve the production environment). Subsidies on inputs surprisingly had a significant effect only in the Northern Zone. Table 9 presents the estimates of the MTR.

Table 9: Determinants of the meta-technology ratio (MTR)

Variable	Northern Zone		Middle Zone		Southern Zone	
Name	Coefficient	SE	Coefficient	SE	Coefficient	SE
Infrastructure						
Road condition	0.056*	0.032	0.058**	0.224	0.057***	0.017
Electricity	0.094**	0.034	0.051**	0.229	0.068***	0.015
Government support programmes						
Extension	0.089*	0.045	0.016	0.021	-0.036**	0.173
Input subsidy	0.087***	0.033	0.017	0.026	0.029	0.019
Private and public market participation						
Fruit traders	0.027*	0.017	0.015***	0.005	0.006**	0.003
Input stores	0.061***	0.021	0.022***	0.007	0.008***	0.003
Soil and weather						
Erosion	-0.003	0.029	-0.023	0.027	-0.177***	0.016
Floods	-0.046	0.029	-0.083***	0.025	-0.029*	0.016
Bushfires	-0.111***	0.031	-0.045**	0.022	-0.017	0.015
Soil quality	0.042	0.296	0.006	0.056	0.005	0.007
Constant	0.188*	0.108	0.522***	0.058	0.643***	0.035
Number of observations	93		91		181	
R squared	0.5872		0.6815		0.6943	

Source: study findings based on 2012 field survey data. *, **, *** indicate significance at the 10%, 5% and 1% levels respectively.
Note: Coefficients and standard errors have been rounded off to three decimal places.

Access to extension services had a positive and significant effect on MTR in the Northern Zone, an insignificant effect in the Middle Zone, but a surprisingly negative and significant effect in the Southern Zone. This observation in the Southern Zone contradicts our expectation; however, this observation indicates how a lack of incentive, motivation and work materials needed for effective extension work could hamper efficient extension delivery in the Southern Zone. Interaction with extension workers across the country during the data collection revealed how extension work is being hampered in the country, as the extension workers expressed their concern about a lack of work materials and delays in financial grants they urgently need to enable them do their work effectively. Hence, to promote effective extension service delivery in the country, ways of motivating extension workers through proper remuneration and material support should be a priority for all stakeholders.

Seasonal floods, bush fires and erosion negatively affect the MTR value in all zones; however, the effect of floods is significant only in the Middle and Southern Zones, while bush fires exhibit significant effects in the Northern and Middle Zones. Variables with positive effects on the MTR improve the production environment and therefore enhance farmer's access and ability to use certain input technology(s) to enhance output towards the sectoral frontier, while variables with a negative effect on the MTR put restrictions on farmers in the production environment and therefore limit farmers' ability to use such productive inputs.

5. Conclusion and recommendations for future policies

Declining productivity is affecting the ability of the Ghanaian mango sector to meet the rapidly increasing export demand. This has led to a loss of international market share and the foreign exchange revenue the country so urgently needs. Increasing productivity is paramount to the sector's competitiveness in international trade. This study therefore uses cross-country farm household data to identify and analyse potential ways of enhancing farmers' productivity and provides policy relevant empirical information for designing performance enhancing programmes to boost output in the industry.

The study used the metafrontier estimation technique to derive performance estimates and drivers of production inefficiencies in the sector. The results of the analysis reveal that, besides technical inefficiency, technology gaps play an important part in explaining production shortfalls in the sector. This has important implications for policy-targeting programmes. For instance, the average technology gaps (MTR) of 48%, 79% and 70% in the respective sectors are due to inhibitions prevailing in the production environment and therefore impair farmers' ability to attain the sectoral maximum. This implies that, if these inhibitions in the production environment are properly addressed, farmers in the respective zones potentially could increase output by 52%, 21% and 30% respectively. The result of equation (11), which enables us to identify the factors influencing the production environment, reveals that an improvement in rural road conditions and access to input and output markets have positive and significant effects in improving the production environment (MTR). The analysis also shows that the Middle and Southern Zones have an average zonal technical efficiency (TE) of 79% and 80% respectively, with a relatively high proportion of farmers having an efficiency score of less than 50% (as depicted in Figure 2). These estimates suggest that it would be economically more prudent to design programmes that enhance farmers' managerial capabilities and agronomic skills, thereby enabling such farmers to make better use of existing technologies to increase output towards their zonal frontier. The ability of farmers to use the local resources and production technologies at their disposal efficiently has a dual effect of simultaneously increasing output while reducing production costs. This combination of lower production costs and higher output could enhance the sector's competitiveness in international trade.

To conclude, the study reveals that there is much scope for output improvement in all zones; however, the attainment of maximum output is possible only if the causes of inefficiency due to technology gaps and farmers' efficiency in using the available resources are properly addressed. Even though our analysis has provided some insight into the problems facing the mango industry and recommend some remedies, it should be stressed that these recommendations are not in any way a panacea for all the problems facing the industry. Improving important intermediate processes along the entire value chain, such as enhancing postharvest activities through proper packaging, storage and transportation, could contribute to the overall improvement in performance of the sector. To sustain the sector's competitiveness in the international market arena, it is necessary, in any future intervention programmes, for policymakers to give priority to policy support in terms of introducing better and modern production technologies (e.g. high-yielding varieties) that are suitable to Ghana's agro-ecological zones in order to push output beyond the current production frontier.

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Appendix

Table 10: Variable name (unit) and definition

Variable name (unit)	Definition
Output (kg)	Total farm output
Labour (hours)	Total number of hours farm labourers devote to working on plantation
Land (ha)	Total land area under mango cultivation only
Crop density	Number of mango plants per hectare
Education (years)	Years of schooling of decision maker or household head
Plant age (years)	Age of the mango plantation
Experience (years)	Number of years as mango farmer
Hage (year)	Age of farm operator or decision maker
Hsize	Household size
Distmkt (km)	Distance from farm household to market
Agrochem (new Gh cedis)	Total cost of agrochemicals
Fertcost (new Gh cedis)	Total cost of chemical fertiliser
Fruit traders	Number of fruit traders to whom the farmer regularly sells fruit
Input stores	Number of input stores/dealers in the area the farmer patronises regularly
land status	Dummy (1 = Owns land; 0 = Otherwise)
gender	Dummy (1 = Male; 0 = Otherwise)
farmer association	Dummy (1 = Member of mango farm association; 0 = Otherwise)
credit access	Dummy (1 = Has access to credit; 0 = Otherwise)
extension	Dummy (1 = Receives extension advice; 0 = Otherwise)
irrigation	Dummy (1 = Irrigates; 0 = Otherwise)
manure	Dummy (1 = Applies manure; 0 = Otherwise)
fertiliser	Dummy (1 = Applies chemical fertiliser; 0 = Otherwise)
Input subsidy	Dummy (1 = Inputs are subsidised by government or NGOs; 0 = Otherwise)
Road condition	Dummy (1 = Access to road in good condition; 0 = Otherwise)
Electricity	Dummy (1 = Connected to the electricity grid, 0 = Otherwise)
Erosion	Dummy (1 = Affected by erosion; 0 = Otherwise)
Floods	Dummy (1 = Affected by seasonal floods; 0 = Otherwise)
Bushfires	Dummy (1 = Affected by seasonal bushfires; 0 = Otherwise)
Soil quality	Rank variable (1= very low, 2 = low, 3 = medium, 4 = high, 5 = very high)

Table 11: Estimates of stochastic production frontier (translog models)

Variable name	All zones pooled		Northern Zone		Middle Zone		Southern Zone	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Production frontier model								
Constant	-0.310**	0.125	-0.137	0.286	-0.252	0.162	-0.367	0.259
log land	0.597***	0.062	1.050*	0.577	0.861***	0.102	0.469**	0.211
log labour	0.450**	0.203	-0.801	2.622	0.975***	0.319	0.696*	0.429
log fertiliser cost	0.220***	0.055	1.894***	0.616	0.175	0.117	0.230	0.159
log plant age	0.310***	0.108	0.970***	0.165	-0.074	0.219	0.415**	0.173
Extension (*dummy*)	0.093*	0.059	0.409***	0.122	0.203**	0.089	-0.072	0.089
Irrigation (*dummy*)	0.226***	0.080	0.343***	0.082	-0.069	0.109	0.448*	0.235
Credit access (*dummy*)	0.090*	0.056	-0.144	0.138	0.090	0.105	0.019	0.069
Gender (*dummy*)	0.087	0.064	-0.203**	0.098	0.311***	0.100	0.139*	0.082
Farmer assoc. (*dummy*)	0.074	0.089	0.516***	0.120	-0.016	0.125	0.079	0.118
.5**log* land^2	-0.222**	0.105	-0.129	0.239	-0.082	0.166	-0.349	0.277
.5**log* Labour^2	-0.130	0.877	-7.861*	4.929	-1.403	1.400	-0.142	2.759
.5**log* fertiliser cost^2	-0.088**	0.037	0.669**	0.317	-0.187***	0.061	-0.091	0.064
log land**log* Labour	0.003	0.209	-0.777*	0.474	0.047	0.317	0.177	0.778
log land**log* fertiliser cost	0.177***	0.039	0.349**	0.151	0.289***	0.057	0.204**	0.088
log Labour**log* fertiliser cost	-0.139	0.107	0.600*	0.844	-0.054	0.163	-0.206	0.239
Inefficiency model								
Constant	-1.326***	0.391	-43.36***	0.694	-0.788*	0.468	-3.116*	1.963
log land	-0.414**	0.208	-3.640	3.722	-0.248	0.265	-0.322	0.340
log Labour	-0.784	0.697	-1.236	2.803	0.787	0.845	-0.415	0.898
log fertiliser cost	0.202**	0.106	-7.351***	2.540	0.050	0.126	0.189	0.375
log agrochemical cost	-0.011	0.043	-0.083	0.259	0.090	0.082	-0.51**	0.247
log experience	0.096	0.419	11.640**	5.305	-0.042	0.479	0.371	0.654
Irrigation (*dummy*)	0.322	0.277	-3.886*	2.114	0.121	0.352	1.989	1.814
Education (*years*)	0.014	0.014	0.337**	0.160	0.008	0.021	0.016	0.022
Farmer assoc. (*dummy*)	-0.264	0.316	1.815	1.228	-0.244	0.309	-0.159	0.351
Land status (*dummy*)	-0.037	0.128	4.306**	1.753	0.318*	0.202	-0.007	0.195
Log-likelihood	-120.543668		-10.0840349		-10.7959386		-38.7112554	
Number of observations	365		93		91		181	
Gamma	0.6738		0.5111		0.9488		0.7676	

*, **, *** indicate significance at the 10%, 5% and 1% levels respectively.
Note: Coefficients and standard errors have been rounded off to three decimal places.
Source: study findings based on 2012 field survey data.