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Supply-Side Interventions in Cocoa Production in Ghana: A Regional Decomposition of Technical Efficiency and Technological Gaps

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Abstract

Although Ghana Cocoa Board (COCOBOD) promotes technical change in cocoa farming with innovative technologies and input support, crop productivity is better advanced by improving on the efficiency of input use by farmers. This study thereby investigates the technical efficiency of cocoa farmers in Ghana. The study uses cross sectional field data covering Western North, Ashanti, Eastern, Volta and Brong-Ahafo regions of Ghana on a sample of 899 cocoa farmers and adopts Meta frontier stochastic frontier analysis to derive production efficiencies for each region. The findings are that supply-side interventions such as hand pollination, hybrid seedlings, farm pruning and extension services can improve on technical efficiency of cocoa farmers, more especially in Ashanti, Eastern and Western region. Notably, the CODAPEC input support programme which encapsulates insecticides and fungicides spraying has failed to improve on production efficiency as compared to the Hi-Tech (fertilizer application) programme. Eastern region cocoa farmers stand out as the most efficient producers, producing about 87% of their potential output given technology, whereas Western North produces 76% of its output potential, the lowest of the five regions. The three other regions, namely, Brong-Ahafo, Ashanti and Volta can produce on average 83%, 80% and 78% of their output potential in cocoa respectively. Averagely, cocoa growing regions are underutilizing 21.5% of available technology in the industry while losing 36.5% of output potential due to technical inefficiencies.

Keywords: Technical efficiency, Productivity, Stochastic frontier, Stochastic meta frontier, Cocoa

1. Introduction

Sustainability of the cocoa industry hinges on the acceleration of farm productivity. Productivity concerns over the years have been addressed by COCOBOD with supply-side interventions comprising of disease and pest control packages, hybrid seedling, fertilizer programmes, extension services, pruning of cocoa farms and hand pollination. Despite intensified efforts to improve on productivity since 2001 through the introduction of varied supply-side interventions, yields remain low and below potential (Vigneri & Kolavalli, 2018). Mean cocoa yields are said to be 18% of experimental and farm-based production potential of 1,900 kilogram per hectare (Aneani & Ofori-Frimpong, 2013). Production increases in cocoa have largely been driven by expansion in land cultivation rather than intensification in input use (Baah, Anchirinah, & Amon-Armah, 2011; Nkamleu, Nyemeck Gockowski, 2010), which remains a limited option given increasing population pressures and current environmental concerns.

Productivity in agriculture is driven by technical change and economic efficiency. Whereas technical change shifts the production frontier occurring in the longer term, economic efficiency enhances productivity growth in the short to medium term (Wondemu, 2016). Economic efficiency is the ability of the firm to use existing technology in the best possible way and consists of scale, technical and allocative efficiency. Scale efficiency measures optimum input and output allocation for maximum production by firms and technical efficiency measures the ability to obtain maximum output from a given set of inputs while allocative/price efficiency assesses the producers' ability to use inputs in their optimum proportions given prices. According to Wondemu (2016) productivity in African agriculture is driven more by improvements in technical efficiency, as scale and allocative efficiencies are not substantial. Although COCOBOD through research promotes technical change in cocoa farming with innovative technologies, it is essential for the regulator to champion efficiency in farming more especially technical efficiency to sustain productivity growth in the sector.

Some Studies (e.g., Besseah & Kim, 2014; Onumah, Al-Hassan & Onumah, 2013; Danso-Abbeam et al., 2012; Danso-Abbeam & Baiyegunhi, 2020) has investigated how input support programmes such as the cocoa high technology (Hi-Tech) and Cocoa Disease and Pest Control (CODAPEC) impacts on crop productivity. The introduction of additional supply input packages such as farm pruning and hand pollination gives credence to the fact that disease prevention and soil fertility enhancement alone cannot achieve the desired productivity on farms. Far reaching gains in farm productivity each crop season is facilitated by the full application of all existing technologies to growth. Against this background, this study investigates the impact of each of the supply-side interventions to supporting technical efficiency of cocoa farmers. This research is expected to generate relevant information to contribute to policy review and implementation of such programmes. This is essentially so given the fact that there are conflicting results on the effectiveness of input subsidies to agricultural productivity and efficiencies in production in several countries as reported by Latruffe, Bravo-Ureta, Carpentier, Desjeux & Moreira (2017).

Specifically, the study will estimate the technical efficiency levels of cocoa farmers in five cocoa growing regions of Ghana and after that estimate the gaps in cocoa technology use. Also, the study will investigate the contribution of supply-side intervention to efficiency in cocoa production. This is necessitated by the fact that existing stochastic meta frontier analysis of farmer efficiency in cocoa regions failed to evaluate the impact of supply-side interventions on efficiency in cocoa farming, which is the departure point and contributions of this current study. Further to this earlier work used linear programming method to estimate the meta frontier function which has been shown by Huang, Huang & Liu (2014) as failing to account for the distributional properties of the error terms, thus defeating the rationale behind frontier modelling while biasing estimated inefficiency indices. In light of this, the study will focus on how the policy environment is contributing to or otherwise to cocoa productivity gains, while applying recent techniques to modelling production efficiency. The rest of this study will proceed as follow; section two will present a review of major supply-side interventions in the cocoa industry, followed by a review of relevant literature to this study in section three. Section four will present the methods adopted to investigating the research objectives as outlined, with the results and discussion given in section five. Conclusions and recommendation from the research will be given in section six.

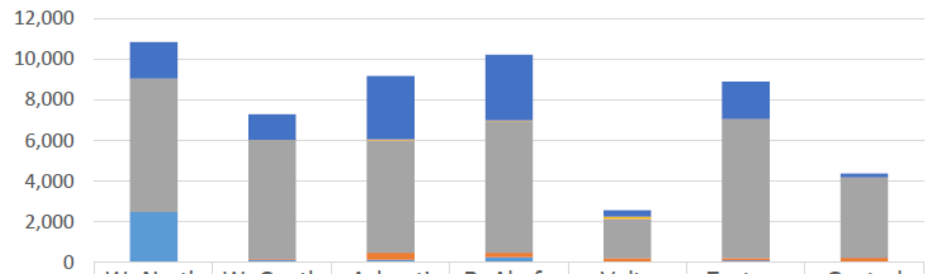
2. Supply-Side Interventions in the Cocoa Industry

The cocoa industry has received innovative product development support since the 1930's when the industry experienced its first outbreak of disease identified as cocoa swollen shoot virus disease (CSSVD) (CRIG, 2013). Policy direction with respect to disease and pest control and productivity drive has gone through many phases and changes. In discussing supply-side interventions in the industry, the focus of the review will be from 2001 mainly given by the fact that current projects and programmes were introduced from that period.

2.1 Hybrid Cocoa Seedlings Programme

The outbreak of cocoa swollen shoot disease in the 1930s provided the grounds for supply of hybrid seedlings cloned to be more disease resistant and high yielding. These seedlings were supplied to farmers with infected plots for replanting. The programme initially started with cloned pods given to farmers at 20 pesewas for nursing and transplanting. However, this was not effective for several reasons; one because farmers broke such pods and added to their beans for sale rather than nursing the seeds. Further to this those who planted the seed did so at stake without nursing seeds first (COCOBOD, 2018). This initial intervention was further foiled when private traders sold pods that were not recommended to farmers leading to abysmal result for the entire programme.

A decision was made following such incidents to nurse seeds into seedlings before distribution to farmers. Various models of this have been rolled out, beginning from initially giving seedlings out for a minimum fee, to recent times in which seedlings are given out to farmers at no charge beginning 2013/14 crop season. This scheme covers all the cocoa growing regions and supply to recipient farmers is carried out from the district office level (Figure 1 gives regional demand for seedlings). These recommended seedlings which have been designed to protect against CSSVD, and black pod disease are also more productive hence helping to reduce farm maintenance cost. To this end COCOBOD spends over GH₵53.7 million each crop season to raise such seedlings for distribution with a production cost of a single seedling in 2017 being GH₵0.90.



	W. North	W. South	Ashanti	B. Ahafo	Volta	Eastern	Central
Fill Vacancies	1,805	1,255	3,124	3,233	309	1,835	190
Burnt Farm	0	3	49	29	108	15	5
New Establishment	6,547	5,855	5,532	6,479	1,941	6,827	3,962
Rehabilitation	0	48	340	210	168	112	199
CCVD	2,495	133	138	267	41	99	25

Figure 1. Regional farmer seedlings request by category in 2017

Source: Seed Production Unit, COCOBOD, 2018

2.2 Cocoa Disease and Pest Control (CODAPEC) Programme

Continuing incidence of pests and diseases is a major contributory factor to low cocoa yields. The first pest and disease control interventions took place in 1938, under the Gold Coast Department of Agriculture at Tafo in the Eastern region of Ghana (CRIG, 2013). Cocoa Research Institute (CRIG) is responsible for scientific research into disease preventions in the industry with Cocoa Health and Extension Division (CHED) charged with the responsibility of providing extension services to facilitate the adoption of the new innovations to production. Cocoa Mass Spraying programme was initiated in the 1960s to control pests and diseases in cocoa. This, however, was discontinued when the initial objective of disease control was temporary achieved (COCOBOD, 2018).

The resurgence of the pests and diseases with dire consequence for productivity necessitated the reintroduction of this programme in 2001 under the name "Cocoa Diseases and Pests Control (CODAPEC)" programme. The disease marking of Ghana's cocoa growing areas is categorized into two major subdivisions, labeled as "Black pod Areas" and "Capsid Areas" in all the sixty-two (62) Cocoa districts in Ghana. The treatment for black pod covers all districts in Volta, Brong-Ahafo and some parts of Eastern, Western and Ashanti regions, while capsid treatment covers some districts of Western and Ashanti and all districts in Central and Eastern region (COCOBOD, 2017). The model of operations for this programme requires the Board to spray half of the recommended number of applications for black pod and capsid control, that is 3 and 2 applications respectively using spraying gangs. The rest of the recommended spraying rounds are to be carried out by the farmer, another 3 and 2 applications respectively.

2.3 Cocoa High Technology (Hi-Tech) Programme

With effective disease control in cocoa, yields are expected to increase, however, as the trees bear more pods, soil nutrient use also increases. As a follow up to the CODAPEC programme, the Cocoa high technology (Hi-Tech) programme commenced during the 2003/04 season to maintain the fertility of cocoa soils at levels that are economically viable, ecologically sound and culturally acceptable. Since its inception, this programme has gone through three phases starting in 2003/2004 crop season, with a target coverage of 1.6 million hectares. The fertilizer is deployed through Local Distributors, Licensed Buying Companies, Ministry of Agriculture (MOFA) and Cocoa Input Companies. Farmers access the fertilizer at a subsided price of 50% of market value.

In 2013/14 crop season, the Board supplied fertilizer free of charge to farmers through CHED. The programme covers farms that are aged between six to thirty years in addition to CCSVD farms. In 2017, COCOBOD reverted to the operational layout under phase one, where fertilizers were sold at subsidized prices to cocoa farmers. There are 111 registered distributors made up of Private Agents and Licensed Buying Companies (LBCs). The Distributors enter into a Fertilizer Supply Agreement with the Board and sell the fertilizers at 50%

of market price to farmers, while being entitled to a commission of 18.5% for a bag or liter of fertilizer sold. The method of acquisition of the fertilizer by the farmers is on cash and carry terms with a window for credit through the LBCs.

2.4 Cocoa Hand Pollination Programme

As far back as 1990, the Cocoa Services Division (CSD) of COCOBOD engaged in hand pollination at its cocoa stations in the Ashanti region to clone hybrid cocoa pods for distribution to farmers. However, with persistent low yield in cocoa despite the roll out of CODAPEC and Hi-Tech programmes it became necessary for the Board to have a relook at pollination processes for the whole industry. Hand pollination for individual farm plots was officially launched on the 7th of May in 2016/17 crop year. One hectare of hand pollinated field yields 30 bags of dried cocoa beans as compared to 7 bags under natural pollination (CHED, 2018). At the start of the programme 14,000 hectares of land was pollinated with an initial target of 19,000. In 2017/18 this increased to 14,785 hectares of pollinated area with 36,963 farmers benefiting. For qualification the farm must not be diseased, should be more than 5 years old but not more than 20 years old.

2.5 Cocoa Mass Pruning Programme

Pruning of cocoa trees involves cutting down the extra branches of the tree. Most farmers find it extremely difficult to prune their cocoa trees; because of the labour cost involved in carrying out such an exercise and because some are not aware of the benefits of pruning to farm yields. As cocoa trees grow the canopies of trees close which prevents sunlight from getting into the farm and limiting appropriate ventilation. Thick canopies create too much shade which becomes conducive for the infestation of black pods especially during the rainy season. To assist farmers with this exercise which also contributes to the productivity of farms, COCOBOD through CHED launched the cocoa mass pruning exercise in 2017/18 crop year. Under the programme punning is undertaken for only one month ending middle of the month of May to allow trees to recover and start producing.

2.6 Cocoa Extensions Programme

The main task of extension agents is to transmit information and facilitate farmers' access to inputs support from the Board. Extension services are categorized into two, extensions on agronomic/cultural practices of cocoa farming and extension on disease control. Currently extension services to cocoa farmers are under the mandate of CHED, partners include World Cocoa Foundation, Akuapa, Mondelez, Cargill, Solidaridad and Rainforest Alliance, however as at 2018, the partners in active standing were Cargill and Mondelez. Extension services are carried out in 7 cocoa regions out of the 6 political regions with 62 districts. There are 864 operational areas, with front line staff comprising of community extension agents (CEA). CEA interacts with farmers to educate and train them on good agronomical practices (GAPs). Further to this they organize farmer business schools to teach farmers to be entrepreneurs also helping to mobilize farmers into cooperatives to facilitate easy dissemination of programmes and projects. Given the enormity of the work, COCOBOD staffing is not able to handle effectively all operational areas, as such they are assisted by some local cocoa facilitators (LCF) acting on grounds of voluntarism. The target is to get COCOBOD to cover all operational areas to increase the farmer-extension ratio which currently stands at 1:1900 (CHED, 2018).

3. Review of Literature

3.1 Efficiency in Production

Neoclassical production theory assumes an efficient producer, operating at the optimum necessary to fulfill profit maximization or cost minimization objectives. Optimum production being constrained only by existing technology, in which deviations from this optimum are allocated to random errors. Production efficiency literature advances on the neoclassical theory by considering the possibility of firms producing below the boundary of technology as a result of technical inefficiency ((Belotti, Daidone, Ilardi & Atella, 2013; Kumbhakar & Wang, 2010).

In efficiency estimation, the task lies in constructing the frontier of production which is unobservable. There are two main estimation methods for production efficiency, using either parametric methods or nonparametric methods (Ghali, Latruffe & Daniel, 2016). Parametric techniques adopt stochastic models which prescribes a composite random term consisting of random effects due to statistical errors and random effects due to inefficiency. The key assumptions underlying the model are that all producers are operating with the same production technology under the same production environment (Alem, Lien, Hardaker & Guttormsen, 2019). Furthermore, there are some technical inefficiencies in the production process (Belotti et al., 2013; Battese & Coelli, 1995). To distinguish inefficiencies due to managerial abilities from random unpredicted disruptions and statistical errors, an error term that is decomposed into pure random disturbance term and error due to inefficiencies is proposed referred to as stochastic frontier models (Frick & Sauer, 2016; Ghali et al., 2016).

Efficient/optimum production is given in equation 1

$$\ln q_i^* = F(X_i, B) + \nu_i \tag{1}$$

Where q_i^* is the frontier production that is not observed, X is the production inputs, B is the parameters of the production function to be estimated, $i = 1, 2, ..., m$ represents the individual producer. while ν_i is the random disturbance term or statistical noise. The error term is assumed to be normally distributed with a constant variance and zero mean $N(0, \sigma_v^2)$.

Observed production is given in equation 2

$$\ln q_i = \ln q_i^* - \mu_i \tag{2}$$

where μ_i, captures the effect of inefficiency and is shown to be positive $\mu \geq 0$. Therefore, observed production in equation 2 is bounded below the frontier (Kumbhakar & Wang, 2010). The distributional properties of μ_i are assumed to either be half normal, exponential or truncated normal.

Substituting equation 1 into 2, observed production is simply written as

$$\ln q_i = F(X_i, B) + \nu_i - \mu_i \tag{3}$$

The composed errors $(\nu_i - \mu_i)$ are independent of each other and the parameters to be estimated are B, σ_v^2, σ_u^2

$$\mu_i = \ln q_i^* - \ln q \tag{4}$$

Where u_i gives the percentage loss of output due to inefficiency, the closer μ_i is to zero, the less inefficiency in production. From equation 3

$$\exp(-\mu) = \frac{\ln q}{\ln q^*} \quad \text{or} \quad TE = \exp(-\mu) \tag{5}$$

$\exp(-\mu)$ is the ratio of observed production to maximum/unobserved production, referred to as technical efficiency (TE) index. Given that $\mu \geq 0$, TE lies between zero and one, the closer to one the more efficient is production.

3.2 Exogenous Factors of Technical Inefficiency

The main thrust of frontier studies is to detect inefficiencies in production and to identify the factors that improve on efficiency. To achieve this, the basic frontier model is extended with a separate model for inefficiency in a two-stage estimation technique (Kumbhakar, 2015). In this case μ_i is given as a factor of exogenous variable d_k which can include farmer specific factors, geography, institutional regulations, market structure and many other influencers generally classified as the production environment by Alem et al. (2019) and given as

$$\mu_i = f(d_k) + \varepsilon_i \tag{6}$$

The variables remain as already defined but ε_i is the errors within the model. Several writers have put up arguments against a two-stage estimation of parameters of the frontier and inefficiency function (Hung et al., 2014; Wang & Schmidt, 2002)

Considering this, the frontier model specified by equation 3 is extended such that the one-sided error is a factor of some exogenous variables and parameters,

$$g_i = f(X_i{}'\mathrm{B}) + \nu_i - \mu_i(d_k{}'\alpha) \tag{7}$$

The empirical application of frontier modelling to cocoa production has been carried out by several studies e.g. (Besseah & Kim, 2014; Onuamah et al., 2013; Danso-Abbeam et al., 2012; Kyei, Foli &Ankoh, 2011). The extensions from individual regional estimates to a comparative analysis of group efficiencies using a Meta frontier is undertaken by Nkamleu et al. (2010) covering Cameroon, Nigeria, Cote d'Ivoire and Ghana. Application of meta frontier analysis to Ghana's cocoa industry for regional comparison was undertaken by

Danso-Abbeam & Baiyegunhi (2020). However, Danso-Abbeam & Baiyegunhi (2020) do not account for the policy environment in which farmers operate and how that impacts on their technical efficiency, which will be the focus of this research.

4. Methodology

4.1 Research Design and Sample

The sample for this study is obtained using stratified sampling for the first stage and multistage cluster sampling subsequently. Five cocoa growing regions were selected out of seven operational regions (Western North, Western South, Eastern, Ashanti, Brong-Ahafo, Volta and Central regions) conditioned on the time to completion and funding. The selection of the five was undertaken using stratification. The stratum was formed using cocoa output volumes and the method of proportional allocation to select regions. In this regard Western North, Western South and Ashanti regions formed the first strata. Brong-Ahafo, Eastern and Central the second strata, while Volta region formed the last strata. The selected regions were Western North, Ashanti, Brong-Ahafo, Eastern and Volta. Data was gathered through face-to-face interviews of a randomly selected sample of 1,100 respondents. A total of 220 respondents were allocated to each region for the interviews.

4.2 Designing and Deployment of Survey Instrument

The construction of the questionnaire was guided by existing instrument used in related studies with its specificity directed by the objectives of the study and subdivided into sections. The instrument was administered in the local dialect '*Twi'*. The ethnical standard observed on the field included first explaining the objective of the study to the respondents. This was done through group debriefing exercises at each community. Farmers were informed that; this was a voluntary exercise and given the opportunity to opt out with verbal consents taken. The compensation to farmers who were willing to participate comprised of one cake of cocoa soap produced by CRIG worth GH ₵4, which was moderate and in sync with ethical requirements that compensation to respondents in a survey should not cause coercion. To achieve a reasonable level of reliability in the instrument used to collect the data, the questionnaire was pretested on three different occasions between October and December, 2018 in New Tafo district of Eastern region of Ghana, namely, Nobi, Tontro, Obodanso and Sansakwa. The main survey started in December, 2018 and ended in July, 2019. It was carried out in phases by regions, beginning with the Eastern region. The survey objectives as set out by the design was 94% completed with a raw uncleansed sample of 1,003 due to some administrative and financial challenges. Below is the map of surveyed regions.

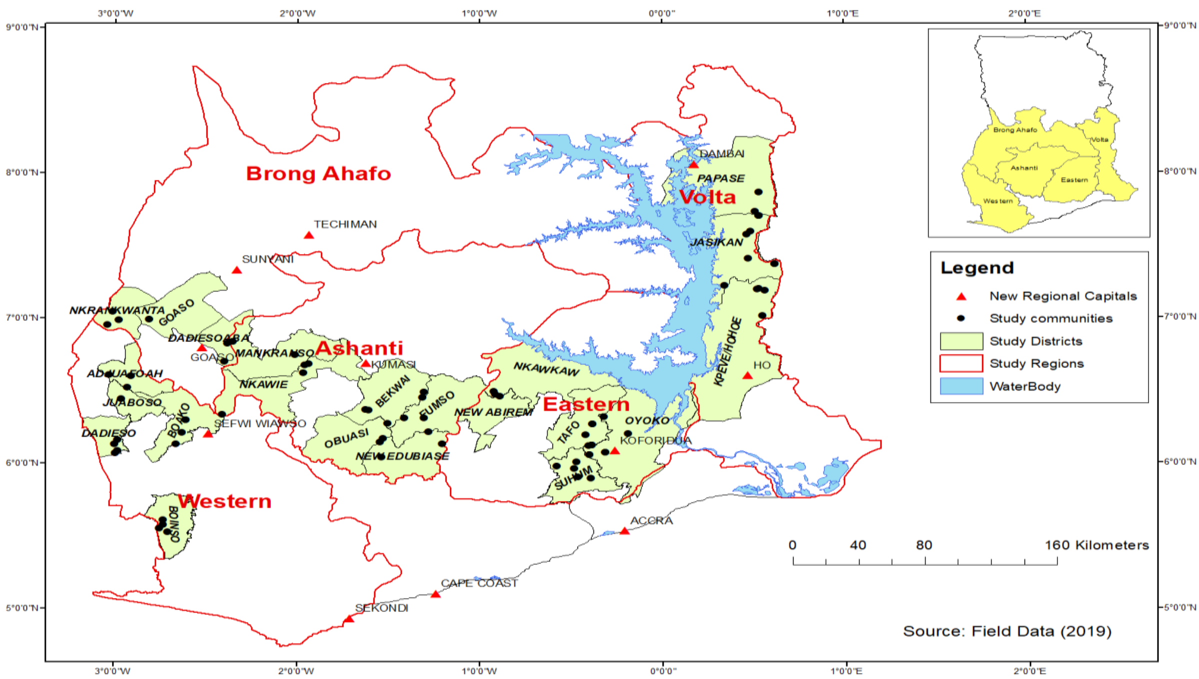


Figure 2. Survey Map

Source: Field survey, 2019

4.3 Theoretical Model

The Meta production function is based on the idea that producers within an industry are exposed to varying production technologies because of the regulatory environment, resources availability and input prices. Each producer conditioned on these external factors chose different levels of the existing technology. The conditioning environment for production prevents some producer from using the best of technology, the gap between the technology used and the potential available is the technological gap referred to as the group specific frontier.

Battese & Rao (2002) operationalize the concept of the Meta production function and formulate the stochastic Meta frontier function with two error components similar to an individual stochastic frontier. Battese et al. (2004) and O'Donnell, Rao & Battese (2008) provide the means for estimating the parameters of the function. The writers present a two-stage mixed approach in which a stochastic frontier model is estimated at the first stage for the individual group members following which mathematical programming is used to estimate the Meta frontier.

Hung et al. (2014) have raised concerns with this approach indicating the Meta frontier is estimated without any underlying statistical properties which creates some challenges in interpreting the results. More so it fails to account for the different production environment by ignoring the idiosyncratic errors, the bedrock for stochastic frontier estimation. The writers propose a new two-step formulation in which the second stage formulation still follows the stochastic frontier framework.

Adopting the formulation of Kumbhakar & Wang (2010) the stochastic frontier model for t^{th} cocoa farmers in m^{th} regions is given as

$$\ln Y_{t(m)} = f(X_{t(m)}; B_{(m)}) + V_{t(m)} - U_{t(m)} \tag{8}$$

$$U_{t(m)} \geq 0, \quad m = 1, 2, 3, ..., n \quad t = 1, 2, 3, ..., n$$

$Y_{t(m)}$, is cocoa output for individual farmers in the m^{th} region, $X_{t(m)}$ is the vector of production inputs and $B_{(m)}$ are the parameters of the production function for each region while $V_{t(m)}$ and $U_{t(m)}$ are the two error components of the stochastic function which are assumed to be independent of each other. The random error component is assumed to be normally distributed and the inefficiency component is assumed to be truncated normal distribution

$$U_{t(m)} \sim N^{+}\left(U_{t(m)}(d_{k(m)}), \sigma^2_{u(m)}(d_{k(m)})\right) \tag{9}$$

$(d_{k(m)})$ is the region-specific covariate of inefficiency (factor determining the level of efficiency or otherwise)

Observed production in equation 8 is bounded below the frontier/optimum production in equation 10 given that $U_{t(m)} \geq 0$

$$\ln Y^{*}_{t(m)} = f(X_{t(m)}; B_{(m)}) + V_{t(m)} \tag{10}$$

Leaving out the subscripts the Meta frontier function is an envelope of the individual group stochastic frontiers in equation 8, composed from the entire group efficient producers as

$$\ln Y_t^M = f(X_t; B^M) + v_t - u_t \tag{11}$$

B^M, is the vector of parameters for the Meta frontier (MF), the MF is constrained to lie above or remain equal to the individual regional frontier given by the inequality

$$X_t^{'}; B^M \geq X_t^{'}; B_{(m)} \tag{12}$$

Battese &Rao (2002) have demonstrated that combining 8 and 11, the MF function can be decomposed as

$$\frac{\ln Y_t}{\ln Y_t^M} = \frac{X_t B}{X_t B^M} * \frac{V_t}{V_t^M} * \frac{-U_t}{-U_t^M} \tag{13}$$

Where the technological efficiency gap

$$(TGR_t) = \frac{X_t B}{X_t B^M} \tag{14}$$

TGR represents highest technology use by producers in a region relative to the group technology as given by the MF, TGR ≤1

$$\frac{V_t}{V_t^M} \quad \text{is the random error ratio} \tag{15}$$

The technical efficiency ratio of the individual frontier to the MF is

$$TER = \frac{-U_t}{-U_t^M}, \quad \text{or} \quad TER = \frac{TEF_t}{TEF_t^M} \tag{16}$$

The Meta frontier technical efficiency (MTE) is the regional technical efficiencies (TE) by the TGR

$$MTE_t = TE_t * TGR_t \tag{17}$$

Estimating the Meta frontier and its decomposed parts using the new regression-based two-step estimation techniques as stipulated under Hung et al. (2014), requires first estimating the regional frontiers in equation 8. Estimates from all m^{th} region (i.e., Western North, Ashanti, Brong-Ahafo and Volta) are pooled and used to estimate the MF as in equation 18

$$\hat{f}(X_{t(m)}; B_{(m)}) = f^M(X_t; B^M) + v_t^M - u_t^M \tag{18}$$

4.4 Empirical Model

The model is estimated using translog stochastic production function as proposed by Battese and Rao (2002). The translog function is selected since it is shown to be flexible by not constraining the production function to exhibit constant returns to scale.

$$\ln Y_t = B_0 + \sum_{k=1}^{4} B_k \ln X_{tk} + \sum_{k=1}^{4}\sum_{h=1}^{4} A_k \ln X_{tk} \ln X_{th} + V_t - U_t \sum_{z=1}^{n} \delta_z d_{zt} \tag{19}$$

Y_t, represents log of dried cocoa bean in kilograms per hectare of land for the t^{th} producer. B_k, A_k are the parameters of the production function, X_{tk} log of the conventional inputs used in cocoa production, specifically, cultivated land in acres, labour (family labour), machinery/ farm asset in unit number (harvesting hook, knapsack sprayer, drying mat, pruner, mist blower and earth chisel) and tree age.

V_t represents deviations from production due to unobserved factors, U_t represents production shortfall due to technical inefficiency, which is a function of some covariates

$$\sum_{z=1}^{n} \delta_z d_{zt} \tag{20}$$

where d_{zt} (i.e., farmer specific characteristics) and δ_z are the parameters to be estimated. The covariates of inefficiency that are tested are farmer specific indicators and supply policy indicators (i.e., education, gender, age of farmer, farm experience, association membership, land ownership structure. Also access to extensions, fungicides and insecticides spraying, hand pollination, pruning and hybrid seedlings with Hi-Tech (fertilizer access), being the control group).

5. Results Discussions

5.1 Descriptive Statistics

In table A1 and A2 (in the appendix) we present the summary statistics of indicator variables used in the estimations. Beginning with the production function, Cocoa output which is the dependent variable is captured in number of bags of dried beans. A bag of cocoa contains 64kg of beans, this amount was used to convert bags of beans into kilograms (kg). The average cocoa farm output was 674 kilograms of dried bean with a regional breakdown of 581kg, 957kg, 601kg, 602kg and 727kg for Ashanti, Brong-Ahafo, Eastern, Volta and Western North respectively. The inputs to production were four specifically, farm size, which ranged from a low of 1 hectare to a high of 48 hectares. Farmers were more comfortable in giving their farm size in acres; however, acreages were converted to hectares by a division of 2.471 to meet reporting standard for agricultural land which is usually stated in hectare. The second input to production was farm age, which ranged from a minimum of 3 years with an average of 18 years. The third input was labour consisting solely of family labour which ranged from 1 person to 32 with average of 6 persons. Machinery was given by farmers' possession of major farm inputs used in farming activity, which was captured in unit number with an average of 4 inputs. All production inputs are expected to positively impact cocoa output.

Moving from the production inputs, the variables controlled for in the inefficiency function were, age of the farmer, which is a continuous variable ranging from a young age of 23 years to 88 years with a mean age of 52 years. The effect of age depends on the starting point, age is linked to experience and is hypothesized to improve on efficiencies however, at higher age brackets increasing age can reduce efficiency levels. The educational level of farmers spanned from no formal education given by 0 years to a maximum of 21 years with a mean education of 8 years. Education is expected to facilitate the adoption of new technologies by farmers. Also 81% of respondent farmers were males, with about 50% of the farmers belonging to some farmer association. Participation in such farmer groups facilitates information transfer for better appreciation and adoption of farming innovations to improve productivity. With reference to COCOBOD interventions, 13% of farmers in the sample had some extension contact for 2017/18 crop year, 24% received fungicides and insecticides, 13% received fertilizer support with 10% having their farms pruned. Additionally, about 8% had their farms hand pollinated and 11% indicated they had in years past accessed free seedlings (see table A2 in the appendix for regional breakdown). Access to input support should improve on efficiency in production and hence productivity.

5.2 Technical Efficiency and Technological Gaps

To discuss the results of this study, we begin with the efficiency scores as given in table 3. The first set of scores are the individual regional technical efficiency indices. We found Eastern region to be the most efficient with a mean efficiency score of 0.87, indicating that the region could produce 87% of its potential output given technology, with Western North producing 76% of its output potential, the lowest of the five regions. The three other regions, namely, Ashanti, Volta and Brong-Ahafo produced on average 80%, 78% and 83% of their production potential in cocoa, respectively. Mean efficiency in relation to the group production capacity i.e., the MTE were much lower at 61% for Ashanti and Western North respectively, 67.3% for Eastern, 61.6% for Volta and 66.5% for Brong-Ahafo. The results showed cocoa farmers from the five regions were losing on average 36.5% of output due to inefficient use of existing production technologies. Brong-Ahafo and Eastern regions remained the most efficient of the five with reference to the group technology.

Table 3. Estimates of technological gaps and technical efficiency

Variable	Mean	Std. Dev.	Minimum	Maximum
Frontier technical efficiency (TE)				
Western North	0.759	0.188	0.109	1.000
Ashanti	0.803	0.181	0.171	1.000
Eastern	0.870	0.159	0.000	1.000
Volta	0.777	0.142	0.174	0.998
Brong-Ahafo	0.832	0.148	0.111	0.984
Technological gap ratio (TGR)				
Western North	0.803	0.024	0.632	0.841
Ashanti	0.757	0.030	0.617	0.850
Eastern	0.774	0.033	0.630	0.897
Volta	0.794	0.039	0.652	0.883
Brong-Ahafo	0.798	0.037	0.711	1.004
Meta frontier efficiency (MTE)				
Western North	0.610	0.152	0.088	0.832
Ashanti	0.610	0.140	0.129	0.795
Eastern	0.673	0.127	0.000	0.874
Volta	0.616	0.115	0.151	0.823
Brong-Ahafo	0.665	0.122	0.112	0.845

Again, the study found Western North and Volta to be the least efficient at the regional level. The findings for Western North are a confirmation of the assertion by Baah et al. (2011) that expansion in cocoa production in the Western region is largely driven by land expansion rather than efficiency in production. Also given that fresh forest land is being cultivated with higher fertility there is no incentive for intensification in input use from this region. Efficiency gains for Eastern region could be coming from the added advantage of having CRIG the body responsible for cocoa innovation within its jurisdiction. This presents the opportunity for farmers in the region to be first recipients of new technological advances. This research findings are similar to that of Danso-Abbeam & Baiyegunhi (2020) who also found Eastern region farmers to be the most efficient producers relative to the Meta frontier at 65% with Brong-Ahafo region being the most efficient with regard to the individual frontiers and Ashanti region the least efficient.

In terms of the TGR, the results revealed all regions were underutilizing their production capacity. Ashanti region was the lowest performing region lagging in capacity utilization by 24.3% as compared to 19.7% for Western North, 20.2% for Brong-Ahafo, 20.6% and 22.6% for Volta and Eastern region respectively. Without further increases in input applications, efficiency improvement could increase cocoa production in all five regions by an average of 21.5%.

A graphical examination of the efficiency scores in figure 3 points to a much more symmetrically distributed technology use for only Volta, all other regions efficiency scores can be said to be left skewed.

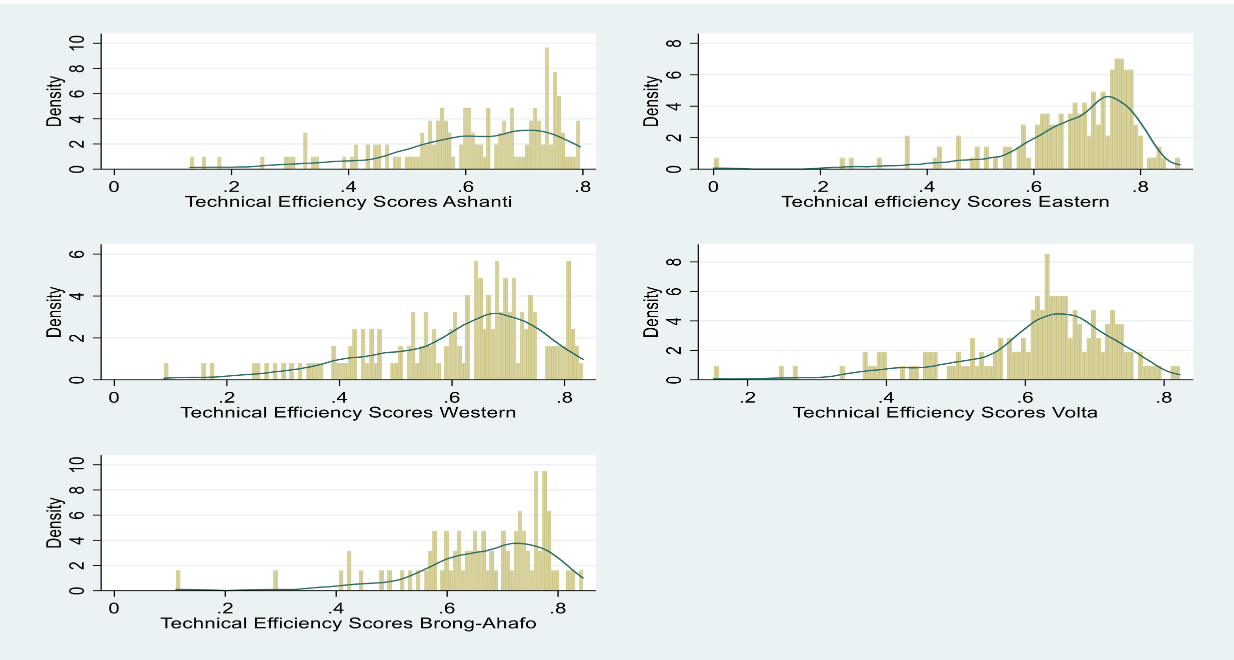


Figure 3. Technical efficiency scores

5.3 Estimates of Cocoa Production Frontier

We now present the discussion on the production function the basis for the construction of the efficiency scores. Estimates of the translog production function and meta frontier function are presented in table B4 (in the appendix) after diagnostic test have confirmed the use of both the translog function and the estimation of the function in a single stage estimation. All results are computed with robust standard errors to account for any potential heteroscedasticity that may exist in the errors of the estimates. The variance parameters given by sigma squared and gamma, supported the use of a stochastic production function for analyzing the data rather than a regular production function. The sigma squared for all regions were above zero and significant at 1% indicating there was some variation of observed output from the frontier. Secondly gamma which specifies the variance of output due to farm effect relative to the total variation in production for each region was below 1. Also, the likelihood functions was highly significant further supporting model fitness.

Progressing to the production inputs elasticities as reported in table 5 and computed from table B4 as mean elasticities, we found from the Meta frontier that all inputs to production were significant at 5% level except for machinery. Therefore, productivity in cocoa is driven by the tree age, labour and the size of farms with a size elasticity of 0.44. This is explained premised on the fact that, the age of the stock of cocoa trees determines both the start of first fruits and the progression in yields. Also, the size of the farm land allows for economies of scale in input use, which increases the output of larger farms relative to smaller farms. The results are consistent with other studies such as Nkamleu et al. (2010) who indicated that the greatest share of Ghana's productivity in cocoa was accounted for by the farm size and tree age with farm size elasticity of 0.66. We also found that increasing family labour by one additional person improved on the production of cocoa by 0.2%.

For the regional frontier function estimates, the results showed that cocoa production was responsive to increasing land use in Ashanti, Western North and Brong-Ahafo but not for Eastern and Volta regions. The response of production to land use in Western region reiterated earlier discussions that cultivation of cocoa in that region was largely driven by land expansion. The non-response of production to land for Volta and Eastern could be attributed to the fact that these regions soil fertility may have declined more especially for Eastern region which is one of the oldest cocoa cultivating regions as pointed out by Ofori-Bah & Asafu_adjaye (2011). Aneani et al. (2011) also puts forwards that cocoa lands are over utilized in production relative to other inputs which leads to the exhaustion of land thereby reducing returns to cocoa land.

The effect of labour was varied depending on the region. Since this is family labour, it is expected that for small and family-owned farms increasing size of the family provides labour to farms and hence improves on farm maintenance and output. However, for bigger farms using more labour and technology to production, greater number of hired labour will be used given skill requirements and higher labour needs. This makes family labour insignificant and in some regions negative to production. For instance, production was responsive to family labour for Eastern and Ashanti but not significant for the other three regions. Labour for Eastern region was significant but negative, these results are explained premised on the submission by Reddy & Sen (2004) who makes the point that, the availability of family labour encourages the use of excess human labour with negative returns to output. The producers in Eastern region maybe applying more labour than required on farms which has resulted in decreasing returns to labour. Also, the skills required in production may be lacking in the family labour affecting farm output. This point is premised on the fact that the technical efficiency indices computed revealed Eastern region as the most efficient producers out of the five regions, which presupposes the use of more technology in production requiring more skilled labour.

Increasing family labour however, improved cocoa production in Ashanti by 0.95 percent. This is consistent with the technical efficiency scores that showed Ashanti region farmers as the least efficient of producers in the sample of five regions. The limited use of technology, allowed producers in the region to benefit more from family labour. The inability of family labour to explain productivity in Western North could be explained by the fact that the region produces high volumes of cocoa output yearly which calls for more labour beyond what the family can provide.

The possession of farming inputs/machinery explained cocoa production for Eastern and Brong-Ahafo but not for Western North, Ashanti and Volta regions. The production elasticities for Eastern and Brong-Ahafo confirmed their efficiency scores, which pointed to intensification in the use of inputs. On the other hand, cocoa production in Western North and Ashanti are influenced more by the stock of trees and the size of land.

The different production elasticities for the different regions in this study reiterates the concept behind Meta frontier analysis that regions differ in production environment and intensities of input use. Supporting the need for commonality in production environment for effective comparison. In all the regions, the age of the cocoa tree was significant to production. The high elasticities of tree age to output was not surprising as cocoa tree age is key to its productivity, with output falling as the tree ages, this is confirmed by the negative square of tree age in table B4.

Table 5. Frontier and Meta frontier output elasticities

Variables	Eastern	Ashanti	Western	Brong-Ahafo	Volta	Meta Frontier
Land size	0.354	0.884**	0.907***	0.69***	0.016	0.437***
	(1.52)	(2.06)	(3.29)	(7.81)	(0.05)	(7.27)
Labour	-0.687**	0.953**	0.17	-0.03	0.508	0.199**
	(2.5)	(2.35)	(0.49)	(0.25)	(1.17)	(2.36)
Machinery	0.824*	-0.707	-0.811	0.974**	-0.421	0.089
	(1.75)	(1.02)	(1.43)	(2.74)	(0.7)	(0.54)
Tree age	0.965***	1.396***	1.389***	0.004***	1.462***	1.185***
	(3.02)	(3.35)	(5.84)	(0.03)	(6.14)	(21.87)
Return to scale	1.456	2.526	1.655	1.638	1.565	1.910

t-statistic in parenthesis p<0.01, ** p<0.05, * p<0.1

5.4 Parameter Estimates of Inefficiency

The interpretation of the results in table B6 (in the appendix) is in terms of the sign, whether positive or negative. A negative sign indicates the specific variable reduces inefficiency and promotes efficiency in production. We discuss first the meta frontier function. The results pointed out that extensions, CODAPEC (i.e., free spraying of fungicides and insecticides) and hand pollination did not improve on production efficiency of farmers as compared to fertilizer applications. In terms of gender, male farmers were less efficient compared to their female counterparts, relying more on extensive use of inputs rather than efficiency gains. This finding is supported by the submissions of Dadzie & Dasmain (2011) who indicated that productivity gains by male food crop farmers in Western region of Ghana was driven more by increasing application of inputs rather than improved managerial skills because they have greater access to credit. Being the owner of the farm land reduced efficiency level as compared to being a sharecropper. Cocoa is a long-term business project with tree production life of 40 years (Bateman, 1965). Those who own cocoa land have longer gestation period for expected returns as compared to sharecroppers. There is greater motivation for sharecroppers to follow farm maintenance culture to get quicker and higher returns from their farm investment since they have a shorter gestation period in terms of the farming business.

The results are supported by Latrufee et al. (2017) who also found for European dairy farmers the obligation of paying rent for land improved efficiency in production relative to those who owned land. Guta & Ahmed (2018) also found sharecropping land ownership structure as the most efficient for production

Proceeding to the regional estimates of inefficiency, the study found that the drivers of efficiency varied across the different regions. For instance, the level of education improved on efficiency level of cocoa producers in Western North and Brong-Ahafo region, while reducing efficiency gains in Eastern region. The level of education was not able to contribute to efficiency gains in Eastern region in our study perhaps because of the high level of extensions and product education already given by CRIG in that region. The type of education needed to advance efficiency further in that region will be to increase product specific education.

The effect of age on efficiency is linked to experience in farming which is expected to improve efficiency gains. The study results showed that increasing age improved on efficiency level of farmers in Eastern region. The age of the farmer was however not significant to explaining efficiency level for farmers in Ashanti, Volta and Brong-Ahafo regions, while contributing to inefficiency in Western region. The effect of age in Western region could be explained based on the mean age of farmers from that region which is the lowest at 48 years as given in the summary statistics. The region has younger farmers who rely more on their level of formal education and farm extensions to improve on their efficiency in farming. This is supported by the results that showed that formal education, improved on efficiency in Western North.

The gender of the farmer was largely not significant in explaining efficiency in cocoa production for the four regions, remaining significant at 10% for Eastern region The reason male farmers were more efficient than their female counterpart is linked to the fact that male farmers are more likely to attend extension programmes than their female counterparts. Given the potential for higher level of extension services in the Eastern regions as compared to the other regions as revealed in the summaries statistics except for Ashanti, it was not surprising to find such results.

The ownership structure of the land used for cocoa production contributed to inefficiency in farm management in Western North remaining insignificant for the other regions. Being a sharecropper enhanced the efficiency level of farmers in Western region. This is informed by the fact that the region has a significant number of migrant farmers who access farming land through sharecropping arrangements. In terms of farmer association membership, farmers in Volta and Brong-Ahafo regions who belonged to some farmer association gained more in efficiency levels through the information sharing and resource allocation that take place within such groups; this was however not the case for the other three regions.

With regards to the supply-side interventions, the study found that extension services significantly reduced inefficiency for Ashanti and Western region producers in comparison to the fertilizer subsidy programme. This was not surprising as extension services promote good agricultural practices. We also found that pruning held the potential for improving on farm productivity, however the programme only significantly improved on production efficiency in Ashanti region, perhaps because the region availed itself more for this exercise. The CODAPEC/mass spraying programme was not significant in reducing inefficiency in any of the regions as compared to fertilizer programme. The effectiveness of the mass spraying programme relies on the proper application of the chemicals. For instance, the government sprays half the round of chemicals for farmers. Failure or delay by farmers to complete the second round of spraying builds resistance in the pests, negating the effect of the intervention and leading to more crop losses on farms.

The recent hand pollination programme as compared to the fertilizer programme improved production efficiency for farmers in Ashanti and Eastern region but not for all other regions. The significant impact of hand pollination in these two regions could be attributed to several factors. For instance, Ashanti cocoa farmers, being the most educated (see summary statistics) predisposes the farmers to more information for better appreciation of new technologies and effective participation. Secondly, Eastern region is host to CRIG with an open-door policy for farmer groups to visit and seek information and for technical support which facilitates the effectiveness of COCOBOD interventions in that region as opposed to the other regions. Hand pollination did not improve on farm productivity for the other regions perhaps because pollinated trees require more fertilizer and maintenance to keep pods on the tree, which may be lacking in Volta, Brong-Ahafo and Western region leading to pod loss and increasing inefficiency.

The free seedling programme contributed to inefficiency in Eastern and Volta region, this is because hybrid seedlings often require more maintenance and fertilizer support to sustain production, in the absence of effective input use, the programme cannot achieve its target of improving productivity. Nonetheless for Ashanti producers the programme helped to improve on their productivity. This outcome is supported by the information in figure 1 which showed that Ashanti region farmers had the highest seedling request for rehabilitation of farms, reflected in their improved efficiencies from this subsidy package.

6. Conclusions and Recommendations

The general outcomes of this study are that supply-side interventions can improve on production efficiency depending on the region which calls for some specialization in the module implementation in each region. The key driver of productivity gains is fertilizer application (Hi-Tech). Also, recent introductions such as hand pollination and pruning can improve efficiency levels on farms more especially for Ashanti region and Eastern region. Extension services remain key to productivity gains in Western and Ashanti region. In the absence of extension, association membership improves cocoa productivity in Brong-Ahafo and Volta region. The CODAPEC programme is not able to contribute to efficiency gains as compared to the Hi-Tech programme.

Considering the above, we recommend some investment by COCOBOD in data mapping systems to improve logistical, quality control and traceability of programmes and projects. This particularly will be of benefit to projects such as the CODAPEC programme. The ineffectiveness of this laudable project rest on the application challenges. The Board does its part of the spraying each year without ensuring farmers can meet the other half of the scheduled spraying. With comprehensive data set of active farms in each region, COCOBOD can strategize to take charge of the full spraying of farms. Following which arrangements can be made with the licensed produce buyers with the agreement of farmers to retrieve cost of spraying with some cocoa proceeds during harvest.

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Appendix A

Table A1. Summary statistics

	Cocoa Output (kg)	Land size (ha)	Farm age	Family Labour	Farm Asset	Farmer age	Education	Sex: Code 1= male
Ashanti								
Minimum	32	1	5	1	1	28	0	0
Mean	581	5	19	6	4	54	7	0.73
Maximum	3840	27	40	17	6	85	21	1
Observations	207	206	205	212	212	212	212	212
BrongAhafo								
Minimum	64	1	4	1	1	24	0	0
Mean	957	8	21	6	4	52	8	0.74
Maximum	4160	48	60	20	6	85	20	1
Observations	115	113	114	118	118	117	117	117
Eastern								
Min	64	1	4	1	1	26	0	0
Mean	601	5	17	6	4	53	9	0.84
Max	5760	20	62	15	6	88	17	1
Observations	184	183	183	186	186	186	186	186
Volta								
Minimum	32	1	3	1	1	23	0	0
Mean	602	4	14	6	4	51	10	0.89
Maximum	4608	15	55	18	6	78	20	1
Observations	172	178	170	186	186	186	186	186
Western North								
Minimum	64	1	3	1	1	23	0	0
Mean	727	6	20	7	4	48	7	0.84
Maximum	5120	35	50	32	6	80	17	1
Observations	228	227	227	230	230	229	229	229
Total								
Minimum	32	1	3	1	1	23	0	0
Mean	674	6	18	6	4	52	8	0.81
Maximum	5760	48	62	32	6	88	21	1
Observations	906	907	899	932	932	930	930	930

Source: Survey data, 2019

Table A2. Summary statistics cont'd

	Farmer Association	Extensions	Fungicides	Hand Pollinatio	Hi-Tech Fertilizer	Insecticides	Pruning	Seedlings
Ashanti								
Minimum	0	0	0	0	0	0	0	0
Mean	0.36	0.2	0.19	0.06	0.13	0.25	0.09	0.08
Maximum	1	1	1	1	1	1	1	1
Observations	212	212	212	212	212	212	212	212
Brong-Ahafo								
Minimum	0	0	0	0	0	0	0	0
Mean	0.44	0.2	0.23	0.08	0.1	0.25	0.07	0.07
Maximum	1	1	1	1	1	1	1	1
Observations	118	118	118	118	118	118	118	118
Eastern								
Minimum	0	0	0	0	0	0	0	0
Mean	0.77	0.2	0.22	0.08	0.1	0.2	0.1	0.1
Maximum	1	1	1	1	1	1	1	1
Observations	186	186	186	186	186	186	186	186
Volta								
Minimum	0	0	0	0	0	0	0	0
Mean	0.78	0.19	0.2	0.09	0.1	0.21	0.11	0.1
Maximum	1	1	1	1	1	1	1	1
Observations	186	186	186	186	186	186	186	186
Western North								
Minimum	0	0	0	0	0	0	0	0
Mean	0.24	0.1	0.28	0.07	0.1	0.31	0.06	0.09
Maximum	1	1	1	1	1	1	1	1
Observations	230	230	230	230	230	230	230	230
Total								
Minimum	0	0	0	0	0	0	0	0
Mean	0.51	0.13	0.24	0.08	0.12	0.24	0.08	0.11
Maximum	1	1	1	1	1	1	1	1
Observations	930	932	932	932	932	932	932	932

Appendix B

Table B4. Frontier and meta frontier production estimates

Variables	Ashanti	Eastern	Western North	Volta	Brong-Ahafo	Meta
Constant	-1.164	2.367**	0.242	1.289	-1.286	1.534***
	(2.732)	(0.926)	(1.762)	(1.897)	(3.501)	(0.534)
Land size	0.891	-0.149	1.376***	-0.325	0.589	0.333***
	(0.711)	(0.495)	(0.518)	(0.671)	(1.184)	(0.100)
Labour	1.551*	-1.701***	0.0406	-0.0481	0.237	0.211
	(0.805)	(0.460)	(0.623)	(0.783)	(1.044)	(0.150)
Machinery	-1.538	0.387	-1.875	-2.510*	1.159	-0.939***
	(1.408)	(0.648)	(1.151)	(1.437)	(3.455)	(0.248)
Tree age	3.519***	2.741***	4.063***	4.068***	3.633**	3.622***
	(1.307)	(0.656)	(0.735)	(0.724)	(1.452)	(0.164)
Land size square	0.253	0.143	-0.212	-0.557**	-0.109	-0.0658**
	(0.164)	(0.101)	(0.141)	(0.269)	(0.307)	(0.0285)
Labour square	0.189	0.993***	0.298*	0.488**	0.0334	0.372***
	(0.297)	(0.230)	(0.162)	(0.228)	(0.270)	(0.0461)
Machinery square	0.233	0.0504	0.212	0.336	-0.841	0.264**
	(0.567)	(0.704)	(0.519)	(0.499)	(1.669)	(0.115)
Tree age square	-1.077**	-1.868***	-3.042***	-2.911***	-2.521**	-2.440***
	(0.425)	(0.422)	(0.419)	(0.502)	(1.132)	(0.0886)
Land size *Labour	-0.213	-0.0962	-0.167	-0.0800	-0.0955	-0.0692***

	(0.168)	(0.139)	(0.161)	(0.180)	(0.177)	(0.0235)
Land size*machinery	0.102	0.363	0.0260	0.689**	0.113	0.183***
	(0.295)	(0.274)	(0.188)	(0.349)	(0.802)	(0.0501)
Land size*tree age	-0.144	0.109	-0.116	0.289*	0.125	0.0693***
	(0.191)	(0.117)	(0.105)	(0.174)	(0.322)	(0.0253)
Labour*Machinery	-0.132	0.0609	0.170	0.598**	0.186	0.138***
	(0.433)	(0.324)	(0.205)	(0.284)	(0.740)	(0.0502)
Labour*tree age	-0.420**	0.0757	-0.171	-0.450*	-0.112	-0.273***
	(0.213)	(0.190)	(0.155)	(0.254)	(0.269)	(0.0400)
Machinery*tree age	0.630	-0.120	0.656**	0.466	0.0673	0.275***
	(0.284)	(0.300)	(0.270)	(0.321)	(0.799)	(0.0686)
Observations	156	163	166	157	86	734
Diagnostics						
Total Variance σ^2	0.517	0.354	0.588	0.456	4.817	0.057
Variance ratio γ	0.448	0.165	0.546	0.312	0.935	0.025
Chi2(14)	162.91	330.00	211.00	244.64	108.96	5002.07
Log likelihood	-142.03	-138.72	-150.90	-143.67	-80.24	-14.46

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Table B6. Coefficient estimates for determinates of inefficiency

	Ashanti	Eastern	Western	Volta	Brong-Ahafo	Meta
Constant	4.091	-1.176	-11.04***	-7.746	16.67	-44.44***
	(-5.607)	(5.051)	(4.222)	(7.268)	(19.73)	(13.58)
Education	0.108	3.247**	-1.405***	-0.979	-3.023*	4.597
	(1.41)	(1.466)	(0.468)	(0.670)	(1.737)	(4.479)
Age of Farmer	-0.666	-2.253*	2.190**	1.613	-3.087	-6.014
	(-1.511)	(1.347)	(0.909)	(1.841)	(3.814)	(6.745)
Extensions	-2.063***	0.831	-1.811*	1.071	-6.144	13.47***
	(-0.727)	(1.279)	(0.942)	(1.367)	(6.447)	(2.516)
Pruning	-6.856***	0.353	-0.643	1.567	0.105	-2.081
	(-2.432)	(1.338)	(1.044)	(1.437)	(2.834)	(2.977)
Fungicides	-1.034	0.0243	-0.435	1.832	1.714	11.79***
	(-0.795)	(1.262)	(0.662)	(1.432)	(2.278)	(3.134)
Hand pollination	-6.810***	-11.64***	-0.233	-5.071	-0.766	17.96***
	(-1.178)	(1.405)	(0.839)	(31.40)	(2.834)	(4.294)
Insecticides	-0.752	0.247	0.202	-0.255	-1.632	17.12***
	(0.904)	(1.166)	(0.655)	(2.010)	(4.790)	(4.220)
Seedlings	-1.176*	3.237**	-0.897	2.813**	2.572	1.871
	(0.7)	(1.409)	(0.685)	(1.348)	(2.289)	(4.771)
Farmer association	-2.249	-0.180	-0.244	-1.388**	-2.373*	1.870
	(-2.254)	(0.731)	(0.485)	(0.666)	(1.385)	(2.400)
Gender (Male)	-0.774	-2.209*	-0.675	1.650	-1.062	14.60***
	(0.825)	(1.270)	(0.460)	(1.978)	(1.075)	(3.091)
Land Tenure (Owner)	-0.787	2.154	5.868**			18.87***
	(-0.812)	(1.340)	(2.489)			(0.666)

Robust standard errors in parentheses