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Determinants of MD2* Adoption, Production Efficiency and Technology Gaps in the Ghanaian Pineapple Production Sector

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Abstract

This study examined the response of the Ghanaian pineapple production sector to the 2004/05 crisis where a swift shift of international market demand from the traditional smooth cayenne and sugar loaf variety to the MD2 variety nearly destroyed the entire fruit industry. We quantify the proportion of our sample farmers cultivating the MD2 variety and analysed the factors influencing adoption of the MD2 variety using a logistic regression model. We further employed a metafrontier analytical technique to assess the current productivity level of organic and conventional pineapple producers in three regions where commercial production for export is most concentrated. The high average performance scores (i.e. 97% mean TE and 95% mean MTR) suggests that there is not much scope for productivity gain given the current state of technology available to the industry. This implies: to substantially increase output levels in the industry to meet rapidly expanding domestic and international market demands, Government policies should aim at agricultural research development framework which not only encourages but expedite transfer of innovative production techniques to aid push output levels beyond what is currently achievable in the industry.

Keywords: Technical Efficiency, Technology gaps, Ghanaian Fruit industry, MD2 variety.

* ***MD2*** *is not an abbreviation but a name of a new pineapple variety developed in Costa Rica*

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1. Introduction

The importance of the fruit crop industry for Ghana's national development has increased over the past decades. Increasing export orientation and moving towards higher value fruit supply chains has opened up new development pathways toward reducing rural-urban poverty. The export oriented nature of the sector plays a very important role in generating employment opportunities for farmers, fruit traders and exporters which have in turn enhanced welfare and poverty reduction schemes in both rural and urban areas (Jaeger, 2008). The pineapple sector took leadership in the Ghanaian fruit industry by contributing a greater share of foreign exchange earnings to the economy (approximately €372 million, 66.2%) from 2000 to 2013 (Eurostat, 2013). Over the last decade the EU[1] has been constantly recording a trade deficit in fresh and processed fruit and vegetables, totaling €9,8 billion in 2011(DG Agric, 2012). However, a closer look at the balance (i.e. the gap between exports and imports) reveals that this deficit in fruit trade is particularly due to tropical fruits in particular for bananas and pineapples. Imports of tropical fruits have been steadily growing in the EU over the decades (Pay, 2009). The market for fresh pineapples is one of the fastest growing fruit markets in Europe. Imports grew at an average annual growth rate of 12 percent from 317,478 tonnes in 2000 to 873,936 tonnes in 2008. These volumes correspond to a total value of imports of €555 million in 2008 (Pay, 2009). This fast growing pineapple market in the EU therefore presents an excellently huge opportunity for the Ghanaian fruit industry to explore since a bilateral trade agreement in 2008 with the EU opens up the entire EU market to the industry due to removal of all trade barriers for agricultural produce from Ghana (Wolter, 2008). The ease of cultivation and comparative advantage by the sector in producing pineapple is mostly driven by the following factors (Jaeger, 2008);

1. Favourable climate and soil conditions for the production of pineapples all year round.
2. Geographical location of Ghana (i.e. a closer proximity to the European Union) guarantees low air and sea freight charges to Europe and ensures competitiveness of its export produce.
3. Abundantly cheap skilled and unskilled labour force (i.e. low labour costs).

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[1] EU-Ghana trade measures (i.e. import values and quantities) are discussed here because the EU is the principal export market for the Ghanaian fruit industry. Also, we focused primarily on the export performance to the EU due to data availability and reliability (extracted from Eurostat). Availability of Ghana's trade data with other major international markets like the United State of America, China and the Middle East could enhance the analysis, unfortunately, we could not include them due to lack of reliable data.

4. A relatively stable political situation in the country which creates a good investment environment for investors.

These factors present the sector with an excellent comparative advantage of becoming a major producer and supplier of quality but inexpensive pineapple products (i.e. raw and processed) to the EU markets. As depicted in Figure 1, the pineapple sector played a prominent role in driving forward the impressive performance of the entire fruit industry at the initial establishment stages (i.e. up to 2004/5).

(Insert Figure 1 here)

With high demand for the fruit locally and internationally (Kleemann 2011, 2014), pineapple became not only the first but also the most important export fruit of Ghana (Gatune et al., 2013)(Jaeger, 2008). Export volume increase rapidly from virtually zero in 1990 to around 68,000 tonnes in 2004 production year generating over U.S $59,20 million ((USAID/TIPCEE, 2005). The success story of the pineapple sector was abruptly interrupted by a series of crisis starting 2005 production year:

1. First, international market preference (i.e. export demand) shifted swiftly in 2005 from the traditional well adopted smooth cayenne and sugar loaf varieties to MD2[2] variety developed by Del Monte in Costa Rica. The swift pace of shift badly affected small scale growers who constitute a sizable portion of the sectors' producers.
2. Second, strict certification standards (e.g. global gap) for ensuring quality and safety were set for farmers and companies who want to export to EU.
3. Third, increasing demand trend for organically produce fruits (pineapple) in the EU market means farmers wanting to take advantage of this demand trend have to switch from conventional to organic system of production.

The consequence of above crisis was sharply reflected in the share of EU import from 2005 to 2013. The value of pineapple exports dropped significantly from a peak of €59, 20 million to around €30 million (i.e. 49.3% fall in the total value of pineapple exports (Eurostat, 2013)). In terms of quantity; trade volumes fell by about 40% from a peak of 51,726 tonnes in 2004 to less than 32,000 tonnes in 2013 (Eurostat, 2013). At the peak of the crisis, the favourable comparative advantages of Ghana (i.e. location, freight, climate and labour) were no longer sufficiently strong enough in enhancing the sector's competitiveness to challenge competing nations (especially Costa Rica) in the European markets. Large commercial farm entities (like

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[2] It currently accounts for approximately three quarters of the European pineapple market.

Bomarts[3] and Golden Exotics Ltd) with sound financial and technical resources were able to switch approximately 98% of their production to MD2 by the end of 2007 (Manasseh, 2007). However, large proportion (approx. 70%) of the sectors production is based on small scale[4] out-grower farmers often with weak financial backing. Overwhelming majority of such small-scale farmers could not react quickly and effectively to these sudden changes. These changes require that farmers have to incur extra cost in replacing existing stocks with the new MD2 variety which requires intensive use of specific chemical inputs in order to achieve maximum output (Gatune et al., 2013). Also, switching production from conventional to organic produce in order to take advantage of rapidly expanding premium niche organic markets in EU entails substantial cost in terms of meeting certification standards and adjustment costs. Consequently, huge portions of ready to harvest pineapple were left to rot on the field as the local market could not absorb all outputs. Demoralization and frustration by farmers lead to a downward production trend as farmers switched to producing other crops or completely abandoned their pineapple fields (Gatune et al., 2013) (Jaeger, 2008).

In an effort to restore farmers' confidence and revamp production, various government agencies, NGOs and other stakeholders intervened to provide both technical and financial support to farmers. The adoption rate and the effect of such intervention measures on output are yet to be quantified empirically as done in this study. A few decades ago, the bulk of pineapples on the European market were sourced from West Africa (i.e. Ghana and Ivory Coast). However, while competing nations in pineapple production (especially Costa Rica) have dramatically improved their efficiency of production, little or no such improvement could be observed in the Ghanaian pineapple production sector[5] (Gatune et al., 2013). Consequently, average yield per hectare is far below that of Costa Rica[6]. Costa Rica is by far the largest exporter of pineapples to the European market, supplying 670,119 tonnes or 73 percent of all imports in 2008, while Ghana currently accounts for only 4 percent (35,601 tonnes) of total import.

The financial and economic consequence of decreasing export volumes cannot just be ignored due to its ripple effect on other sectors of the economy. This decline in the industry

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[3] In 2008, 6,000 tonnes of MD2 pineapples were produced by Bomarts of which 2,200 tonnes were sold to the Fairtrade markets in the EU.

[4] By 2004, it was estimated that smallholders contributed over 50% to export volumes (Gatune, 2013)

[5] Sluggish productivity growth might be one of the main barriers hindering successfully development of Ghana's young export-oriented fruit crop industry

[6] The average productivity of Ghana pineapple farms is 60 T/Ha compared to 120 T/Ha for Cost Rica (Gatune et al., 2013)

does affect both forward linkage (i.e. supply side) activities such as agro-processing, exporters and transportation, and backward linkage (i.e. demand side) activities through the provision of inputs and services to the sector. The phenomenon of falling output and export levels in the sector could be assigned to a range of factors beside volatility in the international marketplace. Among which are deficiencies emanating from the production side, poor service delivery in the transport and logistics sector reflecting the poor infrastructural state of the country as well as impact of adverse weather effects prevailing in the production environment. These factors may be broadly categorized into factors under the control of farmers *(i.e. technical efficiency factors)* and those outside the control of farmers *(i.e. factors inducing technology gaps).* Against this background, this study embarks on identifying and analysing the effect of such factors on the production efficiency of farmers and how they impact the trade performance of the sector as a whole. We believe any attempt by policy makers in formulating adequate future intervention measures should be based on sound empirical information (i.e. science bases solution) and not on ad hoc political expedience as is often the case in most developing countries. Formulation of informed productivity enhancement mechanisms is therefore a necessary condition for ensuring sustainable development in the sector. The Empirical insights gained from this study should therefore aid policy makers in formulating appropriate future intervention programs to help boost output levels in the sector.

1.1 Research Objectives

This study seeks to identify the socioeconomic, infrastructural and institutional factors in the production environment as well as farm management practices that influence pineapple production outcomes and efficiency of input use in the sector. Specific objectives include:

1. To assess farmers’ response to international market demand of MD2 variety by quantifying the proportion of MD2 variety under cultivation in both systems of production as well as analysing the factors influencing the adoption of MD2 variety in the Ghanaian pineapple production sector.
2. To assess how output level of farmers using conventional or organic production system(s) are affected by farm management decisions and production practices (i.e. effects of technical efficiency on output)
3. To investigate to what extent conditions prevailing in the production environment (such as road condition, inputs markets access and availability, technical support

through extension and credit provision, weather and other environmental factors - i.e. factors capable of inducing technology gaps) affect output of both conventional and organic farmers.

4. Identify the drivers of technical efficiency and technology gaps of both farming systems.

Policy implication: Productivity improvement can clearly influence the survival and how the Ghanaian fruit industry benefits from participating in international trade. Lack of empirical information regarding factors influencing adoption of the newly introduced and international market preferred MD2 variety as well as drivers of technology gaps in production regions and their effect on farm level productivity in the Ghanaian pineapple sector, limits policy maker's ability to formulate the appropriate intervention response to help stimulate output to enable the sector meet both domestic and international market demand. This study therefore contributes by filling this gap using a comprehensive data set covering all the three major pineapple production regions in Ghana. The study goes beyond obtaining just estimates of technical efficiency and technology gaps between regions but also identify factors influencing these estimates. Hence, policy maker are provided with detailed and comprehensive empirical information to enhance formulation of better future intervention programs.

1.2 Research Area

Pineapple production is viable in most of Ghana's ten administrative regions, however, due to logistic and financial constraints; data collection took place only in the three major producing regions (i.e. eastern, central and Volta regions) where average annual rainfall and temperature regimes support commercial production all year round. These three regions constitute a fair representation of the main pineapple production areas in Ghana. These regions are characterised to some degree by similar climatic and soil conditions, however, there exist disparities in terms of quality, access and availability of certain basic agricultural infrastructures (e.g. rural roads conditions, number of extension workers, electricity access, input stores and output markets) needed to enhance the production environment and performance in the sector. Such disparities in terms of quality and access to these basic but important agricultural infrastructures may impose limitation on the type of production technology employed in a specific region or production area. Also, cultural diversity across these three regions may also influence production practices. Confirmation of statistical test together with our prior knowledge of different production technologies between conventional and organic pineapple production across the three regions justified the metafrontier estimation technique used for identifying and analysing factors influencing production performance in the sector.

1.3 Data Set

This research uses an integrated approach that draws upon both quantitative and qualitative methods of primary data collection[7]. A list of villages with farmers producing pineapple on commercial basis was obtained from district extension offices in each region where data collection took place. Base on this list together with other qualitative information gathered from opinion leaders in each village, pineapple farmers were sampled randomly.

(Insert Figure 2 here)

Regions with high number of farmers were given a higher proportion in the sampling process compare to regions with smaller number of farmers. The proportion chosen for each region is based on the total number of registered farmers in that region, hence, more farmers were selected from the eastern region to capture the large concentration effect in this region as most commercial pineapple growers in the sector are located in this region (i.e. around Nsawam area). In total, our sample comprises 404 pineapple farmers. Figure 2 presents an overview of the number of farmers' sampled using organic or conventional system of farming across the three regions. Using a structured questionnaire, detailed information on pineapple production activities (e.g. input use, maintenance cost, farm output etc.) as well as some socioeconomic characteristics of each household was obtained. Lack of systematic documentation of farm production activities by most farmers' means most information obtained could be classified as recall information[8].

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[7] Quantitative information was gathered using a structured survey questionnaire while qualitative information was gathered through farm observation and interaction with farmers, extension officers and opinion leaders in the villages

[8] Ideally, systematically well documented farming information would have been prefer as compare to recall information; since recall information could aggravate the problems of outlier in statistical estimation; This could be a draw back and so has to be kept in mind for interpretation.

2. A Brief History of Ghana's Pineapple Production Sector

Ghana started the intensive commercial exploitation of its immense productive resources and comparative advantage in producing tropical fruits to supply the international markets as part of an export diversification program in the 1990s. Within the two decades that followed, the economic potential of the various tropical fruits Ghana produce and export has helped transform the entire fruit sector into a formidable industry creating jobs in both rural and urban areas. Commercial Production of pineapple for export reached peak export level of 52,000 tonnes in 2004 with market share increasing from virtually zero to 10% in EU fruit markets around the same time. The proximity of Ghana to Europe made the EU market a target export destination due to low sea and air freight charges (Mensah, 2012). The initial rapid growth in the pineapple sector through a knock-on effect induced strong growth in other sectors of the economy especially in the export sector, the transport and logistics sector, the agro-processing sector and the local retail sectors; This lead to increased employment and wealth generation in both rural and urban areas of the country (Pay, 2009). The two major traditional varieties grown in Ghana are the smooth cayenne and the sugar loaf. Sugar loaf is conical in shape with very sweet juicy pulp while smooth cayenne is middle sweet with very intensive flavour. These varieties due to their relatively large size are very suitable for extraction of pineapple juice/concentrate and making pineapple salad; however, they don't have the intensively bright yellow colour which most EU consumers associate with a ripe pineapple fruit. There are claims that, the relatively bigger size and shape of smooth cayenne and sugar loaf varieties pose some difficulty for orderly arrangement and space conservation in the EU super-market shelves (Wardy et al., 2009)(Achuonjei et al., 2003).

The introduction of MD2 variety to the European market marked the beginning of demand decline for Ghanaian smooth cayenne and sugar loaf pineapple varieties (Pineapple exports declined by 40% between 2004 and 2013). Ghana dropped from 3rd to 5th place in the supplier rankings and market share dropped from 10.5% to 4% between 2005 and 2007 (Jaeger, 2008). The MD2 is relatively small and uniform in size and ripeness with intensively sweet taste and bright yellow colour which renders it aesthetically appealing to most EU consumers. It is said to have higher shelf life and allows better arrangement on the super market shelf (Achuonjei, 2003). The introduction of MD2 nearly collapsed the Ghanaian pineapple sector since most small-scale farmers, which constitute the bulk of producers could not easily switch to the MD2 variety as demanded by changes in the international market. Due to the sector's inability to react quickly to changes in international market demands; both market share and comparative advantage were lost to Costa Rican exporters[9]. Despite intervention measures by Government agencies and NGOs, smallholder farmers' adoption response to the MD2 variety has been very slow, due primarily to higher production and adjustment cost involved in transition to the MD2 variety. At such difficult period, surviving farmers in the sector had a choice to make.

1. Either to switch completely to the cultivation of MD2 variety to help regain international market share thereby risk forfeiting secure revenues from the local and regional markets or
2. Be innovative through quality improvement in securing new buyers for the local varieties while taking time to adjust to the MD2 variety.

Information gathered during field interview indicates; majority of small scale farmers eventually stick to production of the local smooth cayenne and sugar loaf varieties and are now concentrating on achieving higher fruit quality and yield to serve emerging new buyers and local agro-processing industries demanding high volumes on a weekly basis. The emerging high demand of the local varieties by agro-processors is due to the fact that the juice yield of Smooth Cayenne and the sugar loaf is significantly greater than the MD2 variety (i.e. approximate juice volumes of 205.72 ml/kg of Sugar loaf compare to 134 ml/kg of MD2, (Wardy et al., 2009)). The high volume demand by these new buyers provides a new opportunity to revive production in the sector. However, the long term sustainability of the sector will not depend on serving only the local market but will depend on drastic improvement in production efficiency to sustain output growth in serving both local and the international markets. Seven years after the 2005 crisis, we studied how Ghanaian pineapple farmers have responded to international market demand. We estimated the proportion of farmers cultivating the internationally preferred MD2 variety and analysed the factors influencing its adoption using a logistic regression model. We further employed metafrontier analytical techniques to assess the current productivity level in the sector and identify the factors which affect production efficiency of farmers in the pineapple sector. We conclude by recommending some potential ways to aid policy makers' formulation of future intervention programs to help boost output in the industry.

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[9] The ideal growing conditions of MD2 in Costa Rica lowered production cost which then neutralized the Ghanaian cost advantage gained from lower freight costs as a result of its proximity to Europe.

3. Analytical Framework

3.1. The Stochastic Frontier Model

Building on the work of Hayami (1969), Hayami and Ruttan (1970, 1971), Battese and Rao (2002) and Battese et al., (2004) propose the stochastic metafrontier 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 or use the same technology[10]. The metafrontier conceptually represent a boundary of an unrestricted technology set potentially available to the industry as a whole, while the zonal/group frontier represent the boundaries of restricted technology sets where the restrictions may be due to constraints prevailing in the production environment which limit farmers in certain region from using the full range of technologies potentially available to the industry (O'Donnell et al., 2008). The metafrontier estimation technique therefore enables technology gaps to be estimated for groups under different technologies relative to the potential technology available to the industry as a whole. In line with Battese et al., (2004) and (O'Donnell et al., 2008) the metafrontier function estimated in this study is assumed to be a smooth function (not a segmented envelope) that envelope all the frontiers of the individual groups (i.e. group k_c = Conventional production system and k_o = Organic production system) in the industry. The estimation technique employed in this study involves a single process[11] data generation where the estimates from the group specific frontiers are enveloped by the metafrontier such that the envelope covers from above the deterministic maximum outputs predicted from the estimated group-specific frontiers. The metafrontier function model could be conceptually or graphically depicted as in Figure 3:

(Insert Figure 3 here)

Thus, considering k systems of production in the pineapple sector, a standard output oriented stochastic frontier model for production system k could be specified as follows ((Battese et al., 2004) (O'Donnell et al., 2008)):

$$Y_{i(k)} = f(x_i\,, \beta_{(k)})e^{v_{i(k)} - u_{i(k)}} \equiv e^{x_i\beta_{(k)} + v_{i(k)} - u_{i(k)}}. \qquad (1)$$

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[10] Technology in this study is broadly defined as the state of knowledge, skills and production tools pertaining to the transformation of agricultural inputs into outputs.

[11] Please refer to O'Donnell et al., (2008) for detailed discussion on single process data generation technique for a metafrontier analysis.

Where the expression in model (1) assumes that the exponent of the frontier production function is linear in the parameter vector, $\beta_{(k)}$, so that x_i is a vector of logarithm function of the inputs for the *ith* farmer involved in the pineapple sector. $Y_{i(k)}$ denotes the total pineapple output for the *ith* pineapple farmer in the *kth* farming system; $x_{i(k)}$ denotes a vector of inputs used by the *ith* farmer in the *kth* zone; the functional form $f(.)$ is specified as translog function (as defined in section (3.2)), so $\beta_{(k)}$ denotes the parameter coefficients associated with the *x*-variables for the translog stochastic frontier for the *kth* production system; the $v_{i(k)}s$ are noise error term which is assumed to be identically and independently distributed as $N(0, \sigma^2_{v(k)})$ (Aigner et al., (1977)) random variables, independent of the inefficiency term $u_{i(k)}$. The $u_{i(k)}$ s are a systematic and non-negative random variables which account for technical inefficiency in production which is under the influence of farmers and are assumed as the truncation (at zero)[12] of the $N(0, \sigma^2_{ui(k)})$ distributions such that the $u_{i(k)}$s are defined as in Wang and Schmidt, (2002) model;

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

Where $z_{i(k)}$ is explanatory variables of the variance of inefficiency term $\sigma_{u_{i(k)}}$ for the *ith* farmer*;* δ is a vector of parameters to be estimated, reflecting the impact of the variables $z_{i(k)}$ on technical inefficiency. A positive or negative estimate of δ indicates that the corresponding variable leads to an increasing or decreasing variance of the inefficiency term. Model (2) generally known as “heteroscedasticity-model” was developed by Wang and Schmidt in (2002) for stochastic production frontier estimation framework. This model corrects for possible heteroscedasticity which is often present in cross-section survey data(s). The specification of model (1) which implicitly assumes that both error terms (i.e. *v* and *u*) are homoscedastic (i.e. conditioned on the explanatory variables, the variance of the unobserved errors ($v + u$) are constant). However, since our sample is a cross section survey data and we observed considerable variation in terms of farm size and other inputs usage, it is likely both error terms are affected by heteroscedasticity (i.e. the inefficiency term would vary according to farm size with larger farms having more variation than small farms (Lakner et al., (2013)). Hence, if such heteroscedasticity effects are not corrected, it implies estimated standard errors are biased and t statistics cannot be used for drawing inferences.

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[12] i.e. half-normal distribution are assumed for the $u_{i(k)}$s

The metafrontier production function model for farmers in the entire pineapple production sector could be express as:

$$Y_i^* \equiv f(x_i;\beta^*) = e^{x_i\beta^*}, \quad i = 1,2,...,N_k, N = \sum_{j=1}^{2} N_j \qquad (3)$$

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

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

Model (4) specifies that the metafrontier dominates all the two systems frontiers. The metafrontier production function as specified by equation (3) is a log linear production function form and the constraint imposed in equation (4) does not allow the metafrontier function to fall below the deterministic functions for the two systems involved in the sector (Battese et al., 2004). The estimated metafrontier function which enveloped the two estimated group frontiers was obtained by solving the optimization problems in equations (10) and (11). The observed output for the ith pineapple farmer defined by the stochastic frontier for the kth system of production in equation (1) is alternatively expressed in terms of the metafrontier function of equation (3) by:

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

The first term on the right-hand side of model (5) captures the technical efficiency of the *ith* pineapple farmer relative to the stochastic frontier for the kth production system. Equation (6)[13] 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 individual system frontier (e.g. given observation “a” under the organic production system as depicted in figure 3):

$$TE_{i(k)} = \frac{Y_i}{e^{x_i\beta_{(k)} + v_{i(k)}}} = e^{-u_{i(k)}} \text{ (i.e. } TE_i = ao/bo \text{ in figure 3)} \qquad (6)$$

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[13] Is estimated by the conditional expectation of u given the observed residual w (E[u | w], see (Jondrow et al., 1982) and (Battese et al., 1988).

The second term on the right-hand side of equation (5) is what Battese et al., (2002, 2004) call Technology Gap Ratio (TGR) but O'Donnell et al., (2008) call it Meta Technology Ratio (MTR) for the observation of the sample farms involved in the sector. This is expressed as:

$$MTR_{i(k)} = \frac{e^{x_i\beta_{(k)}}}{e^{x_i\beta^*}} \quad \text{(i.e. } MTR_i = bo/co \text{ in figure 3)} \tag{7}$$

This measures the ratio of the output for the frontier production function for the *kth* production system 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 group and the industry as a whole. The MTR plays an important part in explaining the ability of one farming system to compete with the other system in the industry. The technology gap ratio has values between zero and one. Values close to one imply that the farmers are producing nearer to the maximum potential output given the technology available for the industry as a whole.

The technical efficiency of the *ith* pineapple farmer compared to the industrial frontier (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* pineapple farmer relative to the metafrontier output adjusted for the corresponding random error, such that:

$$TE_i^* = \frac{Y_i}{e^{x_i\beta^* + v_{i(k)}}} \quad \text{(i.e. } TE_i^* = \text{ao/ac in figure 3)} \tag{8}$$

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

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

So the technical efficiency relative to the metafrontier (TE_i^*) is the product of the technical efficiency relative to the stochastic frontier of a given production system ($TE_{i(k)}$) and the metatechnology ratio ($MTR_{i(k)}$) for that system. 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 (*note*: it could be less than or equal to the technical efficiency relative to the stochastic frontier for the production system of the *ith* farmer (i.e. $TE_i^* \leq TE_{i(k)}$)).

In line with Battese et al., (2004) and O'Donnell et al., (2008) we estimated the parameters and measures associated with the metafrontier model as follows:

1. We obtained the maximum likelihood estimates, $\hat{\beta}^k$ for the β^k parameters of the stochastic frontier for the *kth* production system (group) using the statistical software OxMetrics version 7 (Doornik, 2008).
2. We then estimated, $\hat{\beta}^*$, for the β^* parameters of the metafrontier function such that the estimated function best envelops the deterministic components of the estimated stochastic frontiers for the different groups.
3. The metafrontier parameters are obtained by minimizing the sum of squares of deviations or the sum of absolute deviations of the metafrontier values from those of the group[14].

The numerical values of the metafrontier parameters were obtained using the OxMetrics programming language in solving the objective functions in equations (10) and (11) below[15]:

$$\min LP \equiv \sum\nolimits^{N}_{i=1} \left| (\ln\ f(X_i,\beta^*) - \ln\ f(X_i, \hat{\beta}_K)) \right| \quad \text{......}\textit{Linear optimization function} \qquad (10)$$

$$s.\ t.\ \ln f(X_i,\beta^*) \geq \ln f(X_i, \hat{\beta}_K)\ \textit{for all } i.$$

$$\min QP \equiv \sum\nolimits^{N}_{i=1}(\ln\ f(X_i,\beta^{\sim}) - \ln\ f(X_i, \hat{\beta}_K))^2 \quad \text{.......}\textit{Quadratic optimization function} \qquad (11)$$

$$s.\ t.\ \ln f(X_i,\beta^{\sim}) \geq \ln f(X_i, \hat{\beta}_K)\ \textit{for all } i.$$

Estimates for the technical efficiencies of all pineapple farmers relative to the metafrontier function were then obtained by:

$$\hat{TE}^*_i = \hat{TE}_{i(k)} \times \hat{MTR}_{i(k)} \qquad (12)$$

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[14] Please refer to Battese et al., (2004) and Rao et al., (2012) and O'Donnell et al., (2008) for detailed outline of how to obtain both the minimum sum of absolute deviations and minimum sum of squares of deviations.

[15] As outlined by Rao et al., (2012) in solving equation (10) and (11), the $\hat{\beta}_K$ are treated as fixed. So that the second term in the summation is constant with respect to the minimization.

Where $\hat{TE}_i$ is the predictor for the technical efficiency relative to the given system frontier as proposed by O'Donnell et al., (2008). The $\hat{MTR}_{i(k)}$ is the estimate for the $MTR_{i(k)}$ for the *ith* farm in the *kth* group relative to the industrial potential, obtained by using the estimates for the parameters involved (specifically, the MTR is estimated by substituting estimates of $\beta_{(k)}$ and β^* into equation (7), the constraints in the LP problem defined by equation (10 and 11) guarantee that metatechnology ratios estimated in this manner will lie in the unit interval). Standard errors for the estimators for the metafrontier parameters were obtained using statistical simulations (specifically, we used the estimated asymptotic distributions of the zonal frontier estimators to draw M = 5,000 observations on the group frontier parameters. Each draw was then used to calculate the right-hand side of the constraints in the LP/QP problems. The estimated standard errors of the metafrontier estimators were calculated as the standard deviations of the M solutions to these LP/QP problems (Battese et al., 2004).

3.2. Empirical Specification

Empirical estimation of both systems of production were obtained using translog stochastic frontier production function model[16]. The choice of translog model is based on a statistical test (see table 2). Its flexibility allows us to examine interaction between production inputs. A translog model for pineapple farmers in each production system could be defined as:

$$\ln y_i^k = \beta_0^k + \sum_{j=1}^{J} \beta_j^k \ln x_{ji}^k + 1/2 \sum_{j=1}^{J} \sum_{m=1}^{J} \beta_{jm}^k (\ln x_{ji}^k)(\ln x_{mi}^k) + \sum_{s=1}^{S} \beta D_s + v_i^k - u_i^k \quad (13)$$

$\ln y_i^k$ denotes the natural logarithm of total pineapple output for the *ith* farmer in the *kth* production system. $\ln x_{ji}^k$ represents the *jth* input ($j = 1,2,....J$) of the *ith* farmer ($i = 1,2,...N$) using the *kth* production system ($k = 1,2,...K$). $\beta_{jm}^k = \beta_{mj}^k$ for all j and m. The β represent a vector of coefficients associated with the x-variables in the translog specification to be estimated. The x_s represents the various continuous/discrete production inputs variables (i.e. land, labour, fertilizer cost and plant age). D_s are dummy variables (i.e. extension, irrigation, credit access, gender and farmer association) intended to capture unique regional characteristics which may influence the system's production frontier. The discrete

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[16] We have used a parametric approach because it enables us to distinguish the effects of noise (v) from the inefficiency component (u) involved in the production process.

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 production systems and the industrial frontier but also information on what contribute to the formation of these gaps. We therefore specified a multivariate regression function to capture the determinants of the technology gap ratio as follows:

$$MTR_i = \beta_0 + \sum_{j=1}^{J} \beta_j q_{ij} + \varepsilon_i \tag{14}$$

Model (14) specifies climatic, soil, infrastructural and Government program variables outside the control of farmers hypothesised to influence the MTR in Ghana's pineapple 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.

To analyse the factors influencing adoption of MD2 variety, a simple logistic regression model was specified as follows:

$$y* = \alpha + \beta x + \varepsilon \qquad \text{where } \varepsilon \text{ is distributed as in equation (16)} \tag{15}$$

$$y_i = \begin{cases} 1 \; if \; y_i^* > 0 \\ 0 \; if \; y_i^* \leq 0 \end{cases}$$

Where y^* is a binary (i.e. dummy) variable (i.e. 1 = planting MD2 variety; 0 = Otherwise). The value of β is the propensity to adopt the MD2 variety; where higher positive values of β mean that the adoption of MD2 is more likely. The x_s are explanatory variables hypothesised to influence the adoption of MD2 in Ghana's pineapple production sector. The ε captures any statistical noise and is assumed to have the standard logistic distribution of errors as follow:

$$ln\left(\frac{p_i}{1 - p_i}\right) = \sum_{k=0}^{k=n} \beta_k x_{ik} \tag{16}$$

4. Results and Discussion

Empirical results were obtained with the aid of OxMetrics programming language (Doornik, 2008) and Stata statistical software. Maximum likelihood estimates for the metafrontier model as well as the pooled and group stochastic production function frontier models were obtained using a modified metafrontier estimation template for OxMetrics7. Stata (11th edition) was used for all the descriptive and graphic analysis including the estimated average response function for the determinants of the MTR and the logistic model for analysing factors influencing the adoption of MD2 variety.

4.1. Summary Statistics

The total number of pineapple farmers sampled across the three major pineapple producing regions is 404. Table 7 presents how the variables are defined and the unit of measurement. Tables 8 and 9 present summary statistics of all the variables used in the various analytical models. A look at Table 8 shows that farmers using conventional production system on average have higher total farm output, allocated more land and labour to pineapple production compared to their organic production system counterparts. These differences however appear to be moderate yet statistically significant as confirmed by differences of means test. Table 9 which reports on dummy variables used in the various analyses also reveals that a high proportion of males are involved in pineapple production in both systems. The proportion of farmers under contract obligations to supply agro-processing and exporting companies is higher in the conventional system compared to the organic system. No significant proportional difference could be observed in terms of manure applications, extension visits and access to better road conditions.

4.2. Test of Model Quality

Before we proceeded to examine the parameter estimates of the various models used in the analysis, we performed a test to examine the appropriateness of the models using generalised likelihood-ratio statistics. LR = –2[ln{L(H0)} – ln{L(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 $\delta = 0$, then the asymptotic distribution necessitates the mixed Chi-square distribution (Kodde and Palm 1986; Table 1).

(Insert Table 1 here)

The results of tests for various hypotheses on model quality are presented in Table 1. The overall result shows that the models used are an appropriate representation of the data. For instance, the null hypothesis of homogenous technology across all production systems was rejected justifying the use of metafrontier estimating technique. The null hypothesis that the Cobb-Douglas frontier is an adequate representation of the data of both production systems was also rejected. The null hypothesis that technical inefficiency is not present in both systems was rejected implying majority of farmers operate below the production frontier. This also suggests that all the hypothesised variables included in the inefficiency model collectively and significantly contribute in explaining how inefficiency affects output in the pineapple production sector.

4.3. Adoption of MD2

To assess the response of farmers to shift in international market demand preference for MD2 variety, the proportion of farmers in our data cultivating MD2 was calculated. Figure 4 presents a bar and pie chart summary statistics of the proportion of various varieties under cultivation by farmers in our data set. Out of 404 pineapple farmers sample across the three regions, only 74 (18%) farmers in both systems are cultivating the MD2 variety. Majority of the farmers are still cultivating the local varieties. 166 (42%) farmers cultivate the smooth cayenne variety while 164 (40%) cultivate the sugar loaf variety. For farmers producing organic pineapples, only 3 (0.02%) are cultivating the MD2 variety. 71 (31%) farmers under conventional system of production are cultivating the MD2 variety. These summary statistics show that the rate of adoption in response to market change is very slow as shown by majority of farmers in our sample data.

(Insert Figure 4 here)

The peak of the market shift crisis was in 2005. We collected data at the end of 2012 production year, so seven years after the crisis, we expected that the majority of farmers will be cultivating the international market preferred MD2 variety; however, as revealed by our data, only 18% are cultivating the MD2 variety. We therefore proceed to analyse the factors influencing the adoption of MD2 variety by farmers in the pineapple production sector.

The result of a logistic regression model as specified in equation (15) is presented in Table 2. The estimates in columns 2, 4 and 6 can be interpreted as follows: all things being equal (i.e. ceteris paribus), the odds of a farmer having a unit access to one of the predictor variable will facilitate the adoption of the MD2 variety by a margin of the respective log odd estimate.

(Insert Table 2 here)

Table 2 therefore shows a farmer having an access to irrigation water is 2.832 times more likely to adopt the MD2 variety compare to those who do not have any access to irrigation. The marginal effect represents the slope or the elasticity of adoption with respect to a 1% increase in irrigation access (i.e. 0.118), this figure imply, once a farmer adopt the MD2 variety, a 1% increase in irrigation access will influence his/her decision to expand the share of MD2 under cultivation by 0.118%. In general Table 2 shows that farmers capable of irrigating their farms, having access to more pineapple buyers with farms located in the eastern regions are more likely to adopt the MD2 variety. The highest marginal effect is however, observed by the type of farming systems (i.e. conventional farmers are more likely to adopt and expand production of the MD2 variety compare to their organic farmers counterparts). This observation is not very surprising since unlike the well adopted cayenne varieties to the Ghanaian farming and environmental conditions, the recently introduced MD2 variety is more likely to be susceptible to local pineapple diseases (e.g. the phytophthora fungal disease), therefore a relatively high amount and frequency of certain chemical inputs will be required to enable maximum output attainment. Contrary to our expectation, farmers with more extension contacts were less likely to adopt the MD2 variety. This could be due to the fact that the majority of extension workers in the research area were not fully up to date or well trained in understanding the agronomic practices of the MD2 variety and so could not advice farmers to appropriately adjust their cultivation practices to suit the requirement of the MD2 variety. The low adoption rate of the MD2 variety may also be due to its high production and adjustment cost[17]. It appears the shockwaves of the crisis is still reverberating in the minds of a lot of farmers, making them more caution in obtaining new loans to enable them finance the recommended inputs and cultivation requirements should they decide to adopt the MD2 variety. Compared to the initial establishment phase while the industry was doing well before the crisis, a lot of farmers took credit to invest in pineapple production. However, the sudden shift of demand to MD2 bankrupted most of these farmers, hence, their unwillingness to further borrow just to finance adoption requirements of the MD2 variety.

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[17] Cost of certified MD2 crowns/plantlets, also high adjustment cost to meet weather and soil conditions. The MD2 was breed to suit Costa Rican weather and soil conditions; hence, best performance in Ghana is only possible with substantial initial investment in meeting recommended cultivation requirement.

Information gathered during field interview indicates that the majority of farmers who survived the market shock and remained in the sector, have decided to stick to the production of the locally well adopted smooth cayenne and sugar loaf varieties which entail very low production cost. Most of such farmers are now concentrating on achieving higher fruit quality to serve emerging new buyers in the fresh cut retail sector and local agro-processing industries demanding high volumes of these local varieties on a weekly basis. The high demand of these new buyers may provide a new opportunity to revive the industry but this could only be achieve on a sustainable basis if farmers radically improve their productivity level. The subsequent sections of this study therefore assessed current production efficiency level of both conventional and organic farmers. We identified sources of production inefficiency emanating from farmers' production practices as well as those emanating from conditions prevailing in the production environment.

4.4. Parameter Estimates of the Stochastic Production Frontier

In this section we examine how the use of factor endowment impacts farm output and hence the production frontier of each group. The first order maximum likelihood estimates of the organic and conventional frontiers are presented in Table 3. The dependent variable is log of total farm output measured in kilograms[18]. Total farm output is positively and significantly influenced by the total land allocated to pineapple production in both systems. This highlights the importance of access to land in agricultural productivity. Increasing the total number of people working on plantation has positive and significant effect on total farm output in both systems. This reflects the labour intensive requirement nature of pineapple production; hence, an increase in labour input results in real positive impact on output. Increasing experience and maintenance cost have positive effect on output; however, this effect is statistically significant only in the conventional system of production. Aging plants have a significantly negative effect on the output at the sample mean. This could be attributed to decreasing effectiveness of old plants in converting light into stored energy during photosynthesis. Increasing plant density has positive and significant effect on the output while increasing manure use has the opposite effect. This could imply, the excessive amount of nitrogen/urea in organic manure does encourage vegetative growth at the expense of fruit set hence the right balance and timing of manure application should be observed by sampled farmers. Farmers irrigating their

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[18] Farm output as measured here does not take into account for fruit size, quality and post harvest losses. This could be a draw back and so has to be kept in mind for interpretation.

farms observed a significantly positive output as compared to those who do not. Due to high temperature regimes in tropical countries, low soil moisture content normally prompt plants into dormant state, hence plantations under rain-fed system normally observe lower farm output.

(Insert Table 3 here)

Famers who are under contracts obligations to supply exporting and agro-processing firms tend to have significantly positive output. This implies, as farmers are assured of secured buyers for their products, they are willing to invest in production inputs to increase output. Also, due to such binding contractual agreements, buyers and traders are more willing to support such farmers with loans to enhance production. Positive and significant effects were also observed with farms located in the eastern region. The location of a farm appears to be important for output. This may due to the enormous experience gained by farmers in the eastern region considered as pioneers of commercial pineapple production especially those around the town of Nsawam. It also reflects the regions easy access to technical support, market and the suitability of climate and soil in the Akuapem south district for pineapple production. In general, the magnitudes of economic gain as shown by the partial elasticity estimates of the production inputs are very small, though most exhibit statistical significance. Both production systems exhibit decreasing return to scale[19] (i.e. doubling the amount of inputs employed in production will result in less than double output). This means, given the current technology available to the industry, as more of such inputs are employed in production, proportionately less outputs are obtained. This increases the average cost per unit produced. Normally, firms experiencing decreasing return to scale are viewed in the economic literature as huge or too big, hence, a need for restructuring into manageable size. However, summary statistics in Table 8 reveals that, the average farm size of 5.5ha in the organic and 6.5ha in the conventional system are far too small to justify the argument that, the sizes of production in both systems are too big or overstretched[20]. A plausible explanation to decreasing return to scale as observed in both systems could be attributed to the obsolete nature of current production technique which is unable to squeeze maximum performance from each production input (for instance, the work output per hour of 10 workers using hole

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[19] Return to scale is a very important technical property of any production function (i.e. via the homogeneity properties of the production function).

[20] One have to take note that, the concept of decreasing return to scale is more difficult to justify in empirical work because of indivisibility of certain factors. "Returns to scale" requires that we double *all* inputs. In the case of farm analysis, we cannot just double the number of farm owners/managers by just doubling the land size etc without running into conflict of ownership issues etc.

and cutlass in land preparation could be far below that of 1 worker using a tractor and a plough). This confirms the need for introduction and spread of modern production technologies which could greatly enhances outputs even if the same input levels are employed. The value of gamma which gives an indication of how much of the deviation in observed output from the production frontier could be associated with inefficiency was estimated to be 83% and 51% (see table 4) for the organic and conventional models respectively. This implies that a large percentage in output shortfall could be attributed to farmers' inefficiency in input usage especially those in the organic farming. These gamma values reflect the relative importance of inefficiency in the estimated models (it shows that in the organic system for instance, as high as 83% change in the level of output in relation to the frontier is due to inefficiency).

4.5. Determinants of Inefficiency

Table 4 presents the result of the inefficiency model as specified in equation (2) which enables us to identify sources of technical inefficiency in each production system. A negative coefficient means that a variable is associated with greater efficiency and a positive coefficient has the opposite effect. Increasing the share of land allocated to pineapple production has a positive and significant effect on technical efficiency in both systems of production. This implies farmers with large farm size have more incentive to invest in using modern production technologies which help reduces production inefficiency.

(Insert Table 4 here)

Increasing farm maintenance cost as well as the number of plants per hectare reduces inefficiency while as household decision maker becomes older and fragile, inefficiency increases in both systems of production. Increasing household size reduces inefficiency in both systems; however, this effect is significant only in the organic system of production. Inefficiency increases significantly the further a farm is located from a market center. This is not very surprising since fruit traders tend to bargain strongly to reduce farm gate prices to compensate for high transportation cost. Low output price discourage farmers from investing more on production inputs which in turn leads to lower total farm output. This implies production efficiency and output could significantly increase with development of market and improvement of road infrastructure linking rural production areas with urban buying centres.

Farmers with higher formal education levels exhibited positive and significant effect on technical efficiency under the conventional system while the opposite effect is observed in the organic system. The gender of household decision makers has no significant effect on technical efficiency in both systems.

4.6. Average performance scores (TE, MTR and MFTE)

The parameter estimates of the metafrontier presented in table 11 were obtained by solving the linear and quadratic optimization problems of equations (10) and (11) for the entire sample. Simulations were used to get estimates of standard errors of the two metafrontier parameters (i.e. the Linear Programming (LP) and the Quadratic Programming (QP) in table 11). Both the LP and QP gave similar estimates; hence, the QP estimates were used for computation of MTR and are used for discussion under this section.

(Insert Table 5 here)

Table 5 presents summary statistics of group specific technical efficiency (TE), metatechnology ratio (MTR) and metafrontier technical efficiency (MFTE) as defined in equation (5) and show the degree of average production performance for each system. The estimate shows that pineapple farmers across the two groups produce, on average 95% of the potential output given the current technology available to the pineapple sector as a whole. This means, the average performance of farmers in each production system is pretty high. The average MTR of 95% means both systems performance is near the industrial frontier with only 5% performance lag. Even though farmers under the conventional production system achieved a slightly higher average output of 97% with respect to their group frontier, their output performance still lag behind the industrial performance with a 5% technology gap just as those in the organic system. This suggests that farmers operating under either of the two systems faced the same or similar problems prevailing in the production environment; preventing them from reaching full industrial output potential. This observation is actually not surprising since in most cases organic and conventional farmers are located in the same production or geographical area and, hence, faces the same external shocks and production constraints. The metafrontier efficiency estimates aid comparison of farmers’ performance in each group relative to a potential technology available to the industry as a whole. The average efficiency score of farmers in the organic production system relative to the metafrontier was smaller (89%) than in the conventional system (93%).

The bar chart distribution in Figure 6 also shows larger variation in the efficiency scores in the organic system compared to that of the conventional system. This means, a lot more farmers in the organic production system have to improve their efficiency of production given the current know-how in the sector. The distribution also shows some farmers in both systems with efficiency scores ≤ 60% which suggest a large scope of efficiency improvement for such farmers with regard to their group frontier. At the same time, the highly skewed to the left distribution of TE in Figure 6 is an indication that a large proportion of farmers in the sample data recorded high efficiency level in both systems (≥ 98%). The distribution of performance scores as shown in Figure 6 has consequence for policy design. It provides information on the type of intervention measures needed to be put in place in the sector to enhance productivity. For instance, farmers operating far below their group frontier should be assisted through the extension service to make better use of resources and technologies at their disposal to enable them achieve output levels as close as possible to their group frontier maximum.

(Insert Figure 5 here)

Under competitive production environment such as those prevailing in most developed economies, such inefficient farmers will eventually exit the sector due to market pressure and will therefore need no government assistance, however, in the context of developing countries where a sector of agriculture could be the only source of income and livelihood for rural dwellers, helping such farmers through extension service to maximize output could be judged as a cost effective rural poverty reduction and development policy option. The mean MTR scores of 95% for both systems mean each system is operating quit near the industrial frontier. This suggests, even with a 100% production performance with current technology, it will contribute just a small percentage change magnitude to overall output gain (i.e.5%) in the sector. This means that, significant improvement in the output level of the Ghanaian pineapple sector could only be achieved through introduction of modern production technologies with capacity to stimulate upwards expansion of current industrial output level using even lesser level of inputs. Lack of investment to promote technological research and development in the Ghanaian agricultural sector may have hindered transfer of new production technologies to the pineapple subsector. This might have stagnated efficiency improvement efforts in the pineapple production sector. As productivity is compromised, farmers' ability to meet export volumes and quality demands are greatly impaired. This causes a spiral negative effect on farmers' income, welfare as well as rural poverty reduction schemes. Since most sectors of the Ghanaian economy depend directly on the fruit industry, the entire economy could suffer a decline if productivity in the industry continues to worsen.

4.7. Drivers of Variation in the Metatechnology Ratio (MTR)

The MTR estimate captures the effect of factors prevailing in the production environment (i.e. soil and climatic elements, availability of agriculture infrastructural as well as effects of public and private programs). Technology gaps between group frontiers and the industrial frontier is not due to technical inefficiency of farmers but as a result of influence of such external factors which restricts farmers’ ability to access the best production techniques in the industry. Hence, measures to bridge these gaps to enable farmers take full advantage of production technologies available to the industry as a whole lies outside the control of individual farmers. Stakeholders and policy makers can improve the production environment using various legal instruments such as reforms in labour laws and land rights etc and infrastructural development instruments such as building roads to facilitate easy transportation and access to both inputs and outputs. Availability of such basic but important agricultural infrastructure facilities does ensure farmers’ regular access to much needed technical inputs as well as consumers’ access to outputs at all seasons at reasonable cost.

(Insert Table 6 here)

An average response function as defined in equation (14) was used to identify the drivers of MTR in both systems of production. The R- square values of the analysis presented in table 6 reveals that, 81% (in the organic) and 77% (in the conventional) of variation in the MTR could be explain by such factors embodied in government programs, private/public participation in input-output markets, infrastructural, soil and climatic variables. In both systems, access to good road condition, connection to the electric grid, access to more fruit buyers, more extension contacts and lower input cost through government subsidies significantly reduces the technology gaps between the group frontiers and the industrial frontier. Availability of more input stores have a positive influence on MTR, however, this effect is only significant under the conventional system. This is not surprising since most inputs stores in Ghana sell only conventional chemical inputs (i.e. pesticides, herbicides etc.). Seasonal floods and soil erosion negatively affect the MTR in both production systems. This is not very surprising since the impact of such factors on farm output and income could be devastating. This in turn reduces the farmers’ ability and willingness to invest or acquire certain technologies. Intervention programs aim at improving those variables with positive effects on the MTR will favourably improve the production environment and therefore enhances farmers’ ability to improve output towards the industrial frontier. All the same, the magnitudes of economic gain as revealed by the estimates in Table 6 are so small to sustain long term growth development in the sector. This again confirms the need for introduction of better production technologies in the Ghanaian pineapple sector. To facilitate a sustainable productivity growth in the industry, efforts by all stakeholders and researchers should be well coordinated to meet farmers’ requirement in the different agro-ecological zones in which pineapple production takes place.

5. Conclusion with Recommendations for Future Policies

The pineapple production sector plays a very important role in Ghana’s economy. The sector’s employment generation capabilities were widely cited (Jaeger, 2008) (Wolter, 2008) as one of the most effective mechanism of reducing rural-urban poverty. However, the unexpected market shock (i.e. beginning in the 2005 production year) nearly collapsed the industry as farmers were left with tons of outputs with no buyers and no income to finance outstanding production loans. Seven years after the crisis, we studied how farmers in the Ghanaian pineapple sector have responded to international market demand as well as assessing the accompanying effect on farmer’s production efficiency. We analysed the proportion of farmers cultivating the MD2 variety and identify the factors influencing adoption of MD2 variety using a logistic regression function. The result shows that out of 404 pineapple farmers sampled across the three regions, only 74 (18%) farmers are cultivating the MD2 variety. The majority of the farmers in our data are still cultivating the local varieties. For farmers producing organic pineapples, only 3 (0.02%) are cultivating the MD2 variety as organic produce. 71 (31%) farmers under conventional system of production are cultivating the MD2 variety using convention production input chemicals. These summary statistics shows that, the rate of adoption in response to market change is very slow as shown by majority of farmers in our data. The analysis of factors influencing the adoption of MD2 reveals that farmers capable of installing irrigation facilities to irrigate their farms, having access to regular and reliable pineapple market as well as farms located in the eastern regions are more likely to adopt the MD2 variety. The observed low adoption level is not very surprising since most farmers were rendered bankrupt by the crisis and have not been able to recovery very well financially. Hence, only farmers with extra source of income who could afford the high adjustment and production cost of the MD2 variety did adopt it. This highlights the need for flexible agricultural credit programs which enable farmers' access modern production techniques.

To assess current productivity level of organic and conventional pineapple producers and factors driving production performance in the sector, a metafrontier analytical technique was employed. Results of our analysis reveal that the majority of farmers in both systems were operating quiet efficiently (see distribution in Figure 6) given the current technology available to their respective frontiers and the industrial as a whole (i.e. average TE_i scores of 97%, 95% , and 95% MTR scores) yet the sector is unable to meet market volume demand. This implies that continuous use of current production techniques does not give much scope for large output expansion or productivity gain given the current state of technology available to the industry. Therefore to substantially enhance productivity level in the industry, government policies should aim at agricultural-research (R&D) development framework which not only encourages but expedite technological progress through introduction of better suited modern production techniques to farmers in the sector. A productivity study by Brümmer et al., (2002) reveal an annual productivity growth of about 6% by German milk producing firms mainly due to high rate of technological progress in the sector as compared to Poland which experience 5% productivity decline due to technological regress. This observation reflects the importance of technological progress in any industry to sustain output growth.

As Ghana develops, more people are likely to move from the agricultural production sector to other sectors of the economy just as is the case in many advance economies where relatively few people are directly involved in agriculture. Current high rate of rural urban migration as well as urban expansion into rural area is already having a great toll in the number of people involved in agriculture, hence the need for introduction of new labour saving production technologies. The pineapple sector is likely to face new challenges caused by market transformations (i.e. changes in fruit consumption patterns, the changing demands of private retail companies and newer, stricter quality and health standards imposed by importing countries could be the root cause driving some of this change) on a global scale, hence, the need for better production technologies and information dissemination mechanisms to enhance the capabilities of farmers in the sector to adjust accordingly to such future market changes. Policy makers should prioritize investment in improving transport and logistics services sector as well as other supporting infrastructures to ensure efficient delivery of high quality pineapple products by the sector. Improving conditions of rural-urban road networks will support quick and effective transportation of fruits to ports, harbours and urban buying centres, thereby reducing the amount of fruits which are rejected due to deterioration resulting from long transportation delays. Similarly, the creation of flexible agricultural credit schemes will enable easy acquisition of better production technologies as well as facilitating the transfer of such technologies to farmers in resource starve regions of the industry.

To sum up, findings from this study support the notion that improvement in the production environment as well as production efficiency will enhance the capacity of farmers in the sector to meet quality, volume and supply standards of international markets. The study, therefore, recommends; agricultural research and technology development (R & D) programs should aim at incorporating the needs of farmers in the various production regions. This will facilitate the adoption of such modern production technologies when they are introduced.

Even though, the various analytical techniques employed in this study enabled us to shed light on some of the problems facing the Ghanaian pineapple producing sector and recommend some remedies; it should be stressed that, these recommendations are not in any way a panacea to all the problems facing the sector. Further studies exploring the intricate interdependence relationships of important stakeholders, especially donor agencies and NGOs actively working in the industry in various capacities and how they impact the performance of the fruit sector are recommended. This will aid policy makers design holistic productivity improvement strategies to strengthen the industry’s competitiveness on a sustainable basis.

Reference

Achuonjei, P., Pilkes, J., Waardenburg, R., & Hoogendoorn, B. (2003). *Ghana Sustainable horticultural export chain*.

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*, 21–37.

Battese, G. E., & Rao, D. S. P. (2002). Technology Gap, Efficiency, and a Stochastic Metafrontier Function. *International Journal of Business and Economics*, *1*, 87–93. Retrieved from http://ideas.repec.org/a/ijb/journl/v1y2002i2p87-93.html

Battese, G. E., Rao., D. S. P., & O'Donnell, C. J. (2004). A Metafrontier Production Function for Estimation of Technical Efficiencies and Technology Gaps for Firms Operating Under Different Technologies. *Journal of Productivity Analysis*, *21*(2002), 91–103.

Battese G.E and T.J. Coelli. (1988). Prediction of Firm-Level Technical Efficiencies with A Generalized Frontier Production Function and Panel Data. *Journal of Econometrics*, *38*(October 1986), 387–399.

Coelli, T. (1995). Estimators and Hypothesis Tests for a Stochastic Frontier Function - a Monte-Carlo Analysis. *Journal of Productivity Analysis*, *6*, 247–268. doi:Doi 10.1007/Bf01076978

Coelli, T., Rao, D. S. . P., O'Donnel, J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. *Biometrics* (Vol. 41, p. 349). doi:10.2307/2531310

DG Agric, R. D. (2012). Monitoring Agri-trade Policy The EU and major world players in Fruit and Vegetable Trade. DG Agricuture and Rural Development: Agriculture Trade Analysis Unit., pp. 1–14.

Doornik, J. A. (2008). Econometric Computing Using the Ox Matrix Language Hilary Term 2008 , week 0 , Thu / Fri 1pm.

Eurostat. (2013). Eurostat international trade data. EU Fruit Import from Ghana (2000 - 2013). (Eurostat is the Offical Statistical Office of the European Union). Retrieved from http://ec.europa.eu/eurostat

Gatune, J., Chapman-Kodam, M., Korboe, K., Mulangu, F., & Rakotoarisoe, M. A. (2013). FAO COMMODITY AND TRADE POLICY RESEARCH WORKING PAPER NO. 41 "Analysis of Trade Impacts on the Fresh Pineapple Sector in Ghana," (41).

Hayami, Y. (1969). Sources of agricultural productivity gap among selected countries. *American Journal of Agricultural Economics*, *51*, 564 – 575.

Hayami, Y., & Ruttan, V. W. (1970). KOREAN RICE, TAIWAN RICE, AND JAPANESE AGRICULTURAL STAGNATION: AN ECONOMIC CONSEQUENCE OF COLONIALISM. *Quarterly Journal of Economics*, *84*, 562–589. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=5048340&site=ehost-live&scope=site

Hayami, Y., Ruttan, V. W. (1971). Agricultural development: an international perspective. *John Hopkins University Press, Baltimore*.

Jaeger, P. (2008). Ghana Export Horticulture Cluster Strategic Profile Study Part I - Scoping review. Prepared for World Bank Sustainable Development Network (WB-SDN), The Republic of Ghana Ministry of Food and Agriculture and European Union All ACP Agricultural Commodities.

Jondrow, J., Knox, C. A., Materov, I. S., Schmidt, P., & Lovell, K. C. A. (1982). ON THE ESTIMATION OF TECHNICAL INEFFICIENCY IN THE STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL. *Journal of Econometrics*, *19*, 233–238. doi:10.1016/0304-4076(82)90004-5

Kleemann, L. (2011). *Organic Pineapple Farming in Ghana - A Good Choice for Smallholders ?*.

Kleemann, L. (2014). *Knowing Where Organic Markets Move Next – An Analysis of Developing Countries in the Pineapple Market*. *Journal of Economic Literature*.

Kodde. D.A. and Palm F.C. (1986). Wald Criterial for Jointly Testing Equality and Inequality Restrictions. *Econometrica*, *54*(5), 1243 – 1248.

Lakner, S., Muñoz, T. B., Aedo, E. R., & Brümmer, B. (2012). *Technical Efficiency in the Chilean Agribusiness Sector – a Stochastic Meta-Frontier Approach*. *Productivity and Its Impacts on Global Trade* (pp. 1–20). Retrieved from http://iatrc.software.umn.edu/activities/symposia/upcomingsymposium.html

Manasseh, D. (2007). The role of certification in fair trade: FAIRTRADE FOUNDATION PRODUCER PROFILE.

Mensah, A.O., Oehmke, J. F. (2012). Trade and Investment Program for a Competitive Export Economy in ghana, (January), 1–4.

O'Donnell, C. J., Rao, D. S. P., & Battese, G. E. (2008). Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics*, *34*, 231–255. doi:10.1007/s00181-007-0119-4

Pay, E. (2009). THE MARKET FOR ORGANIC AND FAIR-TRADE MANGOES AND PINEAPPLES. Study prepared in the framework of FAO project GCP / RAF / 404 / GER. " Increasing incomes and food security of small farmers in West and Central Africa through exports of organic and fair-trad, (September).

Rao, E. J. O. E., Brümmer, B., Qaim, M., & Brummer, B. (2012). Farmer Participation in Supermarket Channels , Production Technology , and Efficiency : The Case of Vegetables in Kenya. *American Journal of ...*, *94*(February), 891–912. doi:10.1093/ajae/aas024

USAID/TIPCEE. (2005). Ghana's High Value Horticulture.

Wang, H. J., & Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. *Journal of Productivity Analysis*, *18*(2), 129–144.

Wardy, W., Saalia, F. K., Steiner-asiedu, M., & Budu, A. S. (2009). A comparison of some physical , chemical and sensory attributes of three pineapple (A nanas comosus) varieties grown in Ghana. *African Journal of Food Science*, *3*(1), 22–25.

Wolter, D. (2008). Ghana Agriculture is Becoming a Business. Business for Development. OECD Development Centre.

List of Tables

Table 1: Hypothesis Testing for Stochastic Production Frontier Model

Null hypothesis (Ho)	$\chi 2$ Stat	Deg. Of freedom	$\chi 2$ Critical	P-value
Homogenous technology across all production systems	91.35	44	60.48	0.005
Cobb-Douglas functional form is appropriate: $\beta_{ij} = 0$				
Organic production system	72.87	21	32.67	0.001
Conventional production system	41.83	21	32.67	0.050
Pooled model	94.80	21	32.67	0.001
No technical Inefficiency effects:$\delta = 0 = \delta 1 = ... = \delta 9 = 0$				
Organic production system model	81.40	10	15.38	0.000
Conventional production system model	51.62	10	15.38	0.000
Pooled model	101.98	10	15.38	0.000

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

Table 2: Factors Influencing Adoption of MD2 Variety (Logistic Model)

AdoptMD2	Log odds	Std. Err.	Odds Ratio	Std. Err.	Marginal effects (dy/dx)	Std. Err.
Off-farm Income	0.001	0.000	1.001	0.000	0.000	0.000
Irrigation	1.041**	0.489	2.832**	1.384	0.118**	0.054
Farming System	3.447***	0.642	31.412***	20.159	0.392***	0.067
Fruit traders	0.114*	0.063	1.121*	0.070	0.013*	0.007
extension	-1.050**	0.503	0.350**	0.176	-0.120**	0.056
manure	0.714	0.560	2.043	1.145	0.081	0.063
Input subsidy	0.294	0.368	1.342	0.493	0.033	0.042
Eastern	1.250*	0.658	3.491*	2.297	0.142*	0.074
Central	0.663	0.686	1.940	1.330	0.0753	0.078
Constant	-7.140***	1.107				
Log likelihood	-140.8107					
Pseudo R2	0.2680					
Number of obs.	404					

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

Table 3: Estimates of the Translog Stochastic Production Frontier Models

Variable	Organic production system		Conventional production system	
Name	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	-0.094***	0.021	-0.068*	0.044
Land	0.207***	0.033	0.127***	0.037
Labour	0.069***	0.025	0.166***	0.037
Experience	0.019	0.016	0.068***	0.021
Maintenance Cost	0.010	0.025	0.145***	0.031
Plantation Age	-0.074***	0.021	-0.037*	0.020
Density	0.134***	0.034	0.095**	0.038
Manure	-0.165***	0.017	-0.117***	0.025
Irrigation	0.202***	0.016	0.135***	0.024
Contract	0.031**	0.016	0.037*	0.023
Eastern [#]	0.072***	0.020	0.075***	0.028
Central [#]	0.012	0.016	0.013	0.026
RTS	0.365		0.564	
Log-likelihood	209.076		217.452	
Gamma	0.829		0.509	
Number of Obs.	175		229	

Source: Study findings based on 2012 field survey data.,**,*** Significant at the 10%, 5%, and 1% level, respectively.*
[#] the reference region is Volta. Note: squares and cross products have been omitted in this table (please see table 11 of appendix for full table). Coefficients and standard errors have been rounded off to three decimal places.

Table 4: Parameter Estimates of the Inefficiency Models

Variable	Organic production system		Conventional production system	
Name	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	-2.503***	0.571	-7.582***	2.258
Land	-0.067	0.512	-3.432**	1.584
Maintenance Cost	-1.869***	0.548	-2.166*	1.318
Density	-0.933*	0.475	-1.891*	1.210
Age of household head	0.194	0.134	1.604	1.834
Household size	-0.610*	0.364	-0.282	0.482
Agrochemical Cost	1.489**	0.552	-0.582	0.453
Distance to market	0.649**	0.272	0.967**	0.425
Education	0.210*	0.133	-0.229*	0.149
Gender	0.426	0.484	-0.772	0.721
Log-likelihood	209.076247		217.451824	
Gamma	0.8293		0.5085	
Number of Observation	175		229	

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

Table 5: Summary statistics of Technical Efficiency (TE), Meta-Technology Ratio (MTR), and Meta-Frontier Technical Efficiency (MFTE)

	Organic system			Conventional system		
	Group TE	MTR	Metafrontier TE	Group TE	MTR	Metafrontier TE
Mean	0.95***	0.95***	0.89***	0.97***	0.95***	0.93***
Minimum	0.50	0.81	0.48	0.57	0.76	0.54
Maximum	0.99	1.00	0.99	1.00	1.00	0.99
Std. dev.	0.08	0.04	0.08	0.06	0.04	0.08
Numb Obs.	175			229		

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

Table 6: Determinants of the Meta-Technology Ratio

Variable	Organic system		Conventional system	
Name	Coefficient	Std. Err.	Coefficient	Std. Err
Infrastructure				
Road condition	0.007**	0.003	0.008*	0.005
Electricity	0.025***	0.005	0.022***	0.006
Government programs				
Extension	0.017***	0.005	0.006*	0.003
Input subsidy	0.009*	0.005	0.010*	0.006
Private and public participation				
Fruit traders	0.004***	0.001	0.003***	0.001
Input stores	0.001	0.001	0.002***	0.001
Soil and Weather				
Erosion	-0.0161**	0.005	-0.011**	0.005
Floods	-0.001	0.005	-0.010**	0.005
Bushfires	-0.006	0.004	-0.004	0.003
Constant	0.875***	0.010	0.891***	0.009
Number of observations	175		229	
R squared	0.81		0.77	

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

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

Table 7: Variable Name (Units) and Definition

Variable name (unit)	Definition/meaning of variables
Continuous variables	
Output (kg)	Total farm output
Labour (hours)	Total number farm labourers working on plantation (family + hired)
Land (ha)	Total land area under pineapple cultivation only
Density	Number of plants per hectare
Education (years)	Years of schooling of decision maker or household head
Plant Age (years)	Age of the plantation
Experience (years)	Number of years as pineapple farmer
Age of household head (year)	Age of farm operator or decision maker
Household size Household size	Number of people leaving under the same roof
Distance to market (km)	Distance from farm household to market
Agrochemical cost (new Gh cedis)	Total cost of Agrochemicals
Maintenance Cost (new Gh cedis)	Total sum of expenses for mulching and weeding
Fruit traders	Number of fruit traders farmer regularly sells fruit to
Input stores	Number of input stores/dealers in the area farmer regularly patronize
Dummy variables	
Gender	1= male; 0 = Otherwise
Extension	1= Receives extension advice; 0 = Otherwise
Irrigation	1= irrigates; 0 = Otherwise
Manure	1= Applies manure; 0 = Otherwise
Input subsidy	1 = Inputs are subsidized by government or NGOs; 0 = Otherwise
Road condition	1 = Access to good road condition; 0 = Otherwise
Electricity	1 = Connected to the electric grid, 0 = Otherwise
Erosion	1 = Affected by erosion; 0 = Otherwise
Floods	1 = Affected by seasonal floods; 0 = Otherwise
Bushfires	1 = Affected by seasonal Bushfires; 0 = Otherwise
Contract	1 = Under contract obligation to sell harvest to processing/exporting company; 0 = Otherwise

Table 8: Summary Statistics (continuous variables)

Variables	Organic production system (n = 175)			Conventional production system(n = 229)		
	Mean	Min	Max	Mean	Min	Max
Farm output	56365.14***	18000	108000	64709.17***	18000	156000
Land	5.51***	2.00	15.00	6.42***	3.00	15.00
Labour	5.72**	3.00	13.00	6.32**	3.00	15.00
Experience	8.86**	2.00	22.00	10.39**	2.00	23.00
Maintenance cost	126.18**	50.00	366.00	142.83**	50.00	395.00
Plant age (years)	4.99	1.10	10.00	4.66	1.00	10.00
Density (plants/ha)	35471.66	11000	64000	35612.23	10000	65000
Farmer Age	48.28	23.00	75.00	47.70	23.00	75.00
Household size	5.26	1.00	12.00	5.28	1.00	11.00
Agrochemical cost	72.30***	40.00	120.00	296.88***	100	928.00
Dist. to market	6.02	1.00	15.00	6.05	1.50	20.00
Fruit traders	10.70*	5.00	16.00	10.31*	5.00	16.00
Input stores	5.81***	1.00	14.00	6.84***	1.00	15.00

Source: study findings based on 2012 field survey data.
*,**, *** Mean differences between Organic and Conventional system of production are significant at the 10%, 5% and 1% level, respectively. *Note: Coefficients and standard errors have been rounded off to two decimal places.*

Table 9: Summary Statistics (dummy variables)

Variable	Organic production system (n = 175)		Conventional production system (n = 229)	
	Proportion	Std. Error.	Proportion	Std. Error
Gender				
0 |	0.03	0.014	0.03	0.011
1 |	0.97	0.014	0.97	0.011
Extension				
0 |	0.38	0.037	0.40	0.032
1 |	0.62	0.037	0.60	0.032
Irrigation				
0 |	0.66	0.036	0.57	0.033
1 |	0.34	0.036	0.43	0.033
Manure				
0 |	0.33	0.036	0.45	0.033
1 |	0.67	0.036	0.55	0.033
Contract				
0 |	0.70	0.035	0.31	0.031
1 |	0.30	0.035	0.69	0.031
Road condition				
0 |	0.49	0.038	0.34	0.031
1 |	0.51	0.038	0.66	0.031
Electricity				
0 |	0.37	0.037	0.31	0.031
1 |	0.63	0.037	0.69	0.031
Input subsidy				
0 |	0.41	0.037	0.38	0.032
1 |	0.59	0.037	0.62	0.032
Erosion				
0 |	0.50	0.038	0.68	0.031
1 |	0.50	0.038	0.32	0.031
Floods				
0 |	0.53	0.038	0.53	0.033
1 |	0.47	0.038	0.47	0.033
Bushfires				
0 |	0.71	0.034	0.71	0.030
1 |	0.29	0.034	0.29	0.030

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

Table 10: Estimates of Translog Stochastic Production Frontier Models

Variable	Pooled model		Organic model		Conventional model	
Name	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Constant	-0.096***	0.022	-0.094***	0.021	-0.068*	0.044
*log*land	0.177***	0.027	0.207***	0.033	0.127***	0.037
*log*labour	0.118***	0.021	0.069***	0.025	0.166***	0.037
*log*expir	0.053***	0.014	0.019	0.016	0.068***	0.021
log MaintCost	0.080***	0.020	0.010	0.025	0.145***	0.031
log PltAge	-0.048***	0.016	-0.074***	0.021	-0.037*	0.020
*log*density	0.115***	0.025	0.134***	0.034	0.095**	0.038
Manure	-0.125***	0.016	-0.165***	0.017	-0.117***	0.025
Irrigation	0.163***	0.015	0.202***	0.016	0.135***	0.024
Contract	0.045***	0.013	0.031**	0.016	0.037*	0.023
Eastern [a]	0.082***	0.017	0.072***	0.020	0.075***	0.028
Central [a]	0.023*	0.015	0.012	0.016	0.013	0.026
.5**log*land^2	0.153	0.119	-0.018	0.136	0.342*	0.182
.5**log*labour^2	-0.153*	0.101	-0.106	0.123	-0.055	0.211
.5**log*expir^2	0.013	0.041	-0.032	0.052	-0.060	0.068
.5**log*MiantCost^2	-0.032	0.049	-0.136**	0.058	0.185*	0.103
.5**log*PltAge^2	-0.067**	0.035	-0.143***	0.045	-0.062	0.048
.5**log*density^2	0.155**	0.078	0.163*	0.108	0.122	0.101
*log*land**log*labour	0.151**	0.073	0.206**	0.081	0.143	0.119
*log*land**log*expir	0.035	0.043	0.006	0.042	0.037	0.089
*log*land**log*MiantCost	0.096*	0.059	0.240***	0.068	-0.067	0.116
*log*land**log*PltAge	0.078**	0.039	0.121***	0.046	0.012	0.051
*log*land**log*density	-0.057	0.081	0.003	0.108	-0.186	0.142
*log*labour**log*expir	0.044	0.043	0.107**	0.047	-0.016	0.075
*log*labour**log*MiantCost	-0.030	0.045	-0.089	0.059	-0.117	0.099
*log*labour**log*PltAge	-0.024	0.029	-0.009	0.034	-0.058	0.047
*log*labour**log*density	-0.065	0.066	0.020	0.085	-0.007	0.114
*log*expir**log*MiantCost	0.010	0.027	-0.026	0.031	0.035	0.047
*log*expir**log*PltAge	0.005	0.018	-0.008	0.017	0.035	0.034
*log*expir**log*density	-0.001	0.038	-0.031	0.053	0.019	0.057
*log*MiantCost**log*PltAge	-0.012	0.025	-0.030	0.031	0.018	0.043
*log*MiantCost**log*density	-0.024	0.034	-0.010	0.056	-0.013	0.058
*log*PltAge**log*density	0.081**	0.029	0.158***	0.042	0.055	0.047
Log-likelihood	380.853613		209.076247		217.451824	
Gamma	0.6365		0.8293		0.5085	
Number of Observation	404		175		229	

Source: empirical results based on 2012 field survey data.

*,**,*** Significant at the 10%, 5%, and 1% level, respectively. [a] The reference region is Volta.

Table 11: Parameter Estimates of the Metafrontier Model

Variable Name	LP (Sum of absolute deviation) Coefficient	SE	QP (Sum of square deviation) Coefficient	SE
Constant	-0.051*	0.027	-0.044*	0.024
*log*land	0.144***	0.036	0.145***	0.032
*log*labour	0.111***	0.030	0.115***	0.028
*log*expir	0.038*	0.021	0.041**	0.021
*log*MiantCost	0.104***	0.028	0.100***	0.028
*log*PltAge	-0.068***	0.023	-0.066***	0.023
*log*density	0.128***	0.034	0.123***	0.033
Manure	-0.150***	0.022	-0.149***	0.021
Irrigation	0.161***	0.020	0.160***	0.019
Contract	0.041**	0.017	0.042**	0.016
Eastern [a]	0.067***	0.019	0.065***	0.019
Central [a]	0.010	0.018	0.004	0.018
.5**log*land^2	0.258*	0.153	0.237*	0.143
.5**log*labour^2	0.058	0.129	0.031	0.122
.5**log*expir^2	0.017	0.062	0.009	0.060
.5**log*MiantCost^2	0.103	0.100	0.087	0.089
.5**log*PltAge^2	-0.079	0.049	-0.084	0.049
.5**log*density^2	0.240**	0.109	0.219**	0.104
*log*land**log*labour	0.187*	0.105	0.186*	0.096
*log*land**log*expir	0.011	0.067	0.018	0.061
*log*land**log*MiantCost	-0.001	0.096	-0.001	0.088
*log*land**log*PltAge	0.054	0.052	0.100	0.049
*log*land**log*density	-0.062	0.104	-0.049	0.100
*log*labour**log*expir	0.012	0.060	0.008	0.058
*log*labour**log*MiantCost	-0.062	0.076	-0.042	0.066
*log*labour**log*PltAge	-0.003	0.041	-0.001	0.039
*log*labour**log*density	-0.069	0.087	-0.069	0.085
*log*expir**log*MiantCost	-0.003	0.048	0.002	0.046
*log*expir**log*PltAge	-0.007	0.031	-0.001	0.030
*log*expir**log*density	-0.004	0.059	0.004	0.058
*log*MiantCost**log*PltAge	-0.003	0.040	-0.007	0.037
*log*MiantCost**log*density	0.026	0.066	0.013	0.062
*log*PltAge**log*density	0.159***	0.046	0.144***	0.044
Number of Observation	404		404	

*,**, ***, Significant at the 10%, 5%, and 1% level, respectively. *Source: empirical results based on 2012 field survey data. Note: Coefficients and standard errors have been rounded off to three decimal places.*

Table 12: Detail Summary Statistics for Technical Efficiency with respect to Group Frontier

	Organic production system			Conventional production system	
	Percentiles	Smallest		Percentiles	Smallest
1%	.5639133	.5016161	1%	.6566186	.5727474
5%	.7571518	.5639133	5%	.8767372	.5817507
10%	.8408974	.6709166	10%	.9073716	.6566186
25%	.9502026	.6765625	25%	.9843899	.7130628
50%	.9833152		50%	.9995527	
		Largest			Largest
75%	.9950744	.9993104	75%	.9999565	.9999996
90%	.9974845	.9993756	90%	.999999	.9999998
95%	.9981091	.9993977	95%	.9999994	.9999998
99%	.9993977	.9995257	99%	.9999998	1
Mean		.9496754	Mean		.9736526
Std. Dev.		.0822163	Std. Dev.		.0632879
Variance		.0067595	Variance		.0040054
Skewness		-2.70291	Skewness		-3.791113
Kurtosis		11.29216	Kurtosis		19.84528
Observation		175	Observation		229

Table 13: Detail Summary Statistics for Meta-Technology-Ratio

	Organic production system			Conventional production system	
	Percentiles	Smallest		Percentiles	Smallest
1%	.8259851	.8143622	1%	.8353061	.7569078
5%	.8568843	.8259851	5%	.8730127	.808399
10%	.8833504	.8346823	10%	.9015362	.8353061
25%	.9265693	.8372211	25%	.9365745	.8378457
50%	.9576347		50%	.9613656	
		Largest			Largest
75%	.9807306	1	75%	.9807966	1
90%	.9954341	1	90%	.99614	1
95%	1	1	95%	1	1
99%	1	1	99%	1	1
Mean		.9479811	Mean		.9529221
Std. Dev.		.0428541	Std. Dev.		.039785
Variance		.0018365	Variance		.0015828
Skewness		-1.006757	Skewness		-1.45592
Kurtosis		3.383006	Kurtosis		5.966618
Observation		175	Observation		229

Table 14: Detail Summary Statistics for Meta-Frontier-Technical Efficiency

	Organic production system			Conventional production system	
	Percentiles	Smallest		Percentiles	Smallest
1%	.52284	.480352	1%	.5693756	.5359336
5%	.7533561	.52284	5%	.7521945	.5448529
10%	.8153618	.6618084	10%	.8215644	.5693756
25%	.8697171	.6695411	25%	.906392	.6834718
50%	.9170924		50%	.9572059	
		Largest			Largest
75%	.9532007	.9900759	75%	.9790201	.9999821
90%	.9745016	.9902809	90%	.9918161	.9999889
95%	.9854733	.9903311	95%	.9996747	.99999
99%	.9903311	.9948873	99%	.9999889	.9999992
Mean		.8993723	Mean		.9286064
Std. Dev.		.0796053	Std. Dev.		.0799233
Variance		.006337	Variance		.0063877
Skewness		-2.07362	Skewness		-2.225547
Kurtosis		9.560764	Kurtosis		9.115834
Observation		175	Observation		229

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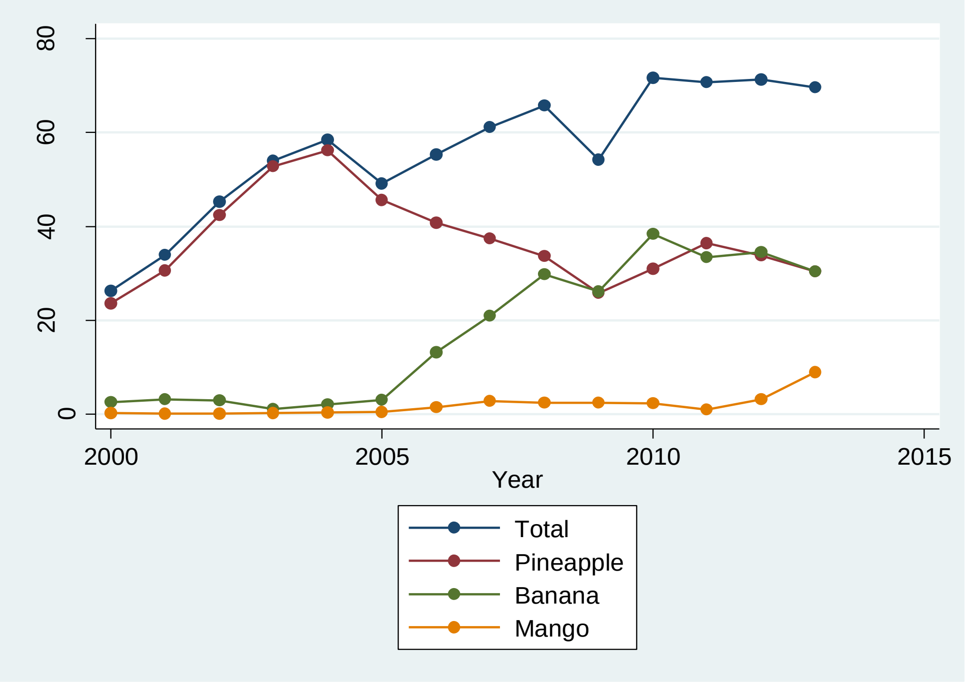
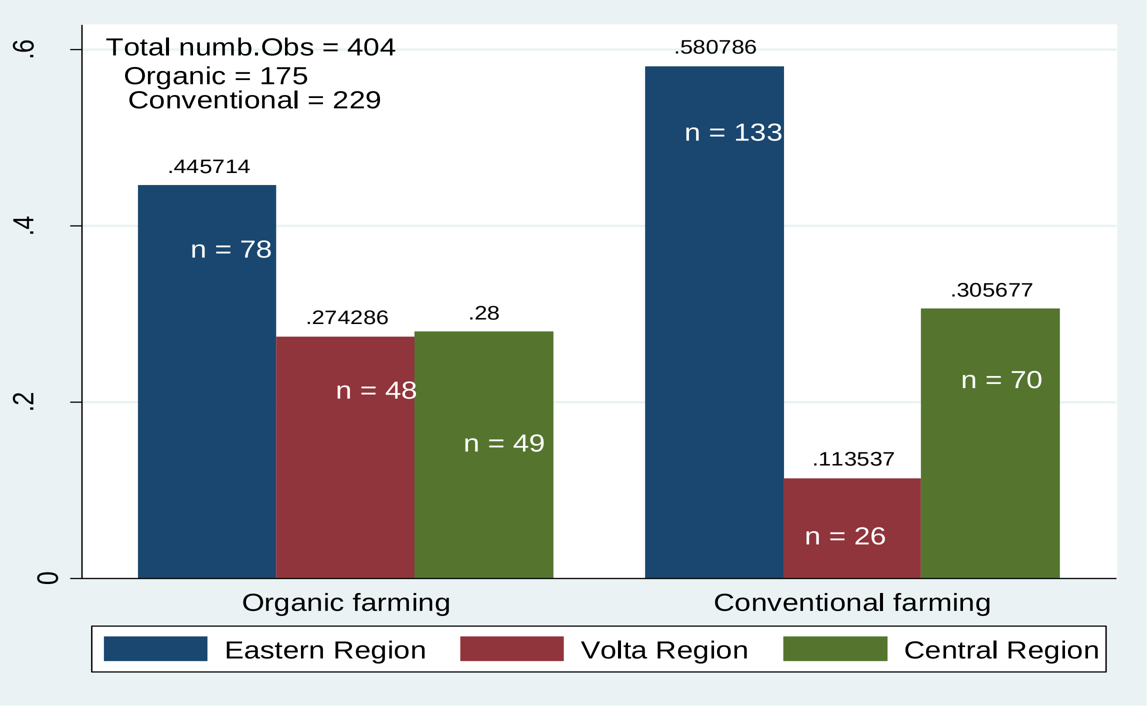
Figure 1: EU Import of Fruits from Ghana (Value in mil. of Euro, 2000 – 2013)



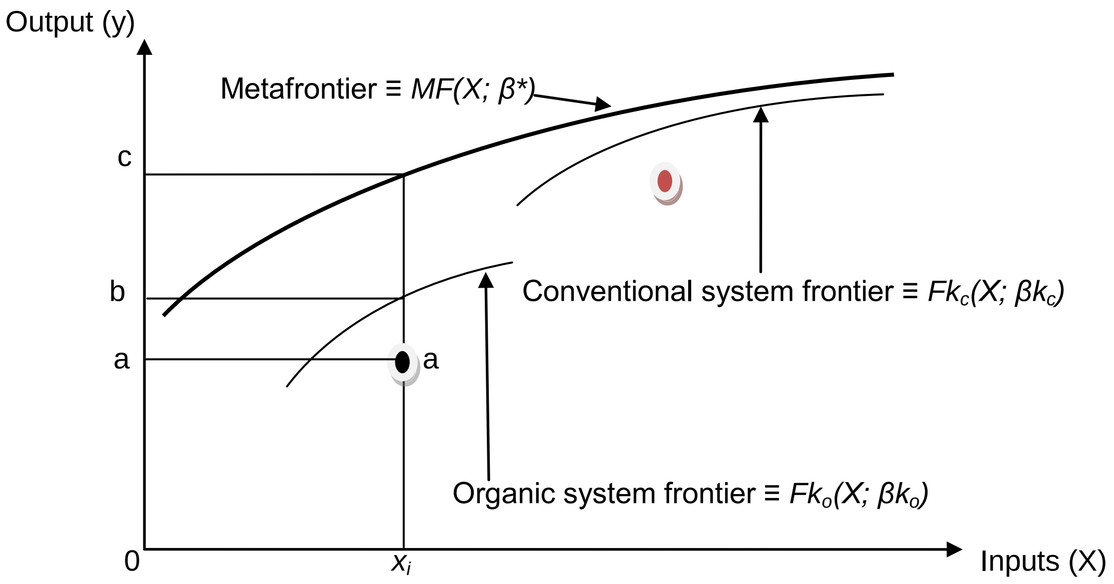
Data source: Eurostat international trade data (from 2000 – 2013)

Figure 2: Number of Farmers Sampled in Each Region (organic and conventional systems)



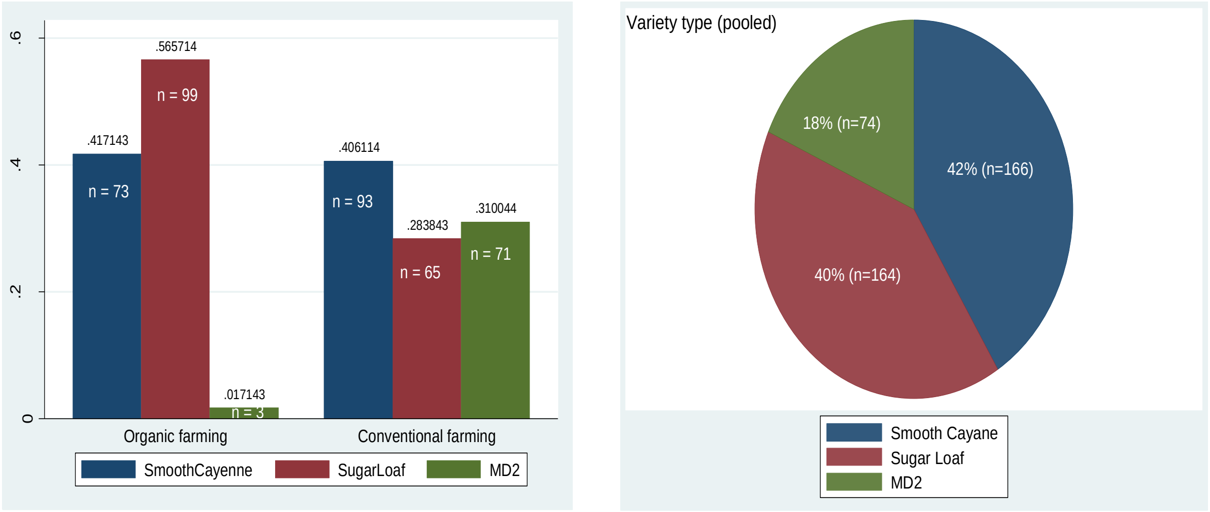
Source: study findings based on 2012 survey data

Figure 3: Metafrontier Function Model



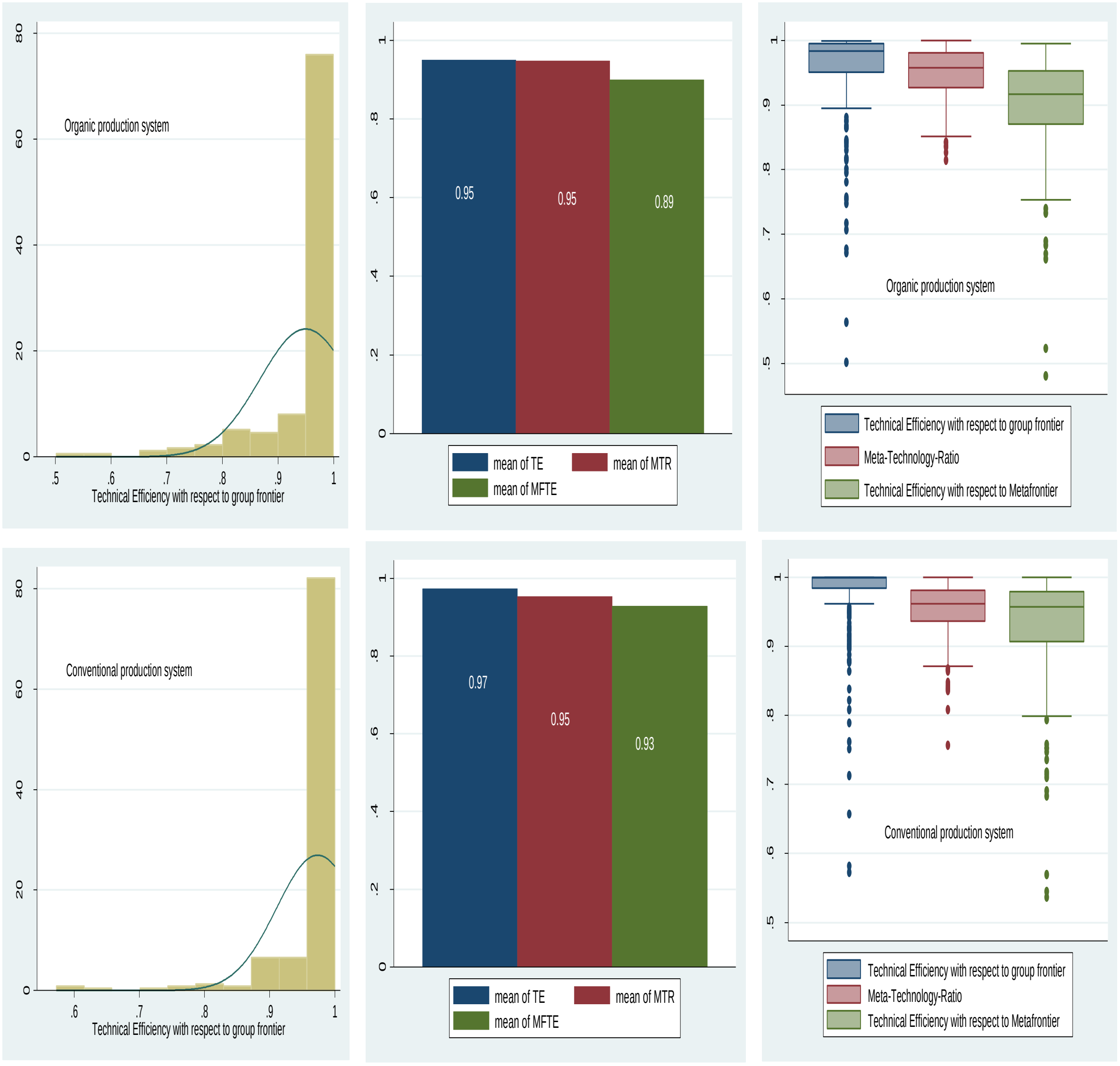
Source: author’s owned conceptual depiction

Figure 4: Bar and Pie Charts of Variety Type under Cultivation



Source: study findings based on 2012 survey data

Figure 6: Histogram, Bar Chart and Box plot of TE, MTR and MFTF for both systems



Source: study findings based on 2012 survey data