

A Service of



Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Kodua, Theophilus Tweneboah; Onumah, Edward E.; Mensah-Bonsu, Akwasi

Article

Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis

Cogent Economics & Finance

Provided in Cooperation with:

Taylor & Francis Group

Suggested Citation: Kodua, Theophilus Tweneboah; Onumah, Edward E.; Mensah-Bonsu, Akwasi (2022) : Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 10, Iss. 1, pp. 1-17, https://doi.org/10.1080/23322039.2021.2022858

This Version is available at: https://hdl.handle.net/10419/303560

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.



https://creativecommons.org/licenses/by/4.0/

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.









Cogent Economics & Finance

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/oaef20

Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis

Theophilus Tweneboah Kodua, Edward Ebo Onumah & Akwasi Mensah-Bonsu

To cite this article: Theophilus Tweneboah Kodua, Edward Ebo Onumah & Akwasi Mensah-Bonsu (2022) Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis, Cogent Economics & Finance, 10:1, 2022858, DOI: <u>10.1080/23322039.2021.2022858</u>

To link to this article: https://doi.org/10.1080/23322039.2021.2022858

9

© 2022 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

đ	1	1	
С			
Е			
E			
_			_

Published online: 07 Jan 2022.

Submit your article to this journal \square



View related articles

V

View Crossmark data 🕑



Citing articles: 3 View citing articles 🗹



Received 17 August 2020 Accepted 18 December 2021

*Corresponding author: Theophilus Tweneboah Kodua Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Legon, Accra, Ghana E-mail theophiluskodua@gmail.com

Reviewing editor: GOODNESS Aye, Agricultural Economics, University of Agriculture, makurdi Benue State, NIGERIA

Additional information is available at the end of the article

GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis

Theophilus Tweneboah Kodua¹*, Edward Ebo Onumah¹ and Akwasi Mensah-Bonsu¹

Abstract: The meta-frontier model technique is employed to compare the technical efficiency levels of improved and local maize seed variety farms in Ghana using a cross-sectional data from 214 farmers. The study shows that inefficiencies in maize production relate to exogenous variables considered even though some of the variables are not statistically significant. All input variables considered contribute positively to maize output in both improved and local seed varieties as well as in the pooled data. Maize farms generally exhibit increasing returns to scale (IRS) in the study area. The mean technical efficiency relative to the meta-frontier is estimated to be 72%, 44% and 50% for the improved, local maize seed variety farms and the pooled data respectively. Based on the estimated TGR of 90% and 72% for the improved and local seed variety maize farms, respectively, the study

ABOUT THE AUTHOR

Theophilus Tweneboah Kodua is a Doctoral Student at the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon. His research interests include rural and agricultural development, production, resource and environmental economics, agricultural trade, and market access. He has experience working on resource recovery and reuse project teams and developing business models for faecal based fertilizers. He has published in Cogent Food & Agriculture; Cogent Environmental Science and Environmental Systems Research and contributed to technical reports.

Edward Ebo Onumah is a Senior lecturer at the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon. He has good understanding of Production Economics, Management of Production Risk associated with Agriculture, Business Economics, Microfinance Investigation, Project appraisal, and Climate Change Analysis.

Akwasi Mensah-Bonsu is an Associate Professor in the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon. His areas of research include development economics and policy analysis for agriculture, modelling of the agricultural sector resources use and production efficiency analysis, benefit cost analysis, project managing.

PUBLIC INTEREST STATEMENT

Efficient production systems of world economies particularly in the agricultural sector is important for its overall development - providing the food/ feed needs of the population; provision of industrial raw materials; and employment. Crop production - particularly maize production in Ghana is very important to the nation's food security and the attainment of SDG 2 (Zero Hunger). However, the sector is confronted with myriad challenges including wide gap between achievable and actual yields partly linked to low-quality inputs. An assessment of the level of efficiency and technology gaps of maize seed varieties have farreaching policy implications for input development and uptake for enhanced production and development of the sector.

🔆 cogent

economics & finance





concludes that maize farmers who cultivated improved maize seed varieties are more technically efficient compared to their counterparts who do otherwise. It is recommended that stakeholder efforts should focus on labour source, education, extension contacts, ready market availability and credit that contribute positively to farmers' efficiency to further increase maize output in Ghana. Furthermore, farmers should be encouraged and educated more on the benefits of newly developed varieties of maize so that they will be convinced enough to adopt in order to increase their output in the near future.

Subjects: Agricultural Development; Agricultural Economics; Agriculture and Food;

Keywords: technology gap ratio; returns to scale; stochastic frontier; maize production; Ghana

1. Introduction

The contribution of Ghana's agriculture sector to its gross domestic product (GDP) over the years has experiences continuous decline. For instance, in 2008, the sector contributed 31% to GDP and increased slightly to 31.8% in 2009, then fell to 29.8%, 25.3%, 22.7% and 21.3% for the years 2010, 2011, 2012 and 2013, respectively (GSS, (2013)). Currently, the sector contributes only 18.5% in GDP to the growth of the country (Budget statement, 2018). Its contribution is mainly through export earnings from principal agricultural products such as timber, cocoa, sea foods, game and wildlife as well as horticultural commodities. The sectors function as a supplier of raw materials to manufacturing industries cannot be underestimated even though it remains predominantly small scale. The sector is also characterized by smallholder farmers who cultivates mainly staple crops such as cassava, plantain, rice, yam, and maize to feed themselves and their immediate families and very little marketable surpluses for sale (MoFA, 2009; Antwi-Agyei et al., 2012). Another important contribution of the sector is its significant support to ensuring food security in both rural and urban economies of the country.

In Ghana maize (zea mays, L) is identified as an important food security staple crop as in other sub-Saharan African countries and other parts of the world. Maize constitutes a lager component of human diet and livestock feed as evident the high demand by poultry feed manufacturers (Ravindran, 2012; Wongnaa & Awunyo-Vitor, 2019). Similarly the brewery industries are also noted for their high demand for maize which serves as an important input in their production processes. According to Wiredu et al. (2010), maize is not only important for food/feed consumption but also an important cash crop for most farm households, hence ensuring sustainable production will eventually promote self-sufficiency among household. Maize is estimated to account for about 50% to 60% of all cereal production in terms of area plannted (MiDA, 2010). The crop is recognized for its important role in emergency preparedness as captured in Ghana's METASIP (Akramov, 2012).¹

Maize production in Ghana is basically done by smallholder farmers under erratic rainfall conditions precipitated by climate change among other things. Even though maize is reported to be a warm season crop, it is equally sensitive to high-temperature stress such that high temperatures reduces maize yield (Tesfaye et al., 2015). Furthermore, higher temperatures encourage the multiplication of some pests and weeds that potentially affect maize yield. It is estimated that high temperatures of about 35°C leads to a reduction in maize yield by about 9% (Adhikari et al., 2015). Valipour et al. (2021) suggest that the mean of monthly global surface temperature anomalies in the period 2000–2019 is 0.54°C higher than that in 1961–1990, indicating rising temperatures in the last two decades. This development to a large extent has implications for the production of food staples such as maize. For example, Banziger et al. (2004) opine that productivity of maize may still be under threat by climate change effects even if plant breeders developed varieties that performed well under different biophysical environment. Production of the staple crop is done in all the administrative regions. However, the five principal producing regions are Brong-Ahafo, Eastern, Ashanti, Northern and Central regions (Amanor-Boadu, 2012; Asante et al., 2019). There is relatively an imbalance between current outputs and maximum potential outputs due to inadequate input resources and poor production approaches *inter alia* (Asante et al., 2019; MOFA (Ministry of Food and Agriculture), 2015; Wongnaa & Awunyo-Vitor, 2019). Food grain failure to keep pace with the increasing population and demand is said to be the main cause of food shortage (Asante et al., 2019; Larbi et al., 2013).

The Brong-Ahafo region leads in the production of maize in the country in terms of yield with an average of about 2.0mt/ha (Amanor-Boadu, 2012). This corresponds to the national average; however, it is still far below the achievable yield of 6.0mt/ha. According to Bempomaa and Acquah (2014), figures from SRID usually portray that estimated cropped area of maize has been increasing with a declining estimated output in metric tonnes. For instance, average production in thousand metric tonnes between 2004 and 2006 was 1,172.60 and that of 2007 to 2009 was 1,436.43 representing a growth rate of 6.93%. Average annual production between 2010 and 2012 was 1,835.20mt, 1,741.68mt for 2012 to 2015 representing -1.71% growth rate (SRID, 2016). On the other hand, between 2006 and 2014 area planted to maize has increased steadily from 793,000 ha to 1,025,000 ha. However, SRID reported a low of 880,000 ha area planted to maize for the year 2015 (MOFA (Ministry of Food and Agriculture), 2015).² It is expected the estimated output growth will correspond to the increase in land area planted to the crop; however, it has not been the case. Such occurrences may be as a result of production inefficiencies due to the management practices followed by farmers. The presence of inefficiencies in production means that output could be increased without increasing input resources. In addition varietal differences in seeds planted could contribute to the differences in other input usage and output levels. Thus modern production inputs have the potential to contribute substantially to outputs even though their levels of adoption are guite low (Asante et al., 2019). This paper therefore investigates to better appreciate the performance level of local and improved maize seed varieties in order to make pronouncement relevant for policy decision-making on which one can boost future production whiles enhancing farmer productivity and efficiencies.

Several studies have investigated the technical efficiencies of firms cutting across financial, manufacturing, services, and agricultural sectors (e.g., Binam et al., 2008; Danquah et al., 2019; Mariano et al., 2010; Moreira & Bravo-Ureta, 2010; Nkamleu et al., 2006; Onumah et al., 2018; Richman, 2010). There are also studies that have focused on the technical efficiencies of maize farms in Ghana (e.g., Anang et al., 2020; Asante et al., 2019; Bempomaa & Acquah, 2014; Kuwornu et al., 2013; Oppong et al., 2014; Sienso, Asuming-Brempong, Amegashie et al., 2014a). However, none of these papers have comprehensively compared technical efficiency levels between local maize seed varieties and improved maize seed varieties. The conventional stochastic frontier analysis usually used in such efficiency studies assume homogenous technology (in our case maize seed variety) among farms. Estimates of these studies are suspect so long as differences exist in seed varieties among farm because technology gaps (i.e. varietal differences) may be mistaken for technical inefficiencies. The meta-frontier analysis allows for technical efficiencies to be comparatively estimated among farms that employ different technologies, processes, varieties in production. Some studies have employed this approach for country-level and regional-level analysis of technical efficiency as well as industries that use different technologies (Valliano et al. 2010; Kramol et al., 2010; Mariano et al., 2010; Moreira & Bravo-Ureta, 2010).

The objective of our study is to investigate technical efficiency levels of maize farms in Ghana accounting for differences in maize seed varieties used by different farmers. Specifically, we estimate the productivity levels of local maize seed varieties and improved maize seed varieties; technical efficiency levels and technology gap ratios; identify and estimate the determinants of inefficiencies. Findings from these objectives have far-reaching policy implications for the maize production industry in Ghana as a whole. Our contribution is to disentangle the potential effects of technical inefficiencies and technological gaps (i.e., varietal differences) in maize yield which is overlooked by the standard stochastic frontier model widely employed in this kind of studies. In addition to the technical efficiency scores estimated in the conventional stochastic frontier model, the metafrontier model

we propose in this study allows us to estimate also technology gap ratios. The technology gap ratio is important for making sound pronouncement on the varietal differences in maize production.

2. Improved and local maize seed varieties

The two main categorization of maize seed varieties are the focus of analysis as they differ significantly in their characteristics and production potential. Agriculture in Ghana is predominantly dominated by smallholder farmers with low levels of output and efficiency in input resource allocation. According to economic theory, the main goal of agricultural production at the micro-level is to maximize profit through efficient allocation of input resources. This can be achieved either by maximizing output from given set of inputs or by minimizing the cost of resource needed to produce a certain level of output.

The variety of crop seed used for cultivation has a major role to play in determining whether or not an individual farmer may or may not operate on or near the industry frontier (Villano et al., 2010). According to Morris et al. (1999), of all inputs used in agricultural production, none has the ability to affect productivity more than seed. Hence, if farmers are able to acquire the rightful seed varieties, the efficiency with which other inputs are converted into output increases and productivity rises. The traditional method of crop production by smallholder maize farmers is predominantly accompanied with the use of farmer-owned seeds.³ These varieties are usually vulnerable to pest and diseases such as the MSV, drought and harsh weather conditions, they are low yielding and late maturing among others. According to Wiredu et al. (2010), the cultivation of local maize seed varieties increasing crop outputs requires the expansion of land area planted to crop. This may however not be a sustainable course in the long run due to the increasing competing demand for agricultural lands for other infrastructural developments such as human settlements precipitated by expanding population and rapid urbanization.

Considerable investments have been made by governments in Ghana since 1979 in areas of maize production technologies.⁵ For instance, between 1979 and 1997 the government of Ghana through Ghana Grains Development Project (GGDP) in collaboration with the Canadian government (CIDA) embarked on a project aimed to improve maize with increasing yield capacity, resistance to disease and pest, nutritional quality and agro-ecological suitability (Morris et al., 1999). The project resulted in the development and promotion of 12 improved seed varieties of maize, fertilizer recommendations and plant configuration.⁶ These varieties were developed based on certain desired characteristics such as improved yield potential, acceptable grain size and colour, resistance to disease and pest especially maize streak virus (MSV), quality protein maize, early maturing, drought tolerant etc. Investments into such varietal qualities aimed at improving the productivity of maize farms in order to make up for the soaring differences in obtained yields and maximum potential yields. However, these improved varieties are found to be associated with extra expenses in terms of intensive use of fertilizer, agrochemicals and more labour requirement if a farmer wants to get the best yield. Negligence and genuine inability to fulfil this would usually result in total crop failure (Wiredu et al., 2010). Kuwornu et al. (2013) have stated that the expected effects of such recommendations have not been adequately felt as a result low performance of cultivated varieties and that this inadequacy could be attributed to physical environment, socioeconomic characteristics of producers and poor rural environment conditions. The auestion is whether or not the purpose of investing resources to enhance the quality of maize seeds has not been met in terms of increased productivity and efficiency.

3. Materials and Methods

The parametric frontier approach is adopted to estimate the technical efficiency levels of local and improved maize seed variety farms in this study. Specifically, the stochastic frontier model proposed by Aigner et al. (1977) is used. The stochastic meta-frontier model was developed by Battese and Rao (2002) and G. E. Battese et al. (2004). It follows Hayami (1969) and Hayami and Ruttan (1970) ideas of meta-production technology making it possible to cater for the differences in the

seed varieties that could be inaccurately labelled as technical inefficiency in maize production. This method is an improvement of the conventional stochastic frontier method because it is designed to deal with the heterogeneity in maize seed varieties (i.e. technological differences). Meta-frontier is a smooth function that envelopes the two categories of maize producers.

The local, improved maize seed varieties and the pooled data can be represented by "k" in a conventional stochastic frontier model as

$$\mathbf{Y}_{i} = f(\mathbf{x}_{i}; \boldsymbol{\beta}^{k}) \mathbf{e}^{\mathbf{v}_{i}^{k} - \mathbf{u}_{i}^{k}} \equiv \mathbf{e}^{\mathbf{x}_{i}\boldsymbol{\beta}^{k} + \mathbf{v}_{i}^{k} - \mathbf{u}_{i}^{k}}$$
(1)

where Y_i represents the maize output of the *ith* farmer in the *k*-th group; x_i is a vector of input resources used by the *ith* producer in the *kth* group; β^k denotes a vector of parameters to be estimated for the individual farms; v_i^k represents the noise error (that is factors that affect production but exogenous to the production unit or the producer); u_i^k on the other hand denotes a non-negative variable associated with technical inefficiency. The meta-frontier production function is specified as

$$Y_{i}^{*} = f(x_{i};\beta^{*}) = e^{x_{i}\beta^{*}}$$
 (2)

where β^* represents the vector of parameters for the meta-frontier production function such that $x_i\beta^* \ge x_i\beta^k$, k = 1,2 (i.e., improved and local maize seed varieties)

3.1. Empirical model specification

The empirical meta-frontier model for the study is defined in terms of a translog functional form. The study specifies a stochastic meta-frontier production function using the flexible translog⁷ specification because of its advantages some of which are outlined in Onumah et al. (2018).

$$\ln Y_i = \ln \beta_0 + \sum_{i=1}^4 \beta_i \ln X_i + \frac{1}{2} \sum_{i=1}^4 \sum_{j=1}^4 \beta_{ij} \ln X_i \ln X_j + (Vi - Ui)$$
(3)

 Y_i is the level of maize output of the *ith* producer measured in kilograms per hectare, X_1 denotes labour measured in man-days per hectare, X_2 is seed measured in kilograms per hectare, X_3 is fertilizer measured in kilograms per hectare, X_4 is other cost measured in Ghana Cedis (Ghc) per hectare.⁸

To explain inefficiency the model below is also specified:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 \tag{4}$$

where Z_1 represents gender measured as a dummy variable that captures whether a primary decision-maker is a male or female. It takes the value 1 if the primary decision-maker is a male and 0 otherwise; Z_2 stands for education measured as the number of years of formal education a farmer has attained; Z_3 denotes farmers' experience measured as the number of years a farmer has in maize farming; Z_4 represents the variable credit measured in Ghana cedis (GHc); Z_5 denotes extension service that measures the contact farmers have with technical experts in their field of operation; Z_6 stands for FBO membership status of a farmer measured as a dummy variable to take on the value of 1 if a farmer belongs to an FBO and 0 otherwise; Z_7 represents labour source measured as a dummy variable taking the value of 1 if a farmer have access to ready market for his/her produce after harvest. It was measured as a dummy variable taking the value of 1 if a farmer have access to ready market for his/her produce after harvest.

3.1.1. Hypothesis test

The study performs the following hypotheses to examine the adequacy of specified models, whether or not inefficiencies are present as well as the relevance of exogenous variables to explain the inefficiencies if present. Whether or not it was appropriate to use the metafrontier model is also tested.

 $H_0: \beta_{ij} = 0$. This is the null hypothesis that Cobb-Douglas production function is a statistically valid model appropriate for the datasets and it adequately represents the production frontier functions. This hypothesis is tested against the alternative $H_1: \beta_{ij} \neq 0$.

 $H_{0:} \gamma = \delta_0 = \delta_1 = \delta_2 = , \dots, = \delta_8 = 0$. This implies that inefficiency effects are nonexistence in the model at every level and that each farmer operates on the production frontier against the alternative that, $H_1: \gamma \neq \delta_0 \neq \delta_1 \neq \delta_2 \neq , \dots, \neq \delta_8 \neq 0$.

 $H_0: \gamma = 0$; hypothesis that inefficiency effects are non-stochastic. This hypothesis implies that the stochastic frontier model turns into traditional average response function (OLS) whereby the explanatory variables of the inefficiency model are incorporated into the production function. This is tested against the alternative that $H_1: \gamma \neq 0$.

 $H_0: \delta_{0=}\delta_1 = \delta_2 = , \dots, = \delta_8 = 0$. the simpler half-normal distribution is an adequate representation of the data given the general truncated normal distribution that is assumed. This is tested against the alternative hypothesis $H_1: \delta_{0=}\delta_1 \neq \delta_2 \neq, \dots, \neq \delta_8 \neq 0$.

 $H_0: \delta_1 = \delta_2 = , \dots, = \delta_8 = 0$, the variables included in the inefficiency effect model have no effect on the level of efficiency. In other words, farm-specific factors do not influence inefficiencies. The alternative hypothesis is $H_1: \delta_1 \neq \delta_2 \neq , \dots, \neq \delta_8 \neq 0$.

 $H_0: f(X; \beta^{IV}) = f(X; \beta^{LV})$, there are no differences in maize varieties, therefore the specification of metafrontier model is not required. The alternative hypothesis is given as $H_1: f(X; \beta^{IV}) \neq f(X; \beta^{LV})$. It is important to assess whether or not all groups share the same production technology or if all farm-level data were obtained from a single production frontier with the same underlying technology. If it so happens that the same technology is use across groups then there would be no need for estimating efficiency levels relative to meta-frontier production function. The generalized likelihood-ratio test is used to validate the stated hypotheses. It is specified as

$LR = -2[ln\{L(H_0)\}] - ln\{L(H_1)\}$

3.2. Study area and Sampling method

⁹This study was conducted in the Brong-Ahafo region of Ghana because the region is predominantly an agriculture area where a lot of the country's maize is grown (SRID, 2016). The Brong-Ahafo region is described as the food basket of Ghana. Two areas of the region, Kintampo and Nkoranza made up of four districts; Kintampo north municipal, Kintampo south district, Nkoranza north district and Nkoranza south district were chosen for the study. With the assistance of MoFA directorate in the selected districts, major maize producing communities were selected. A multistage sampling technique was used to select respondents for the study. The Brong-Ahafo region was purposively selected in the first stage. In the second stage, four districts were purposively selected due to the intensity of maize production in these areas. Communities within the selected districts were randomly selected in the third stage from a list of major maize producing communities. Finally, farm-level data was obtained through interviews with the help of a well-designed questionnaire on output, input, price information and relevant exogenous variables. Twelve communities were visited for the data collection and the sample selected from each community is done based on the total number of registered

(5)

farmers in the community out of the total sample required for the study. Communities with large numbers were given higher proportion compared to communities with smaller numbers. In total, a sample size of 214 was used for the study. This comprised of 117 local maize seed variety farmers and 97 improved maize seed variety farmers.

4. Results and Discussion

The specification of a Cobb-Douglas function for the dataset at the group levels and also in the pooled data is rejected in favour of the translog functional form(Table 1). It implies that the estimates of the translog model are more accurate and consistent compared to the results in the Cobb-Douglas functional form. The second hypothesis test showed that inefficiency effects are present in all the models (i.e. improved, local frontiers and the pooled data frontier). Hence the decision to preclude them from the models was rejected. This is confirmed by a high value of $\gamma = 0.91$ and $\gamma = 0.97$ for improved and local maize farms which is statistically significant from zero. J. A. Onumah et al. (2013); Ayinde et al. (2009) also found similar results. The hypothesis that the inefficiency effects are non-stochastic, suggesting that the stochastic frontier model reduces to average production function (OLS) where the explanatory variables are incorporated into the production function was also rejected. This means that the stochastic frontier model best fits the data. The fourth null hypothesis tested was the half normal distribution against the truncated normal distributional assumption. The decision to adopt the half normal distributional assumption was also rejected in favour of the truncated normal distributional assumption. The half normal assumes the average of the inefficiency error term to be zero whereas the truncated normal assumes a mean, μ for the inefficiency error component. In other words the half normal distribution inherently assumes that most of the observed farms are operating near full efficiency, while the truncated normal distribution assumption posits that majority of farms/firms in some sectors especially the agriculture sector exhibit some degree of inefficiency dependent on certain factors.

The null hypothesis that the exogenous variables included in the inefficiency model have no effects on farmers' level of efficiency was rejected. This therefore means the combined effects of the exogenous variables hypothesized in the inefficiency model are statistically significant in explaining farm efficiency. The final hypothesis that was important to this study tested the assumption that improved maize seed variety farms and local maize seed variety farms are the same was also rejected. The specification of the meta-frontier would not be important if it had turn out that the technologies in the two farms were the same. With 14 degrees of freedom, the LR statistic was 62.66. This value is greater than the LR critical of 35.43, at 1% significant level. Therefore, the null hypothesis was rejected. In other words, the improved and local seed variety maize farms are not the same. The appropriateness of specifying a meta-frontier model was as well tested for with the generalized likelihood ratio test. The value of the likelihood function for the unrestricted model is the sum of the log-likelihood value for improved and local stochastic frontiers. This value was computed to be -117.59. However, the log-likelihood value of the pooled stochastic frontiers of the two technologies is the likelihood function for the restricted model. This value is also -149.30. The degree of freedom is the difference between the number of parameters estimated under the unrestricted and restricted models. This difference is calculated to be 14 parameters. The meta-frontier analysis is therefore an appropriate estimation technique to use in this work. Asravor et al. (2015), J. A. Onumah et al. (2013), G. Battese et al. (2001), and Binam et al. (2008) made similar observation.

4.1. Stochastic frontier and meta-frontier estimates

The results of the study in Table 2 indicate that all input variables contribute positively to the output of maize in the study area. In other words all variable inputs employed in the improved seed and local seed variety frontier models meet our *a priori* expectations. This is an indication that if we want to increase output, then we can increase inputs used. The greatest share of productivity according to the results was due to seed followed by other cost, labour input and fertilizer respectively. Abdulai et al. (2013) and Asante et al. (2019) makes similar observation for maize production across various ecological zones in Ghana. However, the greatest share of productivity is due to seed in the improved group. A percentage

increase in seed, fertilizer, labour and other cost will eventually lead to about 0.59%, 0.03%, 0.13% and 0.25% in output, respectively, in the improved variety farms. In the local variety group however, a percentage increase in the aforementioned input variables will lead to 0.63%, 0.09%, 0.19% and 0.22% increase in output, respectively. The findings of this study confirms what was observed by Asravor et al. (2015) except for seed where their study revealed a negative contribution to output of rice. Ayinde et al. (2009) also observed a positive relationship between labour, fertilizer input variables and output of rice output in Nigeria under Nerica, Mai-Nasara and Ofada varieties. However, seed contributed negatively to rice output. In Binam et al. (2008) study on the productivity potential and efficiency of cocoa farms in some selected West African countries, all input variables contributed positively to cocoa output.

The result of the study revealed that all input elasticities are inelastic. This implies that a percent increase in each input results in less than 1% increase output. The summation of partial elasticities of output with respect to each input used in production across all groups and in the pooled data exhibits increasing returns to scale in maize production in the study area. Function coefficient of 1.01, 1.14 and 1.55 means that a percentage increase in all input variables results in 1.01%, 1.14% and 1.55% increase in maize output in the improved maize farms, local maize farms and in the pooled data, respectively. This is an indication that maize farmers in the study area are still operating in the first stage of production. Therefore, they have enough room to increase their scale of production in the long run when farmer efficiency is improved. Seed, labour and other cost are statistically significant determinants of maize output in the study area. Seed is statistically significant at 1% in both the improved and local varieties. Labour is statistically significant at 10% in the improved and 1% in the local. Other cost is statistically significant at 5% and 10% under improved and local groups, respectively. These are indications that the allocation of these inputs were productive, hence consciously increasing seed, labour and other cost in maize production increases maize output. After seed, other cost has greater coefficient than labour and fertilizer. This therefore means that paying more attention to investment in other inputs such as pesticides, weedicides, hiring of ploughing machines, tractor services can enhance the levels of maize output in the Brong-Ahafo Region of Ghana. This result is consistent with the studies of Sienso, Asuming-Brempong, Amegashie et al. (2014a). However, it is contrary to the observations made by Kuwornu et al. (2013) who reported a negative contribution of seed, fertilizer and family labour to maize output in the Eastern Region.

The estimated gamma values for the improved, local maize variety groups and the pooled data are 0.91, 0.97 and 0.95, respectively. The gamma value is a measure of variation in total output of maize due to inefficiencies in the combination and usage of input variables. Therefore to have a gamma value of 0.91 means that 91% of the variations in maize output under the improved seed frontier is attributable to inefficiency in input use and other farm-level practices. Similarly, 97%, 95% of variations in maize output in the local variety maize farms and in the pooled data, respectively, are due to inefficiencies and farm-level practices. This means that stochastic factors beyond the control of the farmer contributes 9%, 3% and 5% of variation in output for improved, local and pooled data respectively. Endowment constraint, policy constraints, unfavourable weather conditions, disease and pest infestation as well as measurement errors are typical examples of stochastic factors (Binam et al., 2008).

4.2. Technical efficiency and technology gap ratios

Technical efficiency gains translates directly into improvements in farm household incomes and farmers benefit from such gains (J. A. Onumah et al., 2013). The results of the study show that mean technical efficiencies of the individual group frontier models are 0.75, 0.59 and 0.65 for the improved variety maize seed farms, the local variety maize seed farms and the pooled data respectively. This means that on the average, maize farmers achieve 75%, 59% and 65% of their frontier outputs given their present input use and the varietal technology available to them. In other words maize farms are losing 25%, 41% and 35% of their maximum potential output to inefficiencies in input use and poor agronomic practices. Therefore, if maize farmers have to achieve 100% of their frontier output, they should focus efforts to close the gap between their current performance levels and the maximum potential performance of their system by minimizing the effects of some

Table 1. Hypothesis test results					
Hypotheses	LR statistics ())	Critical Value	Decision		
1. $H_0: \boldsymbol{\theta}_{ik} = 0$					
Improved	17.16	18.31	RejectH₀		
Local	20.84	18.31	RejectH ₀		
Pooled	35.26	18.31	RejectH₀		
$2. \\ H_0: \gamma = \delta_0 = \delta_1 =, \ldots, = \delta_8 = 0$					
Improved	42.67ª	28.86 ^b	RejectH ₀		
Local	33.66ª	28.86 ^b	RejectH₀		
Pooled	66.01ª	28.86 ^b	RejectH ₀		
3. $H_0: \gamma = 0$					
Improved	13.84ª	9.50 ^b	RejectH ₀		
Local	20.55ª	9.50 ^b	RejectH ₀		
Pooled	33.53ª	9.50 ^b	RejectH ₀		
4. $H_0: \delta_0 = \delta_1 =,, = \delta_8 = 0$					
Improved	28.84	19.68	RejectH₀		
Local	13.10	19.68	RejectH ₀		
Pooled	32.48	19.68	RejectH ₀		
5. $H_0: \delta_1 = \delta_2 =,, = \delta_8 = 0$					
Improved	27.22	15.51	RejectH ₀		
Local	9.24	15.51	RejectH ₀		
Pooled	28.40	15.51	RejectH ₀		
6. $H_0: f_{LV}(X; \boldsymbol{\mathcal{B}}_{LV}) = f_{lV}(X; \boldsymbol{\mathcal{B}}_{lV})$					
Pooled only	62.66	35.43	RejectH ₀		

 $a \equiv$ Values of test for the one sided error obtained from the Ox output of ML estimates. $b \equiv$ Critical values at 0.001 for the test of hypothesis involving gamma and it is obtained from Kodde and Palm (1986).

inefficiency factors. The best-performing farmer on the other hand achieves 97% and 95% of the frontier output for the improved and the local groups, respectively. On the other hand the least performing farmer achieves 12% and 9% of their potential frontier outputs under the improved and local groups, respectively.

The technology gap ratio measures the gap between a given maize production variety (improved and local seed varieties) and the technology that is available to the whole maize industry given vector of inputs (Gero, 2020; Alem et al., 2019; Nguyen et al., 2019; Villano et al., 2010; Binam et al., 2008; G. E. Battese et al., 2004). In other words, if producers were technically efficient in relation to the stochastic frontier at the farm level, they could still increase output by closing a gap between their current performance and the best practice for the industry. The closer the value is to 1, the smaller the gap between the individual frontier and the meta-frontier. As shown in Table 3, TGRs of 0.90, 0.72 and 0.81 are estimated for improved, local seed variety farms and the pooled data respectively. The implication is that if the average producer in the improved, local seed variety and the pooled were to be technically efficient (i.e. on their group frontier), they could still increase output by closing a gap of 10%, 28% and 19%, respectively, if they were to employ the most efficient meta-technology for the entire maize farming sector. This means that the gap between the current technologies and the meta-frontier is much smaller in the improved maize farms than in the local variety farms. That is the technology gaps for average producers are much smaller in the improved variety group and so their present technologies are near the possibilities frontier of the meta-technology. However, the gap in technology ranges from

Table 2. The stochastic frontier and meta-frontier models estimate					
Variable ¹⁰	Parameter	Improved (ML)	Local (ML)	Pooled (ML)	Meta (LP)
Constant	${\cal B}_0$	0.539 (4.24)***	0.488 (3.34)***	0.070 (0.99)	0.650(7.88)***
LnSeed	B ₁	0.589 (3.55)***	0.630 (7.55)***	0.557 (6.29)***	0.489(3.96)***
LnFertilizer	B ₂	0.032 (0.28)	0.095 (1.05)	0.616 (3.78)***	0.091(0.89)
LnLabour	θ3	0.131 (1.66)*	0.195 (2.65)***	0.177 (3.28)***	0.152(1.60)*
LnOC	$\boldsymbol{\theta}_4$	0.252 (2.09)**	0.222 (1.78)*	0.203 (2.35)**	0.254(2.10)**
LnSeed_sq	B ₅	-0.692 (-2.11)**	-0.640 (-1.46)	-0.695 (-2.91)***	-0.478(-1.30)
LnFertilizer_sq	θ_6	-0.225 (-0.95)	-0.122 (-0.41)	-0.114 (-0.53)	-0.039(-0.17)
LnLabour_sq	θ7	0.118 (0.65)	-0.121 (-0.84)	-0.062 (-0.60)	0.089(0.47)
LnOC_sq	θ_8	-0.129 (-0.34)	-0.986(-3.92)***	-0.656 (-3.51)***	-0.306(-1.01)
LnSeed*LnFert	B 9	0.381 (1.86)*	0.043 (0.16)	0.165 (0.98)	0.146(0.60)
LnSeed*LnLabor	B ₁₀	0.195 (1.14)	0.241 (1.45)	0.204 (1.83)*	0.214(1.39)
LnSeed*LnOC	B ₁₁	0.460 (1.47)	0.764 (2.52)**	0.717 (4.14)***	0.504(1.84)*
LnFert*LnLabour	B ₁₂	-0.103 (-0.76)	-0.180 (-1.45)	-0.190 (-1.80)*	-0.141(-1.05)
LnFert*LnOC	B ₁₃	-0.138 (-0.96)	0.163 (0.99)	0.019 (0.18)	-0.074(-0.46)
LnLabour*LnOC	B ₁₄	0.401 (-1.63)*	-0.213 (-1.51)	-0.232 (-2.32)**	-0.373(-1.71)*
Log likelihood function		-42.38	-75.59	-149.30	
$\gamma = \sigma_u^2/\left(\sigma_u^2+\sigma_v^2 ight)$		0.91	0.97	0.95	

***, ** and * denote statistical significance at 1%, 5% and 10% respectively.

a minimum of 0.44 to 0.99 for the improved maize farms and 0.22 to 0.99 for their counterparts who cultivate the local varieties.

The mean technical efficiency scores for improved variety maize farms and local maize farms relative to the meta-frontier efficiency scores are 0.72 and 0.44, respectively (Table 3). Reinforcing the assertion of the TGR, the values of the technical efficiency scores relative to the meta-frontier implies that farms in the improved group are technically more efficient than their counterparts under the local seed variety system. This may be attributable to correct and timely application of recommended fertilizers as the improved maize varieties come as a complete package in terms of quantities and periods of recommended fertilizer application together with other cultural practices. Therefore, local seed variety producers should be encouraged to increase their learning on managerial practices with regard to the use of inputs in order to catch up with their improved variety grower counterparts. They may also be encouraged to switch to the use of newly improved maize seed varieties with its accompanying cultural packages in their production to enable them obtain significant increases in output while enhancing their use of other variable inputs. From Table 3 it is observed that technical efficiency scores relative to the individual group stochastic frontiers are greater than that of those relative to the meta-frontier. This is because the constraints in the group linear programming problem are a subset of the constraints in the meta-frontier linear programming problem (Nkamleu et al., 2006). The difference between the two efficiency scores indicate the order of bias efficiencies obtained by using the group frontiers, relative to the technology available for the entire industry. Furthermore, the results reinforces the position that using the estimates from the individual group frontiers for improved and local variety seed maize farms for comparison of technical efficiencies may be misleading (Asante et al., 2019; O'Donnell et al., 2008; G. E. Battese et al., 2004).

4.3. Determinants of technical efficiency

Technical efficiency scores of production agents are important yet lacking substance in making pronouncement for evidence-based policy interventions, therefore it is appropriate to go a step further in identifying factors that potentially influence variation in the technical efficiency estimates (J. A. Onumah et al., 2013; Onumah et al., 2018). The results of the inefficiency

Table 3. Technical efficiency scores and technology gap ratios					
	Mean	Minimum	Maximum	Standard Deviation.	
Technology Gap Ratios					
Improved	0.90	0.44	0.99	0.12	
Local	0.72	0.22	0.99	0.15	
Pooled	0.81	0.22	0.99	0.16	
Technical Efficiency (Group frontier)					
Improved	0.75	0.12	0.97	0.22	
Local	0.59	0.09	0.95	0.23	
Pooled	0.65	0.10	0.94	0.21	
Technical Efficiency (Meta-frontier)					
Improved	0.72	0.12	0.96	0.22	
Local	0.44	0.05	0.87	0.20	
Pooled	0.50	0.06	0.91	0.21	

model show that labour source, years of formal education, number of extension contacts, farmgate purchases and credit are statistically significant determinants of maize farmers' technical efficiency in Ghana as shown in Table 4. The variable farm-gate purchase has a negative coefficient and statistically significant at 1% in the improved group and 5% in the pooled data. This implies that having ready market for produce potentially increases the technical efficiency of maize farmers because it serves as an incentive for them towards production. Even though farm-gate purchase was found not to be significant under the local maize farms, it had the appropriate negative coefficient. Availability of ready market¹¹ motivates producers in the study area as they are assured of timely recovery of investments after harvesting their produce which may eventually increase their access to production inputs in subsequent production season. This finding confirms the observation made by Asravor et al. (2015) and Cobbina (2010) who found that reliable access to the produce market will motivate farmers to put in their best in order to earn more income, leading to increased efficiency of the farmers.

Farmers' access to credit is not just enough to boost their efficiency, the amount of credit accessed is more important in determining the quality and quantities of inputs they are able to purchase for production. The study revealed that the amount of credit a farmer receives for production has a negative coefficient and significant at 5% under the improved and 10% in the pooled but not significant under local system. This implies that increased credit amount has positive effect on farmer's efficiency. In other words farmers with access to sufficient amount of credit at relatively less cost tend to be technically efficient in their production process compared to their counterparts who do not. The variable is statistically significant at 5% in the improved variety seed farm group but not in the local even though the a priori sign is met. One may argue that the creditor may assess their level of risk on the basis of their technology employed. This observation confirms that of Binam et al. (2008). They observed that the role of credit cannot be overemphasized in agricultural productivity of poor farmers in West and Central Africa, so developing viable rural credit institutions is a necessary condition for increasing land and labour productivity.

Labour source captures the effect of major sources of farm labour (family labour and hired labour) employed on farm efficiency and it is statistically significant at 10% in the improved group and the pooled data but not significant in the local group. The positive sign of the variable means that farms that depend on hired labour compared to family labour are more technically efficient. Employing hired labour has extra cost implication for farm production; hence farmers try as much

Table 4. Parameter estimates of the inefficiency model				
Variable	Improved	Local	Pooled	
Constant	-0.3539(-0.35)	-3.0284(-0.89)	-0.9626(-0.95)	
Gender	-0.6428(-1.39)	-0.6034(-0.84)	-0.4339(-1.37)	
Labour source	0.7085(1.71)*	1.0136(0.99)	0.6309(1.70)*	
FBO member	-0.4621(-1.18)	-0.0254(-0.03)	-0.2098(-0.68)	
Education	-0.7761(2.07)**	0.1549(1.70)*	-0.0268(2.79)***	
Extension	0.1635(2.21)**	-0.1166(2.86)***	-0.0144(1.34)	
Farm-gate purchase	-1.5536(-2.63)***	-0.7712(-0.88)	-1.0078(-2.42)**	
Experience	0.0298(1.36)	0.0201(0.53)	0.0200(1.19)	
Credit	-0.0035(-2.00)**	-0.0021(-0.74)	-0.0023(-1.90)*	

Note: Values in parenthesis are the t-statistics; ***, ** and * represents significance at 1%, 5% and 10% levels respectively.

as possible to always get the best out of labour hired (i.e. value for money). The variable is significant at 10% level in the improved group but not in the local. This may be partly explained by the relevance of skilled labour in production activities with a given technology. Improved maize seed variety usually comes at a higher cost to the farmer so they would like as much as possible to reduce wastage that may result from using family labour, hence resort intensively to the use of hired labour. Maize cultivation is labour intensive and therefore will require more labour especially for weeding and harvesting operations (Kuwornu et al., 2013).

The coefficient of formal education is negative under the improved and pooled data and it is statistically significant at 5% in the improved group, 10% and 1% in the local group and the pooled data, respectively. This implies that increased years in formal education enhances farmer efficiency in the use of input resources in maize farming. Even though significant under the local group, it had the unexpected apriori sign (positive). With regard to the improved seed variety group, the education variable is statistically significant at 5% level and meets our apriori negative sign expectation. This suggest that farmers with higher formal education are well equipped and positioned to understand the "dos and don'ts" of such technologies. Our finding support the position of other studies that education enhances the stock of human knowledge therefore increasing efficiency (Onumah et al., 2018; Danso-Abbeam et al., 2017; Bhasin, 2009). Generally, more educated farmers are able to perceive, interpret and respond to new information and adopt improved technologies such as fertilizers, pesticides and planting materials much faster than their counterparts with minimal or no years of formal education (Nyagaka et al., 2010). Onumah et al. (2010) also observed that formal fish farming education (FFFE) increases fish farmers' efficiency hence concludes that fish farming programs should be introduced and encouraged at both the higher and basic institutions in order to produce more fish farming expects. This clearly calls for sector-specific training modules as a means of enhancing farmer efficiency for increased yield. Similarly, Yiadom-Boakye et al. (2013), Olarinde (2011), Mariano et al. (2010), and Nyagaka et al. (2010) reported a positive relationship between farmers' technical efficiency and years of education.

The variable extension is statistically significant at 5% in the improved group and 1% under the local group but not in the pooled data. It bears the expected negative sign that implies that farmer's contact with extension service agents for advisory services increases technical efficiency in the improved group and the local group, respectively. Binam et al. (2008), Onumah et al. (2010), and Yiadom-Boakye et al. (2013) made similar observations. Primarily, agricultural extension agents report the needs of farmers to researchers and in turn disseminate new research findings to farmers and so one would expect their contact with farmers to enhance efficiency. In particular, this dual function of extension service is more important in the use of production inputs such as improved varieties of seeds released into the market by research organizations. This study observe that the

higher the frequency of extension contact with farmers the more efficient they become in production under the improved group and the local group. However, in the pooled data same cannot be said.

The study reveal that male maize farmers are technically efficient in resource utilization compared to their female counterparts. This is the same in both the improved seed variety farms and the local farms as well as in the pooled data. This could be explained by the fact that male farmers have easier and greater access to credit, because they usually own a lot of the productive assets that could be used as collateral in accessing credit. Cultural prejudice also play a role in the domineering of male farmers in credit access. This finding confirms the observation of Sienso, Asuming-Brempong, Amegashie et al. (). It is usually expected that years of farming experience will make farmers more efficient as they would have been used to the erratic conditions of agriculture and so would be able to make accurate predictions on when to sow, the inputs to use, the quantity to use as well as the timing of input application (Sienso, Asuming-Brempong, Amegashie et al., 2014a). However, the study revealed a positive coefficient of experience that means that farmers with many years of maize farming experience tend to be less efficient compared to those that are relatively young or new in the maize production. Perhaps experienced farmers in the study area tend to be conservative in adopting newly developed technologies unlike the new ones who want to explore all avenues to increase their output. This revelation is consistent with the observation of Olarinde (2011). The study has shown that farmers who belonged to farmer-based organizations are more technically efficient compared to their counterparts who do not. Even though the variable is statistically not significant in determining technical efficiency of farmers, it had a negative coefficient that implies that farmers who belong to farmer-based organizations are more efficient and they are likely to benefit from better access to inputs and to information on improved practices. In other words farmers who belong to such societies interact among themselves, share information on farming technologies, learn from each other's experiences. Similar observation was made by Nyagaka et al. (2010).

5. Conclusion and Recommendation

The meta-frontier approach is employed to comparatively analyse the efficiency levels of the improved maize seed variety and local maize seed variety farms in Ghana with a cross-section data of 214 farms. The result show that all input variables considered in the study have positive effect on production under both maize seed variety farms. It is also shown that productivity increases more than proportionate increase in the level of all factor inputs for both varieties of maize seed farms. Estimated technology gap ratios (TGRs) and technical efficiencies with respect to meta-frontier demonstrates that farmers who use improved maize seed variety. This also means that users of improved maize seed varieties are more technically efficient compared to the local seed variety users. Therefore future increases in maize output that will lead Ghana to bridging the gap between actual yields and maximum potential yields is much higher in the use of improved maize seed varieties as other studies have also concluded. The study has also shown that operational and farm-specific factors together influence the technical efficiency of maize farms even though individually some variables are statistically not significant.

The study recommends that the adoption of improved maize seed varieties among producers should be intensely encouraged and the management skills pertaining to the use of such varieties should also be improved in order to reap the full benefit it offers. This could be achieved by intensifying farmer education and training by the relevant stakeholders such as the extension directorate of the ministry of food and agriculture (MoFA), Crop Research Institute of Centre for Scientific and Industrial Research Institute (CSIR-CRI), and other relevant research institutions as well as agriculture-based NGOs that spearhead the development of improved maize seed varieties. Such education and training packages should focus on management issues such as rightful application of fertilizers and agro-chemicals in terms of the appropriate product, quantities and time of application. Furthermore, the promotion of improved maize seed varieties should be desired-characteristics (resistance to pest and disease, drought tolerant, quality protein maize, early maturing, etc.) specific to the appropriate agro-ecological zones. Since enhancing efficiency to improve agricultural output is more cost-effective

compared to introducing more and/or new technologies especially when farmers are not making optimal use of already existing technologies, it is recommended that knowledge management and information sharing on existing improved maize seed varieties should be promoted.

Recommendation for future research

Future studies may consider the specific varieties of maize (rather than a broad categorization of "improved seed varieties") that has been developed in Ghana by CSIR-CRI and other research institutes – in a metafrontier framework. The study could also be extended to include all principal maize producing regions of Ghana.

Acknowledgements

The authors are thankful to the MoFA offices in Kintampo North and South Municipalities; Nkoranza North and South Municipalities and all the Agriculture Extension Agents who helped in diverse ways during the data collection. We also wish to express our profound gratitude to all the farmers who shared with us the needed information. Many thanks to Kelvin Darkwa, Ebenezer Hanson Woyome, Bernice Tweneboah-Kodua for their immense support in the data collection process. Finally, we thank all the reviewers for their comments that has help shaped this paper.

Funding

The authors received no direct funding for this research

Author details

Theophilus Tweneboah Kodua¹

E-mail: theophiluskodua@gmail.com ORCID ID: http://orcid.org/0000-0002-9908-0906 Edward Ebo Onumah¹

ORCID ID: http://org/0000-0001-7307-1270

Akwasi Mensah-Bonsu¹

¹ Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Accra, Ghana.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Citation information

Cite this article as: Technical efficiency of improved and local variety seed maize farms in Ghana: A meta-frontier analysis, Theophilus Tweneboah Kodua, Edward Ebo Onumah & Akwasi Mensah-Bonsu, *Cogent Economics & Finance* (2022), 10: 2022858.

Notes

- METASIP is Ghana's Medium Term Agriculture Sector Investment Plan—implemented in 2011 and it is informed by the vision of "a modernized agriculture which culminates into a structurally transformed economy and evident in food security, employment opportunities as well as reduced poverty".
- SRID is the Statistics, Research and Information Directorate of Ministry of Food and Agriculture (MoFA) in Ghana. They computation of the area planted to specific crops are based on regional and district cropped areas.
- These are seeds that have been recycled over several cropping season, degenerated and losing in quality termed in this study as local seed varieties.
- 4. This perhaps is due to the fact that farmers obtain such seeds from their stored harvest of previous season. Furthermore, planting these crops do not require any special layout as would be outlined for newly developed varieties.

- 5. Varieties and accompanying cultural practices.
- There were several other projects that resulted in the development of improved seed varieties of maize including Okomasa, Abeleehi, Mamaba, Dadaba, Obaatanpa, Golden Crystal and many others.
- Translog is the transcendental logarithmic and it is advantageous because it is less restrictive and it also allows for square and cross product terms of input variables to be incorporated in the model to improve the fitness of the model.
- 8. The parameters of the meta-frontier model are estimated by minimizing the sum of the squares of the deviations of the values on the meta-frontier from those of the individual stochastic frontier production systems at the observed input levels as proposed by G. E. Battese et al. (2004). The Ox programme developed by Brümmer (2015) is employed to obtain the maximum likelihood estimates for the parameters.
- 9. L(H₀) is the value of log-likelihood function under the null hypothesis (i.e. the restricted model); L(H₁) is the value of log-likelihood function under the alternative hypothesis (i.e. the unrestricted model). LR has an appropriate Chi-square or mixed Chisquare 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; Onumah et al., 2018). All the critical values can be obtained from appropriate chi-square distribution. However, if the test of hypothesis involves $\gamma = 0$, then the asymptotic distribution necessitates mixed chisquare distribution. The critical value for such a test is obtained from (Kodde & Palm, 1986).
- LnSeed stands for natural log of seed; LnFertilizer is the natural log of fertilizer; LnLabour is the natural log of labour; LnOC is the natural log of other costs and by extension their square terms and cross products respectively.
- 11. A very strong indicator of this variable in the local setting is when farmers before and during harvest of their produce get potential buyers to express interest in their produce and subsequently buy them if they (produce) meet their standards (of buyers) and prices are agreed on.

References

- Abdulai, S., Nkegbe, P. K., & Donkoh, S. A. (2013). Technical efficiency of maize production in Northern Ghana. Vol. 8(43), pp. 5251–5259. 7(November 2013). 10.5897/AJAR2013.7753
- Adhikari, U., Nejadhashemi, A. P., & Woznicki, S. A. (2015). Climate change and Eastern Africa: A review of impact on major crops. *Food and Energy Security*, 4 (2), 110–132. https://doi.org/10.1002/fes3.61
- Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5
- Akramov, K. (2012). Analyzing profitability of maize, rice, and soybean production in Ghana : Results of PAM and DEA analysis. Ghana Strategy Support. Program (GSSP) Working, 28.
- Al-Hassan, S. (2008). Technical efficiency of rice farmers in Northern Ghana. African Economic Research Consortium. No. RP_178

- Alem, H., Lien, G., Hardaker, J. B., & Guttormsen, A. (2019). Regional differences in technical efficiency and technological gap of Norwegian dairy farms: A stochastic meta-frontier model. *Applied Economics*, 51(4), 409–421. https://doi.org/10.1080/00036846.2018. 1502867
- Amanor-Boadu, V. (2012). Maize Price Trends in Ghana (2007-2011).Monitoring, Evaluation and Technical Support Services (METSS) USAID (http://www.agmana ger.info/agribus/METSS/MaizeTrends_01-2012_ Vincent.pdf)
- Amaza, P. S., Bila, Y., & Iheanacho, A. C. (2006).
 Identification of factors that influence technical efficiency of food crop production in West Africa:
 Empirical evidence from Borno State, Nigeria. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 107(2), 139–147. https://jarts.info/index.php/jarts/issue/view/15
- Anang, B. T., Alhassan, H., & Danso-Abbeam, G. (2020). Technology adoption and technical efficiency of smallholder farmers in Tolon district of Ghana: Double bootstrap DEA approach. https://doi.org/10. 21203/rs.3.rs-17237/v1
- Antwi-Agyei, P., Fraser, E. D., Dougill, A. J., Stringer, L. C., & Simelton, E. (2012). Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography*, 32(2), 324–334. https://doi.org/10.1016/j.apgeog.2011.06.010
- Asante, B. O., Temoso, O., Addai, K. N., & Villano, R. A. (2019). Evaluating productivity gaps in maize production across different agroecological zones in Ghana. Agricultural Systems, 176, 102650. https://doi. org/10.1016/j.agsy.2019.102650
- Asravor, J., Onumah, E. E., Wiredu, A. N., & Siddig, K. (2015, September). Rice productivity and technical efficiency: a meta-frontier analysis of rice farms in Northern Ghana. In Conference on International Research on Food Security, Natural Resource Management and Rural Development organized by the Humboldt-Universität zu Berlin and the Leibniz Centre for Agricultural Landscape Research (ZALF), Tropentag (pp. 16–18).
- Ayinde, O. E., Adewumi, M. O., & Ojehomon, V. E. (2009, August). Determinants of technical efficiency and varietal-gap of rice production in Nigeria: A meta-frontier model approach. In A paper presented at the International Association of Agricultural Economics conference, Beijing, China, August (pp. 16–22).
- Banziger M., Setimela P. S., Hodson D., & Vivek, B. (2004). Breeding for Improved drought tolerance in maize adapted to Southern Africa. *Journal of Breeding and Genetics*.
- Battese, G. E., Rao, D. 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(1), 91–103. https://doi.org/ 10.1023/B:PROD.000012454.06094.29
- Battese, G. E., & Rao, D. P. (2002). Technology gap, efficiency, and a stochastic metafrontier function. *International Journal of Business and Economics*, 1(2), 87–93.
- Battese, G., Rao, D. S., & Walujadi, D. (2001). Technical efficiency and productivity potential of firms using a stochastic metaproduction frontier. Oviedo Efficiency Group. No. 200108
- Bempomaa, B., & Acquah, H. D. G. (2014). Technical efficiency analysis of maize production: Evidence from Ghana. APSTRACT: Applied Studies in Agribusiness and Commerce, 8(2–3), 73–79. https://doi.org/10.19041/ APSTRACT/2014/2–3/9

- Bhasin, V. (2009). Determinants of technical efficiency of women entrepreneurs in the food processing enterprises in cape coast. Ghana Policy Journal, 3, 24–47.
- Binam, J. N., Gockowski, J., & Nkamleu, G. B. (2008). Technical efficiency and productivity potential of cocoa farmers in West African countries. *The Developing Economies*, 46(3), 242–263. https://doi. org/10.1111/j.1746-1049.2008.00065.x
- Cobbina, R. (2010). Aquaculture in Ghana: Economic perspectives of Ghanaian aquaculture for policy development. UNU-Fisheries Training Programme. Final Project, 47.
- Danquah, F. O., He, G., Danquah, E. O., & Twumasi, M. A. (2019). The nexus between production input factors and technical efficiency among maize farmers in various regions in Ghana; stochastic frontier approach. CUSTOS E AGRONEGOCIO ON LINE, 15(4), 118–143.
- Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. *Cogent Economics & Finance*, 5(1), 1416896. https://doi.org/10.1080/23322039.2017.1416896
- Gero, A. A. (2020). Regional differences in technology gap ratio and efficiency in African Agriculture: A stochastic metafrontier analysis. *International Journal of Agricultural Economics*, 5(3), 80. https:// doi.org/10.11648/j.ijae.20200503.14
- GSS. (2013). 2010 Population & Housing Census: National Analytical Report. Ghana Statistics Service.
- Hayami, Y., & Ruttan, V. W. (1970). Agricultural Productivity Differences among Countries. *The American Economic Review*, 60(5), 895–911. http:// www.jstor.org/stable/1818289
- Hayami, Y. (1969). Sources of agricultural productivity gap among selected countries. American Journal of Agricultural Economics, 51(3), 564–575. https://doi. org/10.2307/1237909
- Holtkamp, J., & Brümmer, B. (2015). Stochastic Frontier Analysis Using Sfamb for OX (Software-Manual).
 University of Göttingen, Department for Agricultural Economics and Rural Development: Göttingen, Germany.
- Kodde, D. A., & Palm, F. C. (1986). Wald criteria for jointly testing equality and inequality restrictions. Econometrica: Journal of the Econometric Society, 54(5), 1243–1248. https://doi.org/10.2307/1912331
- Kramol, P., Villano, R. A., Fleming, E. M., & Kristiansen, P. (2010). Technical efficiency and technology gaps on'clean and safe'vegetable farms in Northern Thailand: A comparison of different technologies. In 2010 Conference (54th), February 10-12, 2010, Adelaide, Australia (No. 59092). Australian Agricultural and Resource Economics Society.
- Kuwornu, J. K., Amoah, E., & Seini, W. (2013). Technical efficiency analysis of maize farmers in the Eastern Region of Ghana. *Journal of Social and Development Sciences*, 4(2), 84–99. https://doi.org/10.22610/jsds. v4i2.739
- Larbi, E., Ofosu-Anim, J., Norman, J. C., Anim-Okyere, S., & Danso, F. (2013). Growth and yield of maize (Zea mays L.) in response to herbicide application in the coastal Savannah of Ghana. Net Journal of Agricultural Science, 1(3), 81–86. http://hdl.handle. net/123456789/1166
- Mariano, M. J., Villano, R., Fleming, E., & Acda, R. (2010). Meta frontier analysis of farm-level efficiencies and environmental-technology gaps in Philippine rice farming. In Proceedings of the 54th Annual conference of australian agricultural and resource economics society (pp. 10–12). http://dx.doi.org/10.22004/ag. econ.59099

- MiDA. (2010). Investment opportunity in Ghana. Soya and Rice. Maize.
- MOFA (Ministry of Food and Agriculture). (2015). Agriculture in Ghana: Facts and figures statistics. Research and Information Directorate (SRID).
- MoFA. (2009). Agriculture in Ghana: Facts and figures. Statistics, Research, and Information Directorate, (2010). http://mofa.gov.gh/site/wp-content/uploads/ 2011/10/agriculture-in-ghana-ff-2010
- Moreira, V. H., & Bravo-Ureta, B. E. (2010). Technical efficiency and metatechnology ratios for dairy farms in three southern cone countries: A stochastic meta-frontier model. *Journal of Productivity Analysis*, 33 (1), 33–45. https://doi.org/10.1007/s11123-009-0144-8
- Morris, M. L., Tripp, R., & Dankyi, A. A. (1999). Adoption and impacts of improved maize production technology: A case study of the Ghana grains development project. A Synthesis of Findings Concerning CGIAR Case Studies on the Adoption of Technological Innovations, CIS-2314. CIMMYT, No.
- Nguyen, T., Le, Q., Tran, T., & Nguyen, M. (2019). Ownership, technology gap and technical efficiency of small and medium manufacturing firms in Vietnam: A stochastic meta frontier approach. Decision Science Letters, 8(3), 225–232. https://doi. org/10.5267/j.dsl.2019.3.002
- Nkamleu, G. B., Nyemeck, J., & Sanogo, D. (2006). Metafrontier analysis of technology gap and productivity difference in African Agriculture. Journal of Agriculture and Food Economics, 1(2), (December 2006):pp. 111–120. https://mpra.ub.uni-muenchen. de/id/eprint/15103
- Nyagaka, D. O., Obare, G. A., Omiti, J. M., & Nguyo, W. (2010). Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya. African Journal of Agricultural Research, 5(11), 1179–1186. https://doi.org/10.5897/ AJAR09.296
- Nyanteng, V. K., & Asuming-Brempong, S. (2003, October). The role of agriculture in food security in Ghana. A paper presented at *Roles of agriculture project international conference* Rome, Italy. Organized by Agricultural and Development Economics Division (ESA) Food and Agriculture Organization of the United Nations (pp. 20–22).
- O'Donnell, C. J., Rao, D. P., & Battese, G. E. (2008). Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical economics*, 34(2), 231–255. 10.1007/s00181-007-0119-4
- Olarinde, L. O. (2011). Analysis of technical efficiency differentials among maize farmers in Nigeria. *AERC Research Paper 232*.
- Onumah, E. E., Brümmer, B., & Hörstgen-Schwark, G. (2010). Elements which delimitate technical efficiency of fish farms in Ghana. *Journal of the World Aquaculture Society*, 41(4), 506–518. https://doi.org/ 10.1111/j.1749-7345.2010.00391.x
- Onumah, E. E., Onumah, J. A., & Onumah, G. E. (2018). Production risk and technical efficiency of fish farms

in Ghana. *Aquaculture*, 495, 55–61. https://doi.org/10. 1016/j.aquaculture.2018.05.033

- Onumah, J. A., Onumah, E. E., Al-Hassan, R. M., & Brümmer, B. (2013). Meta-frontier analysis of organic and conventional cocoa production in Ghana. *Agriculture Economics CZECH*, 59(No. 6), 271–280. https://doi.org/10.17221/128/2012-AGRICECON
- Oppong, B. A., Onumah, E. E., & Asuming-Brempong, S. (2014). Stochastic frontier modeling of maize production in Brong-Ahafo Region of Ghana. Agris Online Papers in Economics and Informatics, 6(2), 67–75. 10.22004/ag.econ.182492
- Ravindran, V. (2012). Poultry feed availability and nutrition in developing countries. Food and Agriculture Organization (FAO) of the United Nations, Poultry Development Review, 60–63.
- Richman, D. (2010, January). What drives efficiency on the Ghanaian cocoa farm? In CSAE Conference.
- Sienso, G., Asuming-Brempong, S., & Amegashie, D. P. (2014a). Estimating the efficiency of maize farmers in Ghana. Asian Journal of Agricultural Extension, Economics and Sociology, Article No. AJAEES, 3(6), http://hdl.handle.net/123456789/2937
- SRID (2016). Agriculture in Ghana: Facts and Figures. Statistics, Research and Information Directorate -MoFA.
- Tesfaye, K., Gbegbelegbe, S., Cairns, J. E., Shiferaw, B., Prasanna, B. M., Sonder, K., ... Robertson, R. (2015). Maize systems under climate change in sub-Saharan Africa: Potential impacts on production and food security. International Journal of Climate Change Strategies and Management, 7(3), 247–271. https:// doi.org/10.1108/IJCCSM-01-2014-0005
- Valipour, M., Bateni, S. M., & Jun, C. (2021). Global surface temperature: A new insight. *Climate*, 9(5), 81. https:// doi.org/10.3390/cli9050081
- Villano, R., & Mehrabi Boshrabadi, H. (2010). When is metafrontier analysis appropriate? An example of varietal differences in pistachio production in Iran. *Journal of Agricultural Science and Technology*, 12(4), 379–389.
- Wiredu, A. N., Gyasi, K. O., Abdoulaye, T., Sanogo, D., & Langyintuo, A. (2010). Characterization of maize producing households in the Northern Region of Ghana. Country Report - Ibadan, Nigeria: CSIR/SARI - IITA, Ibadan, Nigeria. 24 pp. ISBN 978-978-50004-5-0
- Wongnaa, C. A., & Awunyo-Vitor, D. (2019). Scale efficiency of maize farmers in four agro ecological zones of Ghana: A parametric approach. Journal of the Saudi Society of Agricultural Sciences, 18(3), 275–287. https://doi.org/10.1016/j.jssas.2017.08.003
- Yiadom-Boakye, E. E. O.-S., Nkegbe, P. K., & Ohene-Yankyera, K. (2013). Gender,resource use and technical efficiency among rice farmers in the Ashanti Region. Ghana. Journal of Agricultural Economics and Development, 2(3), 102–110. http://hdl.handle.net/ 123456789/198



© 2022 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Under the following terms: Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

Cogent Economics & Finance (ISSN: 2332-2039) is published by Cogent OA, part of Taylor & Francis Group. Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com