ASSESSMENT OF TECHNICAL EFFICIENCY OF LAYER PRODUCTION IN MAMPONG MUNICIPALITY: STOCHASTIC FRONTIER APPROACH

Yenibehit, N.[1]
Murshed, M.[2+]
Islam, M. J.[3]

[1]Teaching and Research Assistant, Department of Agricultural Economics and Extension, University of Education, Winneba, Mampong Campus, Ghana
[2]Master of Science in Economics, North South University, Dhaka, Bangladesh
Email: muntasir.murshed@northsouth.edu
[3]Master of Science in Agricultural Economics, BSMRAU, Dhaka, Bangladesh
(+ Corresponding author)

ABSTRACT

This study used a Cobb-Douglas functional form of the stochastic production model to assess the technical efficiency of layer producers under commercial production system in the Mampong Municipality of Ghana. The study captures thirty (30) randomly selected layer poultry farms within the Asante Mampong enclave for the study. This study utilized the Maximum Likelihood Estimation (MLE) criteria to obtain farm specific technical efficiencies as well as their determinants of output and inefficiency. The study revealed that output was positively correlated to the number of birds, medication and quantity of water which all have significant coefficients at 5% and 10% levels of significance. The significant estimated gamma value of 0.99 implied that 99% of the total variation in layer output in the study area is due to the technical inefficiency. The study also showed that age, education, experience, extension contact, credit and type of poultry housing were related to socioeconomic characteristics influencing technical inefficiency. It is recommended for egg producers to observe the proper routine medication and add other supplementary drugs to boost the laying performance of their birds while intensifying stock size and increasing water usage to maximize production and close up the production gap. Poultry policies should consider motivating and increasing extension contact between extension agents and poultry farmers in the study area.

Contribution/Originality: The paper's primary contribution is finding that it captures thirty randomly selected layer poultry farms within the Asante Mampong enclave for the study by utilizing the Maximum Likelihood Estimation (MLE) criteria to obtain farm specific technical efficiencies as well as their determinants of output and inefficiency in the context of this municipality of Ghana.

1. INTRODUCTION

Sustainable agricultural practice reduces food loss and can play a key role in overall development of the economy [1, 2]. Thus, emphasis has to be given to this sector, particularly in the context of developing economies that are predominantly characterized as large agriculturally-intensified economies. The agricultural sector in Ghana has long been considered as a firm foothold of the country's economy and contributes 23% of Gross Domestic Products (GDP) while holding a share of 43% of national employment, with small scale farmers contributing 80% of all agricultural production [3]. The rapid population growth and urbanization is a driving force for increasing demand for livestock products including poultry and these have resulted in the expansion of the sector in recent times [4].

Poultry farming, especially on a commercial basis, is a major component of the agriculture sector of the country. Although the crops sector holds a major share of activity in the agricultural sector with about 14.2%, the livestock sub-sector of which the poultry sector is cardinal has maintained a study economic growth of 5.3% between 2014 to 2016 and has contributed a value of GHC 2119 as real GDP in 2017. Poultry production plays an important role in leading commercial activity and possesses enormous potential for quick economic growth especially when considering livestock – based vocations [5]. Poultry production according to Assa [6] is considered as a leader in the global meat production and is, therefore, recording faster growth in developing and transitional countries of the world. Among the subsidiary occupations of farmers, poultry farming is the foremost, supplementing farm's incomes with its quick returns and more importantly with minimum requirements for space, investment and expertise [7]. For instance in Ghana, there has been an increase in annual growth from 2000 to 2007 mostly in the southern part of the country with an 80% growth during this period [8].

Commercial poultry production in Ghana takes the form of raising birds for eggs (layer production system) or raising birds for meat (broiler production system). However, this commercial poultry industry is more tilted towards layer production with only some seasonal broiler production is undertaken to meet seasonal demands in festive seasons. Unlike broiler production, which faces stiffer competition with cheaper imported chicken parts form the EU, USA and Brazil, there is minimal competition in layer or egg production. It is, therefore, profitable to raise layers especially for the fact that about 80% of feed produced by commercial feed millers in the country is layer feed. According to FAO [9] the annual growth in consumption of eggs in Ghana from 1995 to 2005 was 4.0%. Poultry meat and eggs only hold an average share of 0.60% of the total daily calories consumed in Ghana. Killebrew and Plotnick [4] pointed out that, an estimated 1.2 kg of meat and 12 eggs is the annual per capita consumption of meat and eggs in Ghana as compared to the recommended world average of 9.7 kg of meat and 154 eggs per person per year. Meanwhile, in terms of productivity, a fowl have the ability to produce 300 eggs in its first year of laying life but under tropical conditions, potential fecundity ranges between 180-200 eggs although higher levels have been reported [10]. This further makes the sector a reliable sector for a fast and efficient source of animal protein and for closing the country's huge unemployment gap.

With these positive indicators supporting the prospects of the egg production sector of the poultry industry, one would have expected the sector to continue to grow but in recent times most farms have folded up and other large farms that were operating at full capacity are now operating below capacity. The recent crisis in the sector has been cited has been caused by the very high cost of production (feed, inputs and energy) and lack of credit [11]. Apart from the feed which constitutes a major cost of poultry production, prices of other inputs are increasing and therefore requires that the production process be devoid of wastages and ensure efficient output production. This requires empirical data on the technical efficiency of egg production in order to advice farmers. It, however, saddens to know that there is lean literature on technical efficiency of layer production. Most of the economically related researches in the poultry industry only focus on profitability [12] challenges and prospects Adei and Asante [13] and Etuah [14] who also focused on cost efficiency and economies of scale leaving an information lag in the area of technical efficiency of egg production. This study, therefore, seeks to assess the technical efficiency of layer production in the Asante Mampong Municipality of Ghana. The study will provide production efficiency data that can be used in policy direction and also consolidated the database of the poultry sector especially with regards to technical efficiency.

2. THEORETICAL FRAMEWORK OF TECHNICAL EFFICIENCY

The stochastic production frontier approach developed by Aigner, et al. [15] and Meeusen and Van Den Broeck [16] was adopted for this study by using the two-stage analysis method. In the first stage, an index of the vector of individual technical efficiency is generated for the sample layer producers in the study area. Whereas in the second stage, an econometric method is used to analyze and explain the intra-farms inefficiency.

The stochastic frontier production frontier is made up of a production function that has a composite error term that is equal to the summation of two error terms [17]. The random effects caused by the statistical or white noise constitute the first error term while the second component constitutes the socioeconomic factors or effects that are not explained by the production function but are associated with technical inefficiency. However, this cannot be captured by a conventional production function [17]. The frontier production function for this study is specified in Equation 1 as:

$$Yi = F(Xi; \beta) \exp(Vi - Ui) \tag{1}$$

where Yi is the output produced by farm i; Xi is an (n+1) row vector of inputs where the first element '1' represents the intercept and the other elements represent inputs quantities used to produce Y; β (n+1) represents a column vector of technological parameters to be estimated; Vi stands for a random error that is independently and identically distributed (iid) as $N(0, \sigma v^2)$; and Ui denotes a one-sided error $(Ui > 0, \cap i)$ that represents the technical inefficiency of the ith farm [17].

As defined in equation 1 above, the structure of technology of production, deterministic production frontier or external factors to the production process determine the stochastic production function. They are combined to produce the production frontier. From the above representation, the deterministic production function is $F(Xi; \beta)$ and the stochastic production function is represented as $F(Xi; \beta) \exp(vi)$.

From the output orientation method, the technical efficiency of the ith farmer can be calculated as the ratio of the observed output relative to the potential output as shown in Equation 2:

$$TEi = \frac{Yi}{F(Xi;\beta)\exp(vi)} = \frac{E\left(\frac{Yi}{ui'}, Xi\right)}{E\left(\frac{Yi}{ui'} = 0, xi\right)} \tag{2}$$

Efficiency assumes values between 0 and 1 with smaller ratios indicating higher inefficiency. TE is a measure of the actual output to the potential output as measured on the frontier and is produced from the same set of inputs from a fully efficient firm (u = 0), with values implying that actual output is equal to frontier output. The frontier output is gotten by obtaining estimates of technology parameter vector through econometric methods or linear programming techniques.

The Cobb-Douglas functional form is often used to estimate the production function parameters due to its ability to provide more efficient parameters [18]. Additionally, the output elasticities obtained from the Cobb-Douglas may be equivalent to elasticities from the log transformation specification at the sample mean. Following this tradition and for the purpose of this study, a Cobb-Douglas function for egg production in the Mampong Municipality is specified in Equation 3:

$$Yi = \beta \prod_{j=1}^{n} X_{ij}^{\beta i} \, e^{\varepsilon i} \tag{3}$$

where $\varepsilon_i = v_i - u_i$ with the subscript i indexing farmers and j indexing inputs use in production [17]. The log-linear transformation of the above equation, shown in Equation 4 gives the equation for estimating the parameters using frontier regression analysis:

$$Yi = \beta o \sum_{j=1}^{k} \beta_{ij}\, x_{ij} + \varepsilon_i \qquad (4)$$

where $Y_i = Ln\,(y_i)$; $\beta_o = Ln\,(b_o)$; $\beta_{ij} = Ln\,(b_{ij})$; $X_{ij} = Ln\,(x_{ij})$; $\varepsilon_i = Ln\,(e_i)$; Ln = natural logarithm. By this logarithmic expression of the stochastic production function, the technical efficiency according to Battese and Coelli [19] is specified in Equation 5 as:

$$TEi = \exp(-ui) \qquad (5)$$

In estimating stochastic frontier production effects of the socio-economic characteristics, the variation of the dependent variable (Y_i) is often lumped together with the error term, which takes account for the component of variation due to random, unsystematic and unexplained noise.

The error term (ε_i) is made up of two components, u_i and v_i, such that, $\varepsilon_i = v_i - u_i$, where v_i is a random error due to random factors out of control of the farmer with a zero mean and a variance equal to δ^2_v distributed as N $(0, \delta^2_v)$. The u_i component is inefficiency component of the error term assumed to have a non-negative half normal distribution truncated at zero and distributed as N $(0, \delta^2_u)$. It is associated with farm-specific factors and may also have other distributions such as gamma exponential. The mean values of u_i are determined by the equation $ui = \delta' Z + \omega i$ where Z_i represents inefficiency variable for the ith respondent; i = 1, 2......N; δ = vector of parameters to be estimated, ωi represents statistical random noise introduced to capture factors beyond farmers control and is independently and identically distributed (*iid*) as $N(0, \omega i)$. The inefficiency variables include farm characteristics such as gender, age, experience, extension contact, access to credit and poultry housing type. These factors can influence the level of technical efficiency among poultry farmers.

3. EMPIRICAL ESTIMATION OF TECHNICAL EFFICIENCY OF LAYER PRODUCERS

The stochastic frontier was estimated following the two-step estimation process. This was done by firstly using the linearly transformed Cobb-Douglass production function. The total number of crates of eggs produced per farmer over the production period (Y_i) was regressed against independent input variables including the number of birds, medication, the quantity of water, the quantity of feed and number of employees. The function is as specified in Equation 6 as:

$$lnY_i = \beta_0 + \beta_1\, lnX_{1i} + \beta_2\, lnX_{2i} + \beta_3\, lnX_{3i} + \beta_4\, lnX_{4i} + \beta_5\, lnX_{5i} + (V_i - U_i) \qquad (6)$$

where Y_i = quantity of eggs produced over the production period; X_1 = Number of birds; X_2 = medication; X_3 = quantity of water (l); X_4 = feeding; X_5 = Number of employees; β = the vector of input parameters to be estimated; v_i = random errors and u_i = represents technical inefficiency effects. In the second step, the maximum Likelihood method was used to assess the effect of various socio-economic variables on the variation of TE. The inefficiency component of the error term (u_i) was regressed against factors that are hypothesized to have an influence on the deviation of the observed output (Y_i) from the potential output level (Y*). This is shown in Equation 7:

$$u_{ij} = \delta_0 + \delta_{1Z1i} + \delta_{2Z2i} + \delta_{3Z3i} + \delta_{4Z4i} + \delta_{5Z5i} + \delta_{6Z6i} + \delta_{7Z7i} \qquad (7)$$

where; Z_1= gender of the farmers (dummy, male =1, female= 0); Z_2 = age of the farmers; Z_3 = experience of the farmers, Z_4 = Interactive term between age and experience of the farmers; Z_5 = extension contact; Z_6 =credit access (dummy, Access = 1, 0 = otherwise); and Z7 =housing type and $\delta_0, \delta_1, \delta_2$, ... δ_7 = parameter estimates of the linear regression model.

4. VARIABLES AND DATA

The Mampong Municipality which was chosen for this study is partly situated on the Mampong Scarp which runs eastwards. The highest point of the Municipality is 2,400m above sea level, while the lowest is about 135m. Thus, the Municipality is generally low lying and rise gradually through rolling hills stretching southwards towards Mampong. The Municipality is fairly drained by several streams and rivers. The municipality has several species of livestock with notable poultry farmers who are basically into egg production for supply to the urban area. Broilers are only raised during festive seasons in the short run.

Cross-sectional primary data was collected from poultry producers that are raising layers for egg production in the municipality. Simple random sampling was used to draw participants for the study using a list of poultry farmers listed with the help of MOFA staff in the municipality. Data was on socio-economic characteristics of the farmers, inputs used and outputs obtained. Output was measured as the number of crates of eggs produced within the production cycle of layers until taken like two years before they are deposed off. The number of birds was measured as the quantity of matured birds that were laying in the farm, medication was measured as the number of bottles of vaccines and other drugs from day-old to laying and at laying. Total water intake was recorded in liters of water used in the lifespan of the birds, the feed was recorded in kilograms of feed provided throughout the production, employees were considered as the number of laborers both family and hired labor working on the farm. Gender was a dummy variable with male = 1, female = 0; age was the age of the farmers in years; experience was the number of years in egg production; extension contact was considered as the frequency of interaction between a farmer and extension personnel in the two years period; credit is important and can influence production through expansion and was therefore dummied with farmers that have access assigned 1 and those without access given a value of 0; and lastly, housing was a dummy variable with wire mesh and concrete walls assigned 1, 0 = otherwise. The dataset was analyzed with the FRONT 4.1 software [20] and Microsoft Excel spreadsheet.

5. RESULTS AND DISCUSSIONS

5.1. Descriptive Statistics of Variables

The descriptive statistics of the poultry farmers as presented in Table 1 indicates that the mean age of the farmers was about 47.77 years and ranges from 32 and 61 years showing that the farmers were within the working population. The farmers have an average of almost 8 years of experience in a range of 3 and 15 years in the poultry business. This means almost all the farmers have rich experience in the layer production business.

There was a mean extension contact of 1.4 for two years with some farmers reported never having contact with any extension service although some have managed to get 3 extension contacts. There were about 3 employers per poultry farm in the study area. In terms of farm inputs, the reported mean feed intake was 38,275.47kg with a mean water intake in a production season which was defined as two years, as 7,622.67 liters. These were required to produce or cater for a mean number of 4669 birds that required a mean of about 8 bottles of all medication in the production cycle of the birds. The mean number of crates of eggs produced in the study area was recorded as 28,949.70 crates by the time the layers will be disposed off in two years' time.

Table-1. Descriptive statistics of Poultry farmers in Mampong Municipality.

VARIABLES	Units	MIN	MAX	MEAN	STD DEV	SKEWNESS
Output	Egg Crates	597.00	247,296.00	28,949.70	14.28	3.46
Number of Birds	Number	450.00	11,500.00	4,668.67	4,301.32	0.55
Drugs	Bottles	4.00	16.00	7.50	3.09	1.39
Water intake	Litres	600.00	30,000.00	7,622.67	8,251.92	1.74
Feed intake	Kilograms	15,392.00	60,736.00	38,275.47	38,275.47	0.31
Employees	Number	1.00	5.00	2.73	1.39	0.27
Age	Years	32.00	61.00	45.77	6.81	0.08
Experience	Years	3.00	15.00	7.90	3.09	0.56
Extension contact	Number	0	3	1.4	0.89	0.64
CATEGORICAL VARIABLE						
Variable	Label	Frequency		Percentage		
Gender						
	Male = 1	22		26.7		
	Female=0	8		73.3		
Credit Access						
	Access= 1	7		23.3		
	No access= 0	23		76.7		
Housing Type						
	Concrete = 1	24		80.0		
	Mudhouse=0	6		20.0		

Source: Authors' computation, 2018.

In terms of the categorical variables included in the study, 22 (73.7%) were males with only about 8 (23.3%) of the farmers being females. The dominance of the males could be due to the tedious nature of the business and high risk involved in the venture. Very few farmers (7) representing 23.3% of the respondents claim they have access to credit whereas about 76.7% reported not having access to credit. The gross high reportage in lack of access to credit could be as a result of collateral requirements of most of the financial institutions and the lack of interest in most of them to advance credit to people involved in agriculture. Most of the farmers (80%) were able to build their poultry houses with concrete whereas only 20% of them use mud houses to house their birds.

5.2. Stochastic Production Frontier Function

The Maximum Likelihood Estimates presented in Table 2 indicates that three independent variables were positive and significant at 10% and 5% levels, implying that a percentage increase in any of these variables (Number of birds, medication, and Quantity of water) will result in an increase in output. As seen in the table, if the number of birds is increased by 1%, the output will increase by 11.4%. Medication also has a significant effect on output such that when increased by 1%, the output will increase by 79.7%. Increasing the quantity of water (ml) by 1%, resultantly increases output by 80.6%. A positive significant influence of stock size was also reported in the studies of Ezeh, et al. [21] and Adepoju [22].

Table-2. Maximum Likelihood Estimates.

Variables	Parameter	Coefficient	Standard error	t-ratio
Constant	β_0	0.172	0.078	2.205
Number of birds	β_1	0.114**	0.038	3.000
Medication	β_2	0.797**	0.261	3.054
Quantity of water	β_3	0.806*	0.087	9.264
Feeding	β_4	-0.303	0.042	7.214
Number of employees	β_5	-0.634	0.076	8.342
sigma-squared		0.821	0.259	3.170
Gamma		0.999	0.135.	7.400

Note: Significant Codes '**'0.05 '*'0.01
Source: Authors' Computation, 2018.

The sigma-squared (0.821) is significantly different from zero, indicating good fit and correct specification of the model. The value of Gamma measures the relationship between random variations in the use of inputs. Gamma in this study is computed as 99% and therefore indicates that the random variation in egg production in the study area is explained by inefficiency in resource utilization.

5.3. Determinants of Technical Inefficiency

A negative sign on inefficiency variables means that the variables increase T.E, while a positive sign reduces T.E. All the independent variables were expected to have a negative sign, which implies a positive sign for any quadratic term. From Table 3, producers Age (-0.0039), Gender (-0.0828), Interactive term, thus age and experience (-0.0003), and extension contact (-0.4354), all have negative coefficients, implying that, these variables influence the level of technical efficiency of the farmers. While Experience (+0.0171), Credit (+0.0138), and Housing type (+0.1065) were positive implying that, these variables reduce T.E and rather tend to increase inefficiency among egg producers in the study area. The inefficiency input variables in Table 3 were all statistically significant at 10%, 5% and 1% significant levels respectively. These variables have been reported in several studies including Ezeh, et al. [21].

Table-3. Determinants of technical inefficiency.

Variables	Parameters	Coefficient	Standard Error	t- ratio
Constant	Z_0	0.8579*	0.0619	13.839
Gender	Z_1	-0.0828**	0.0326	-2.543
Age	Z_2	-0.0039**	0.0023	-1.752
Experience	Z_3	0.0171**	0.0099	1.713
Age*Experience	Z_4	-0.0003**	0.0002	-1.820
Ext. Contact	Z_5	-0.4354***	0.0439	-9.919
Credit Access	Z_6	0.0138**	0.0133	1.038
Housing Type	Z_7	0.1067**	0.0719	1.482

Significant Codes '***' 0.001 '**'0.05 '*'0.01

Source: Authors' Computation, 2018.

6. CONCLUSIONS

This study used Cobb-Douglas log transformed function to assess the technical efficiency of 30 randomly selected layer producers in Mampong municipality. A FRONT 4.1 software that incorporates inefficiency factors were used to estimate the Maximum Likelihood Estimation (MLE), provided farm specific technical efficiencies as well as their determinants of output. The results revealed a positive and significant influence of the number of birds, medication and water intake to the number of crates of eggs produced in the study area. Farm-specific and socioeconomic factors that were chosen for the study also showed that all the selected factors had varying significance in influencing technical inefficiency positively or negatively. Age, gender and extension contact increase Technical Efficiency while experience, credit access and housing type rather decrease Technical Efficiency and increases technical inefficiency.

It is recommended for egg producers to observe the proper routine medication and add other supplementary drugs to boost the laying performance of their birds while intensifying stock size and increasing water usage to maximize production and close up the production gap. Proper housing structures should be provided and extension contact increased to reduce inefficiency among farmers.

REFERENCES

[1]   M. J. Islam, M. Kamruzzaman, M. J. Uddin, and S. J. Rayhan, "Growth rate and marketing channel identification of seasonal fruits: An empirical study based on Chittagong Hill Districts of Bangladesh," *International Journal of Economics, Commerce and Management*, vol. 5, pp. 186-200, 2017.

[2]   M. J. Islam, "Contextual estimation of marketable and marketed surplus of selected seasonal fruits: A study based on Chittagong Hill tracts (CHT) of Bangladesh," *International Journal of Sustainable Agricultural Research*, vol. 6, pp. 21-32, 2019. Available at: https://doi.org/10.18488/journal.70.2019.61.21.32.

[3]   A. S. P. R. Monitoring and Evaluation Directorate, "Monitoring and evaluation directorate agricultural sector progress report, 2016. Ministry of Food and Agriculture, Accra, Ghana." Available: http://www.mofa.gov.gh. [Accessed 25th August, 2018], 2017.

[4]   K. Killebrew and R. Plotnick, "Poultry markets in West Africa Ghana. Evans school of policy analysis and research," in *Prepared for the Market Access Team of the Bill & Melinda Gates Foundation. EPAR Brief 83*, 2010.

[5]   P. Ekunwe, O. Soniregun, and J. Oyedeji, "Economics of small scale deep litter system of egg production in Oredo local government area of Edo State, Nigeria," *International Journal of Poultry Science*, vol. 5, pp. 81-83, 2006. Available at: https://doi.org/10.3923/ijps.2006.81.83.

[6]   M. Assa, "Poultry production and rural poverty among small-scale farmers in Mzimba District of Malawi," 2012.

[7]   K. Rajendran and S. Mohanty, "Comparative economic analysis and constraints in egg production under cage vs. deep litter systems of rearing in India," *International Journal of Poultry Science*, vol. 2, pp. 153-158, 2003. Available at: https://doi.org/10.3923/ijps.2003.153.158.

[8]   Food and Agricultural Organization, "The structure and importance of the commercial village based poultry in Ghana," *Poultry Review Report*, 2014.

[9]   FAO, *Food and agricultural organisation statistics book on national crop production*. Rome, Italy: FAQ, 2005.

[10]   A. Kumar and U. Pandey, "Growth performance of livestock sector in India." Sources of Growth in Livestock Sector, Policy Paper No. 9, 1999.

[11]   L. Flake and E. Ashitey, "Ghana's poultry and products annual Report," USDA Foreign Agriculture Services GAIN Report2008.

[12]   B. T. Anang, C. Yeboah, and A. A. Agbolosu, "Profitability of broiler and layer production in the Brong Ahafo region of Ghana," *Journal of Agriculture and Biological Science*, vol. 8, pp. 423-430, 2013.

[13]   D. Adei and B. Asante, "The challenges and prospects of the poultry industry in Dormaa District," *Journal of Science and Technology (Ghana)*, vol. 32, pp. 104-116, 2012. Available at: https://doi.org/10.4314/just.v32i1.11.

[14]   S. Etuah, "Cost efficiency and economies of scale in broiler production in Ghana. A case study of the Ashanti Region," (Doctoral Dissertation), 2014.

[15]   D. Aigner, C. K. Lovell, and P. Schmidt, "Formulation and estimation of stochastic frontier production function models," *Journal of Econometrics*, vol. 6, pp. 21-37, 1977. Available at: https://doi.org/10.1016/0304-4076(77)90052-5.

[16]   W. Meeusen and J. Van Den Broeck, "Efficiency estimation from Cobb-Douglas production functions with composed error," *International Economic Review*, vol. 18, pp. 435-444, 1977. Available at: https://doi.org/10.2307/2525757.

[17]   B. Ben-Belhassen and A. W. Womack, *Measurement and explanation of technical efficiency in Missouri hog production*. Tampa FL: In American Agricultural Economics Association Annual Meeting, 2000.

[18]   S. Yao and Z. Liu, "Determinants of grain production and technical efficiency in China," *Journal of Agricultural Economics*, vol. 49, pp. 171-184, 1998. Available at: https://doi.org/10.1111/j.1477-9552.1998.tb01262.x.

[19]   G. E. Battese and T. J. Coelli, "Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India," *Journal of Productivity Analysis*, vol. 3, pp. 153-169, 1992. Available at: https://doi.org/10.1007/bf00158774.

[20]   T. J. Coelli, "A guide to FRONTIER version 4.1: A computer program for stochastic frontier production and cost function estimation. CEPA Working Papers," vol. 7, pp. 1-33, 1996.

[21]   C. Ezeh, C. Anyiro, and J. Chukwu, "Technical efficiency in poultry broiler production in Umuahia capital territory of Abia State, Nigeria," *Greener Journal of Agricultural Sciences,* vol. 2, pp. 001-007, 2012. Available at: https://doi.org/10.15580/gjas.2013.3.1206.

[22]   A. Adepoju, "Technical efficiency of egg production in Osun State," *International Journal of Agricultural Economics and Rural Development,* vol. 1, pp. 7-14, 2008.