DATA ENVELOPMENT ANALYSIS (DEA) APPROACH FOR ASSESSING TECHNICAL, ECONOMIC AND SCALE EFFICIENCY OF BROILER FARMS

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ABSTRACT

This study was surveyed and evaluated technical, economic and scale efficiency of broiler farms in Egypt using DEA technique. So as to accomplish the specified aim, stratified random sampling technique was utilized to gather information from 150 broiler farms. The results showed that mean technical efficiencies of broiler farms were 0.915 and 0.985 under constant returns to scale (CRS) and variable returns to scale (VRS) respectively, implying that on average the farms could reduce input utilization by 8.5% and 1.5% for production level of output to be technically efficient. Notably, 48.7% of the farms were estimated fully technical efficient under VRS-model. The mean allocative and economic efficiency of the farms were assessed as 0.941 and 0.918 respectively, with only 2% of the farms were fully allocative and economic efficient. Furthermore, the average scale efficiency was 0.929 with the majority of broiler farms (82%) were operating with increasing returns to scale. The estimated Tobit regression showed that farmer's age, education, experience, access to extension services, and level of training were the most significant variables contributing to the disparities in efficiency of broiler farms. Such results are useful for extension workers and policy makers so as to guide policies towards expanding efficiency.

Key words: input utilization , stratified random , technical fficiency, VRS model.

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نهج تحليل مغلف البيانات (DEA) لتقييم الكفاءة التقنية والاقتصادية وكفاءة السعة لمزارع دجاج التسمين

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المستخلص

قامت هذه الدراسة بمسح وتقييم الكفاءة التقنية والاقتصادية وكفاءة السعة لمزارع دجاج التسمين في مصر باستعمال تحليل مغلف البيانات. ولتحقيق الهدف المحدد، تم استعمال تقنية أخذ العينات العشوائية الطبقية لجمع البيانات من 150 مزرعة لدجاج التسمين. أظهرت النتائج أن متوسط الكفاءة التقنية لمزارع التسمين كان 0.915 و 0.985 في ظل عوائد السعة الثابتة (CRS) وعوائد السعة المتغيرة (VRS) على التوالي ، مشيرا الي أن المزارع في المتوسط يمكن أن تقلل من استعمال المدخلات بنسبة 8.5% و 1.5% للوصول الي الكفاءة التقنيه. ومن الجدير بالذكر أن 48.7% من المزارع تم تقديرها بكفاءة تقنية كاملة في ظل عوائد السعة المتغيرة (VRS). تم تقييم متوسط الكفاءة التوزيعية والاقتصادية للمزارع عند 0.941 و 0.918 بالتتابع ، مع 2% فقط من المزارع ذات كفاءة توزيعية واقتصادية كامله. علاوة على ذلك ، كان متوسط كفاءة السعة 0.929 حيث كانت غالبية مزارع دجاج التسمين (82%) تعمل تحت زيادة العائد للسعة. أظهر انحدار Tobit التقديري أن عمر المزارع ، وتعليمه، وخبرته، وتوافر الخدمات الإرشادية، ومستوى التدريب كانت من أهم المتغيرات التي ساهمت في التباين في الكفاءة بين مزارع الدجاج التسمين. هذه النتائج مفيدة للعاملين في مجال الإرشاد وصناع السياسات لتوجيه السياسات نحو زيادة الكفاءة.

الكلمات المفتاحية: الكفاءه، التقنية، الاقتصادية، مزارع التسمين، تحليل مغلف البيانات

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INTRODUCTION

The principle of efficiency is known to be a core of economics as it is the crucial factor to achieve the ultimate objective of sustainable development for policy makers and primary producers. It is the state in which the greatest yield for a given set of inputs is achieved (1). So with the extensive rise in the depletion of resources, the efficiency analysis has become an essential and extensive field of research (2). In modern economic, several approaches for efficiency valuation have been established and categorized into two main classes: parametric and non-parametric frontiers (3, 4). They evaluate efficiency by comparing enterprises with ″the best practice″ efficient frontiers created by the most productive enterprises in the sample (5). The parametric approach of efficiency analysis has considerable advantages by enabling the use of panel data, separating random noise from inefficiency and measuring the standard error of efficiency measurement results (6). However, this method requires functional form of production to be defined (7). In contrast, the non-parametric model does not include this specification and estimates the efficiency of all decision making units (DMUs) without requiring priori weights for the inputs and outputs (8). The main drawback of non-parametric approach is that no noise is considered and any deviation from the frontier is a result of inefficiency (9). Since both parametric and non-parametric procedures have its benefits and drawbacks, the determination of assessment techniques has been an issue of discussion and depends basically on information accessibility. In general, the non-parametric Data Envelopment Analysis (DEA) frontier is the most utilized methodology in various economic and management science aspects (10). DEA is a non-parametric deterministic approach for assessing the relative efficiencies of multi-input and multi-output DMUs (11). It also gives direction on how the inefficient production units could get efficiency; utilizing the idea of an efficient decision-making unit reference group which produces a similar output (12). The strength of DEA methodology is that it avoids parametric specification of technology as well as the inefficiency distributional assumption (13). Additionally, DEA is a flexible method that can effectively meet application needs and objectives as it approaches assessment from a multidimensional viewpoint. Nevertheless, since the DEA is non-stochastic, noise is recorded as inefficiency, it is probably to be sensitive to outliers and errors in measurements (14); however this issue can be solved by using a bootstrapping method by Simar and Wison (15). Recently, DEA has been used effectively in estimating the efficiency of livestock-producing farms, such as pig farms (16, 17), dairy farms (18, 19), small ruminant farms (20), laying hen farms (21, 22) and broiler farms (23, 24). In efficiency study, it is not just the degree of inefficiency that is fundamental, but the identification of the socio-economic and institutional factors causing it. The standard approach is that regressed efficiency or inefficiency index as a dependent variable against a variety of explanatory variables known to affect efficiency levels (25, 26). Formal studies identified farm size, years of experience, educational level, household size, extension to services and access to institutions as explanatory variables to efficiency (27, 28, 29). So, this study was done in an attempt to study how to use non parametric DEA technique to assess technical, economic and scale efficiencies of broiler farms. In addition, it is also aimed to gauge the socio-economic determinants of efficiency estimates using a Tobit regression model.

MATERIALS AND METHODS

Data collection: A stratified random sampling methodology was implemented to pick 50 farms from three provinces in Egypt to make a total sample size of 150 broiler farms; all farms of medium-scale (5000-10000 bird, the predominant scale of commercial broiler production in Egypt). Input quantities, input values, prices and output data for efficiency scores estimation were derived from accurate records of farms for the production year 2019 (five cycles per year; Table 1). The data set included cumulative chick weight, cumulative feed intake, labour, fuel, electricity, drug cost and depreciation cost, as well as broiler production as output. Input unit price of day old chick, feed, labour, fuel and electricity were obtained for the allocative and economic analyses. Secondary socio-economic data (age, gender, education level, family size, years of experience, main occupation, access to extension services and training exposure) were collected using pre-tested structured questionnaire for Tobit regression.

Table 1. Descriptive statistics of variables used in DEA analysis. Source: Survey data estimates, 2019

Variables	Unit	Mean	SD	Minimum	Maximum
Output					
Broiler production	**Kg (1000 bird)$^{-1}$**	**1980.83**	**157.36**	**1735.00**	**4288.00**
Inputs					
Day old chick	**.kg (1000 bird)$^{-1}$**	**46.94**	**1.90**	**41.71**	**52.08**
Feed	**kg (1000 bird)$^{-1}$**	**3902.71**	**190.24**	**3510.00**	**4300.00**
Labour	**h (1000 bird)$^{-1}$**	**71.55**	**8.46**	**60.00**	**89.00**
Diesel Fuel	**L (1000 bird)$^{-1}$**	**264.26**	**174.09**	**97.00**	**590.00**
Electricity	**kWh (1000 bird)$^{-1}$**	**605.44**	**72.03**	**501.00**	**797.00**
Veterinary costs	**$ (1000 bird)$^{-1}$**	**155.27**	**25.52**	**109.72**	**244.78**
Depreciation costs	**$ (1000 bird)$^{-1}$**	**54.57**	**7.36**	**39.41**	**79.25**
Input prices					
Day old chick	**$(chick)$^{-1}$**	**0.54**	**0.16**	**0.26**	**0.82**
Feed	**$ (kg)$^{-1}$**	**0.49**	**0.04**	**0.41**	**0.57**
Labour	**$ (h)$^{-1}$**	**1.18**	**0.14**	**1.00**	**1.50**
Fuel	**$ (L)$^{-1}$**	**0.271**	**0.002**	**0.269**	**0.278**
Electricity	**$ (kWh)$^{-1}$**	**0.045**	**0.004**	**0.041**	**0.049**

Model specification

DEA is a mathematical model using linear programming approaches to create a non-parametric piecewise surface (or frontier) across the data, so that efficiencies can be calculated in relation to this surface (Fig.1; 30). DEA was suggested in late seventies by Charnes et al. (31); they set up a model of constant returns to scale (CRS) named the CCR. The model was later adjusted by Banker et al. (32) to enable the presence of variant returns to scale (VRS) and became identified as BCC model. DEA's efficiency is explained in three main structures: technical efficiency, allocative efficiency and economic efficiency. The efficiency scores of all these forms are always less than or equal to one.

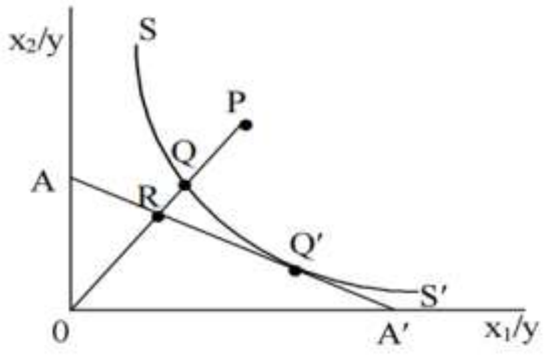

Figure 1. Graphic representation of frontier isoquant.

Source: Coelli (30)

The isoquant SS′ represents the fully efficient farms. The point Q is technically efficient since it lies on the efficient isoquant and has a value of 1. Point P is an inefficient farm with the level of technical inefficiency equal QP/0P, that reflects the ratio by which all inputs can be minimized. The ratio 0Q/0P represents the technical efficiency (TE) of P and is equal to one minus QP/0P. If the isocost, represented by the line AA′, is also identified, the allocative efficiency (AE) of P is defined as 0R/0Q ratio, since the distance RQ reflects a decrease in the cost of production if the farm operates at both technically and allocatively efficient point Q′, rather than at the technically efficient, but allocatively inefficient, point Q. The ratio 0R/0P represents the economic efficiency (EE) of farms, where the distance RP can also be described in terms of expense lessening. The technical efficiency (TE) could be evaluated by how much feasible output is maximized for a limited set of inputs (output-oriented model) or feasible inputs are minimized for a specified level of output (input-oriented model) (33, 34). For the purpose of current analysis, input-oriented model was evaluated under CRS and VRS. Input-oriented approaches were chosen because the producer can control the inputs more than the production levels in the farming system. The CRS linear programming problem can be described as follows (30).

$$\mathrm{Min}_{\theta,\lambda}\,\theta$$

Subject to

$-y_i + Y\lambda \geq 0,$

$\theta_{xi} - X\lambda \geq 0,$

$\lambda \geq 0,$ (Eq. 1)

Where θ is a scalar and λ is a Nx1 vector of constants. The terms x_i and y_i represented the vectors of output and input data for the i-th farm. The value θ is a score always lying between zero and one, with a value of one showing that the farm lied on the frontier and is efficient. The CRS linear programming issue can be changed to represent VRS by including the convexity constraint: N1′λ=1 to provide

$$\mathrm{Min}_{\theta,\lambda}\,\theta$$

Subject to

$-y_i + Y\lambda \geq 0,$

$\theta_{xi} - X\lambda \geq 0,$

$N1'\lambda = 1$

$\lambda \geq 0,$ (Eq. 2)

Where N1 is an Nx1 vector of ones. The VRS specification guaranteed that inefficient farms were only benchmarked against farms with a comparable scale of production (35). By using this configuration, we can evaluate the scale efficiency (SE) that represents the point at which the farm reached the ideal scale for maximizing productivity. The scale efficiency of productive unit is defined to be the ratio TE_{CRS} / TE_{VRS} (36). If there is a disparity for a particular farm in the two TE scores, this means that farm has scale inefficiency, which is equal to the difference between TE_{VRS} and TE_{CRS} value. The main drawback in the estimation of scale efficiency is that the score doesn't show if farm inefficiency is the result of declining returns to scale (DRS) or increasing returns to scale (IRS). This constraint was overcome by implementing an additional DEA problem with non-increasing returns to scale (NIRS) through altering DEA model in eq.2 by replacing N1′λ=1 restriction with N1′λ≤1. If TE_{NIRS} equal TE_{VRS}, the farm exhibits DRS (larger than optimal scale); if $TE_{NIRS} \neq TE_{VRS}$, the farm exhibits IRS (suboptimal scale; 26).Two additional measurements of efficiency were established, taking into account input prices: allocative and economic efficiency. Allocative efficiency (AE) evaluates farmers' potential to utilize resources in ideal quantities, given input prices (37), whereas the economic efficiency (EE) is a product of technical and allocative efficiency (38). The economic efficiency is assessed in two steps; firstly a cost-minimizing vector of input quantities is determining, given the input prices under VRS assumption as follows (30) $\mathrm{Min}_{x_i^*,\lambda}\ w_i' x_i^*$

Subject to

$-y_i + Y\lambda \geq 0,$

$x_i^* - X\lambda \geq 0,$

$N1'\lambda = 1$

$\lambda \geq 0,$ (Eq. 3)

Where w_i is the input price vector for the i-th farm and x_i^* (computed using linear programming) is the cost-minimizing vector of input quantities for the i-th farm, given the input prices w_i and the output levels y_i. The economic efficiency (EE) of the i-th farm is then estimated as the ratio of the minimum cost to observed cost,

$EE = w_i' x_i^* / w_i' x_i$ (Eq. 4)

Residually, the allocative efficiency would be calculated as

$AE_i = EE_i / TE_i$ (Eq.5)

Where EE_i is the economic efficiency of i-th farm and TE_i is the technical efficiency of i-th farm. Like TE, the value for AE and EE will be ≤ one with highest efficiency equal one and present on frontier. The findings of standard DEA models classify the DMUs into efficient and inefficient units. Based on efficiency scores, inefficient units can be ranked; whereas all efficient DMUs have an efficiency score of one.

Tobit regression

Regression analysis was performed to assess the influence of certain socio-economic factors on production efficiency scores. A two-limited Tobit model (39) was utilized in this investigation, since the efficiency scores are constrained in the range from zero to one. The Tobit equation is described as follows:

$y_i^* = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + \beta_8 x_{8i} + \varepsilon_i \sim IN(0, \sigma^2)$

(Eq. 6)

Where,

y_i^*= Latent dependent variable representing the efficiency score for farm i

x_{1i}= Farmer’s age (years)

x_{2i}= Farmer's gender (Dummy 0 = female; 1= male)
x_{3i}= Level of education (years)
x_{4i}= Farming experience (years)
x_{5i}= Family size (number of household persons)
Main occupation (Dummy 1= broiler farmers; 0= otherwise)
x_{7i}= Access to extension services (Dummy 1= have access to extension; 0= otherwise)
x_{8i}= Training exposure (Dummy 1= exposed to training; 0= otherwise)
β_0 = Constant
β_{1i}–β_{8i}= Regression coefficients
ε_i= Error term that is independently and normally distributed with zero mean and constant variance σ^2

Denoting y_i (efficiency score calculated using DEA analysis) as the observed dependent variables,

$y_i = 1$ if $y_i^* \geq 1$
$y_i = y_i^*$ if $0 < y_i^* < 1$
$y_i = 0$ if $y_i^* \leq 0$

The efficiency scores were estimated using DEAP v. 2.1 (Centre for Efficiency and Productivity Analysis, Armidale, Australia). STATA v. 14 (StataCorp LP, College Station, Texas, USA) was used for Tobit regression estimation.

RESULTS AND DISCUSSION

The findings in Table 2 reveal that the technical efficiency score of the broiler farms ranged from 0.786 to 1.00 and 0.883 to 1.00 with the mean value of 0.915 and 0.985 under CRS and VRS, respectively. The mean value implies that the farms can produce on the efficient frontier if their input use is reduced by 8.5% and 1.5% without any decrease on their outputs. The average AE, EE, and SE were 0.941, 0.918 and 0.929, respectively. Estimates of AE and EE indicate that the production cost could be reduced by approximately 5.9% and 8.2% to achieve the same output level under VRS assumption. This was comparable to the reported efficiency scores of broiler farms in Yazad Province, Iran (40), but lower than those estimated for broiler enterprises by Begum et al. (23) in Bangladesh and Mahjoor (41) in Iran. As indicated by Kelly et al. (42) different production systems may have diverse efficiency scores under various climatic regional conditions. In addition, efficiency is a relative concept affected by differences in methodology choice, variables specification, and production costs.

Table 2. Summary statistics of efficiency scores in broiler production

Efficiency	Mean	SD	CV	Minimum	Maximum
TE_{CRs}	0.915	0.06	6.56	0.786	1.00
TE_{VRS}	0.985	0.02	2.03	0.883	1.00
AE	0.941	0.04	4.25	0.804	1.00
EE	0.918	0.04	4.36	0.792	1.00
SE	0.929	0.05	5.38	0.791	1.00

TE_{crs}, technical efficiency at constant returns to scale; TE_{vrs}, technical efficiency at variable returns to scale; AE, allocative efficiency; EE, economic efficiency; SE, scale efficiency; SD, standard deviation; CV, coefficient of variation.

The efficiency estimated regarding returns to scale; grouped into increasing, decreasing and constant returns to scale (IRS, DRS, and CRS) is appeared in Table 3. The results showed that 13.3% of the farms were operating with constant returns to scale (optimum size). Among the scale inefficient farms, about 82% of farms exhibit increasing returns to scale (suboptimal size), thereby suggesting that farms are able to increase their earning by growing their size, and only 4.7% exhibit decreasing returns to scale. Similarly, Eze et al. (43) assessed resource use efficiency and returns to scale among broiler farmers and demonstrated that most farmers were working under increasing returns to scale, with 1.14 production elasticity.

Table 3. Returns to scale summary statistics of 150 broiler farms

Scale classification	Number	Percent
CRS	20	13.3%
IRS	123	82.0%
DRS	7	4.7%
Total	150	100%

CRS, constant returns to scale; IRS, increasing returns to scale; DRS, decreasing returns to scale

The distribution of efficiency scores for CRS-DEA model revealed that approximately 18% of the farms in the study were operating at full efficient, while the majority of inefficient farms (43.3%) were in the TE range of 0.91-0.99 (Table 4). Results from VRS-DEA model showed that 48.7% of the farms were technically efficient, having an efficiency score of 1. As is obvious, 99 units (66%) had an efficiency score of 0.99-0.91 for allocative efficiency and 78 units (52%) had the same rating for economic efficiency**,** while only 2% (n=3) of the farms were determined as economically efficient. This large grade of technical and economic efficiency proposes that so little outputs are being lost to waste resources (44), implies that farmers use their resources efficiently and produce at the lowest cost. As shown in Table 4, the rate of scale efficiency for 20 units (13.3%) was unitary, which means they operate at most productive scale size. About 46.7% of the farms were over 0.90 scale efficiency, which is consistent with previous reports that majority of inefficient broiler farmers in Yazad Province, Iran (45) and central Saudi-Arabia (46) were in scale efficiency range 0.90-0.99.

Table 4. Frequency distributions of efficiency scores obtained with data envelopment analysis model

	TE_{CRS}		TE_{VRS}		AE		EE		SE	
Effiency range	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1.00	**18**	**12.0**	**73**	**48.7**	**3**	**2.0**	**3**	**2.0**	**20**	**13.3**
0.91-0.99	**65**	**43.3**	**72**	**48.0**	**99**	**66.0**	**78**	**52.0**	**70**	**46.7**
0.81-0.90	**63**	**42.0**	**5**	**3.3**	**46**	**30.7**	**64**	**42.7**	**57**	**38.0**
0.71-0.80	**4**	**2.7**	**-**	**-**	**2**	**1.3**	**5**	**3.3**	**3**	**2.0**
Sum	**150**	**100%**	**150**	**100%**	**150**	**100%**	**150**	**100%**	**150**	**100%**
Mean efficiency	**0.915**		**0.985**		**0.941**		**0.918**		**0.929**	

TE_{crs}, technical efficiency at constant returns to scale; TE_{vrs}, technical efficiency at variable returns to scale; AE, allocative efficiency; EE, economic efficiency; SE, scale efficiency.

Table 5 shows input slacks for broiler farms in the study area. A slack variable represents the quantity by which a particular input could be diminished without altering the production levels. The maximum contribution to input saving is 33.16% from diesel fuel, followed by veterinary costs (14.16%), labour (10.06%) and electricity (9.84%) involving 31, 44, 58, and 32 farms, respectively. While, the feed showed the lowest saving percent (2.58%). Similarly, Heidari et al. (45) stated that a total energy saving of 11% could be achieved for broiler production, with a maximum contribution (58 %) of the total energy savings from diesel fuel. However, Amid et al. (47) reported that the electricity shows the highest saving percentage (19%) for broiler production, followed by human labour (18.17%), and fuel (16.96%). Sefeedpari et al. (48) indicated that the greatest contribution to overall energy saving for egg production was 82% from feed intake, followed by fuel (12%) and equipment (4%).

Table 5. Input slacks and number of farms using excess inputs

Input	**Number of farms**	**Mean slack**	**Mean input use**	**Saving (%)**
Feed (kg/1000 bird)	**20**	**101.33**	**3925.98**	**2.58**
Labour (h/1000 bird)	**58**	**7.29**	**72.46**	**10.06**
Fuel (L/1000 bird)	**31**	**88.15**	**265.83**	**33.16**
Electricity (kWh/1000 bird)	**32**	**59.78**	**607.48**	**9.84**
Veterinary cost ($/1000 bird)	**44**	**22.26**	**157.21**	**14.16**

Tobit analysis results of socio-economic determinants of efficiency scores are listed in Table 6. The results demonstrated that age of farmers had no significant impact on technical efficiency under CRS and VRS models. However, age coefficient for AE and EE models was found to be negative and statistically significant (P = 0.031 and 0.029, respectively), implying that these efficiency measures could be improved by decreasing age of farmers and consistent with a priori expectation that managerial activities required in farming decreases with older age. This is in line with findings published by Pakage et al.

(49) and indirect contradiction to those reported by Begum et al. (23) who stated that age was positively related to farm's allocative efficiency. As expected, the education level and experience had a positive and highly significant (P < 0.01) impact across all efficiency measures, in agreement with Begum et al. (50) and Areerat et al. (51). However, Wadud (52) reported that level of education was not significant on its effect on efficiency scores. Udho & Etim (53); Ashagidigbi et al. (54) reported that years of experience and educational status of the farm operator has a negative influence on the efficiency of the farm unit.

Table 6. Tobit regression analysis of socio-economic factors associated with efficiency of broiler farms

Independent variables	TE_{CRS}	TE_{VRS}	AE	EE
Age	- 0.006 (0.008)	- 0.009 (0.018)	- 0.012 (0.003)**	- 0.011(0.005)**
Gender	0.023 (0.031)	0.039 (0.041)	0.021 (0.045)	0.043 (0.056)
Education	0.054 (0.007)***	0.062 (0.001)***	0.036 (0.004)**	0.021 (0.003)***
Experience	0.158 (0.034)***	0.234 (0.021)***	0.266 (0.013)***	0.098 (0.010)***
Family size	0.008 (0.015)	0.005 (0.006)	0.013 (0.021)	0.002 (0.005)
Main occupation	0.017 (0.026)	0.019 (0.023)	- 0.007 (0.009)	0.029 (0.008)***
Access to services	0.072 (0.003)**	0.041 (0.010)**	0.030 (0.005)**	0.002 (0.004)
Training	0.369 (0.017)***	0.298 (0.010)***	0.118 (0.124)	0.079 (0.011)**
Constant	1.093 (0.064)***	1.054 (0.015)***	1.618 (0.154)***	0.976 (0.044)***
Log likelihood	71.62	87.40	111.56	121.81

TE_{crs}, technical efficiency at constant returns to scale; TE_{vrs}, technical efficiency at variable returns to scale; AE, allocative efficiency; EE, economic efficiency
Asterisks ** and * represent statistical significance at the 5% and 1% levels, respectively**
Numbers in parentheses are standard errors

The results also showed that coefficients for gender and family size were not significant in any efficiency score model. In contrast, Areerat et al. (51) reported a positive relationship between family size and technical, allocative and scale efficiency of broiler farms under CRS-DEA model. Yusuf & Malono (44) pointed that housholdsize had significant impact on technical efficiency of egg production farms. Main occupation was positive and significant (P = 0.009) for only EE score, which is consistent with Begum et al. (23). However, the estimated coefficients of access to services displayed a direct and substantial influence on TE_{CRS}, TE_{VRS}, and AE measures (P = 0.038, 0.041 and 0.012, respectively), but insignificant in economic efficiency model. While training did not significantly affect allocative efficiency scores, it had a positive and significant effects on TE_{CRS}, TE_{VRS}, and EE scores (P = 0.001, 0.008 and 0.016, respectively). Similarly, Begum et al. (50) and Islam et al. (55) demonstrated that training was linked positively and significantly to technical and economic efficiency scores, while had no impact on allocative efficiency. From obtained data in this study, most farms have high technical, allocative, economic and scale efficiencies, meaning that inputs are utilized at the lowest level and in proper combination to achieve cost minimization, and farms are close to optimal size. The farm households were commonly operating under increasing returns to scale. Age of proprietor, educational status, years of experience and training are the factors which pertinently affected the efficiency of the sampled farms.

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