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Assessing Performance and Economic Efficiency of Table Eggs Production in Southern Togo

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ABSTRACT

Ensuring better allocation of productive resources necessitates socioeconomic considerations. This study examined the performance of table egg production in southern Togo by determining the breeders' production efficiency level through the stochastic frontier analysis in table egg production. Consequently, identifying the factors that significantly impact technical and allocative efficiency, and explaining the reasons for the technical inefficiency of table egg production. A parametric approach was used to estimate the technical and allocative efficiency levels from a stochastic frontier analysis. Data were collected from primary sources via a structured questionnaire (open-ended) administered to 88 poultry farms in southern Togo (2021) randomly. The parameters measured in this study were table egg production, the feed consumption during the production (each stage separately), veterinary treatment costs (drugs, vitamins), the flock size, the size of the exploitation, and the related costs of production. The finding indicated that 70% of table egg poultry farms in the Maritime Region of southern Togo are moderately technically efficient, although individual efficiency varies. Factors, such as flock size, labor, and veterinary treatments significantly influence the egg production process. Estimating the stochastic production function frontier revealed that inefficiencies in layer production largely stem from technical inefficiency among producers rather than inefficient resource allocation. The present study shows that poultry farms in Southern Togo exhibit medium technical efficiency but demonstrate effective allocation efficiency. Despite high-capacity facilities and financial constraints, the variation in the poultry breeders' production efficiency is explained by both endogenous and exogenous socioeconomic factors revealed through Tobit analysis. These factors are categorized into two groups, including primary (age, education, active membership, density, conflicts, gender), and secondary (credit, type of feed, association membership). Despite moderate technical efficiency, Southern Togo's poultry farms showed effective resource allocation. Financial constraints hinder full facility optimization, and unregulated input markets contribute to fluctuating costs.
Keywords: Allocative efficiency, Poultry farming, Stochastic frontier analysis, Technical efficiency

INTRODUCTION

The socioeconomic development of any nation, particularly in West Africa, hinges on the efficient utilization and effective management of its resources (Okorn and Egbe, 2023). Agriculture, with a special focus on livestock farming, plays a crucial role in this dynamic. The rapidly growing population in this region has significantly heightened the demand for animal protein (Tubb and Seba, 2021). The developing countries would need to produce over 100 billion tons of meat by 2030, emphasizing the critical role of animal protein in meeting nutritional needs. Poultry products, such as broiler chickens and eggs, constitute a substantial portion of the global food supply (Tubb and Seba, 2021). Every year, the world produces over 850 billion eggs, equivalent to over 50 million tons of eggs (Moustafa et al., 2018). The Food and Agriculture Organization emphasizes the need to increase food production and make it more accessible to significantly improve nutritional status (Herforth et al., 2020). The developing countries expect to produce over

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300 billion tons of meat by 2025 to meet the rising demand for animal protein. Globally, egg consumption is staggering, with 67,349 eggs consumed every second, translating to 1,250 billion eggs annually and an average per capita consumption of 145 eggs in 2009 (Herforth et al., 2020). Given this urgency, poultry farming is indispensable for meeting the population's needs for animal protein, particularly for egg consumption (Tubb and Seba, 2021).

In West Africa, and specifically in Togo, poultry farming holds significant economic and nutritional importance. Among various livestock sectors, egg production stands out as the most vital source of high-quality animal protein and income (Houndjo et al., 2018). Eggs are one of the richest sources of animal-derived protein, containing all essential amino acids in balanced proportions (Gbaguidi, 2001). In Togo, poultry farming contributes substantially to the Gross Domestic Product (GDP), accounting for 14%. The sector is highly dynamic, with broiler and egg production contributing 4.6% and 2.7%, respectively, to agricultural revenues (Lamboni, 2017). The short production cycle of chickens, the high quality of poultry products, and the relative ease of investment make modern poultry farming a central player in meeting the demand for these products (Tubb and Seba, 2021). Togo ranks as the third-leading country in poultry production within the West African Economic and Monetary Union (WAEMU), following Burkina Faso and Senegal. The creation of the Regional Center of Excellence on Avian Sciences (CERSA) has further bolstered the sector's growth through the professional training offered to the breeders and scientific improvement in the poultry field.

Despite this growth, the production of table eggs has fallen short of expectations in recent years due to several challenges (Soviadan et al., 2022). High feed costs, caused by fluctuating raw material prices and questionable feed quality, as well as a lack of training among poultry farmers, significantly contribute to inefficiency in poultry production across sub-Saharan Africa, particularly in Togo (Balehegn et al., 2020). This has led to an insufficient supply of table eggs, necessitating massive imports (Balehegn et al., 2020). Understanding the factors contributing to inefficiency in modern poultry farming is crucial for making useful recommendations. Many poultry farmers lack technical knowledge and management skills and do not seek expert advice, limiting their profit-maximizing capacity and resulting in significant capital losses (Candemir et al., 2021). The poultry industry in Sub-Saharan Africa, including Togo, faces significant challenges such as disease outbreaks, insufficient grain production, and limited purchasing power in certain regions. These issues must be addressed to support the sector's growth. The need to strengthen poultry farming is further emphasized by supply-demand imbalances in animal protein sources, particularly as Togo works to enhance its domestic production and reduce dependency on imports (Erdaw and Beyene, 2022; Abadula et al., 2022). The COVID-19 pandemic has further highlighted the importance of local production due to disruptions in global supply chains and pandemic control measures (Pujawan et al., 2022). To address these challenges, it is imperative to examine and improve the current productivity and technical efficiency levels in poultry units. The research aimed to explore the factors influencing the economic efficiency of table egg production and assess the current level of efficiency. By identifying these factors, the authors of the current study can provide recommendations to enhance productivity and sustainability in the poultry sector in Togo and West Africa. This Study aimed to determine the level of efficiency in table egg production, identify the factors that have a significant impact on technical and allocative efficiency, and explain the reasons for the technical inefficiency of table egg production.

MATERIAL AND METHODS

Ethical approval

This study was conducted according to the guidelines of the University of Lome, Lomé, Togo.

Study area

The Maritime Region was selected for this study due to its high density of layer hen farming, attributed to favorable climatic conditions and the routine consumption of table eggs in households, restaurants, and hotels. The region spans 6,667 km² and includes seven prefectures, including Golfe (capital: Lomé), Lacs (capital: Aného), Bas-Mono (capital: Afagnan), Vo (capital: Vogan), Yoto (capital: Tabligbo), Zio (capital: Tsévié), and Avé (capital: Kévé). This survey focused on five prefectures with the densest layer of farming activities: Golfe, Vo, Avé, Yoto, and Zio. The region is bordered by the Atlantic Ocean to the south, the Aflao-Ghana border and Avé Prefecture to the west, Zio Prefecture to the north, and Lacs Prefecture to the east. It is characterized by a lagoon system and uneven urban distribution, with population densities ranging from 1,307 inhabitants/km² to 357 inhabitants/km². The climate is sub-equatorial, with an average annual rainfall of 864 mm and an average temperature of 27.4°C.

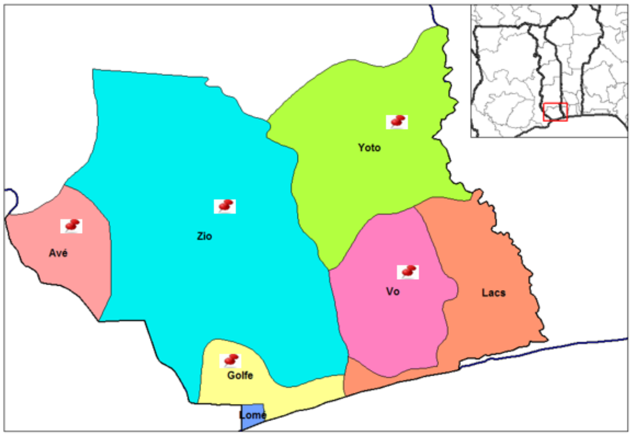

Figure 1. The map of the Delimitations of the 7 prefectures of Lome-Togo and the survey locations.
Source: Authors' compilation (2024)

Data collection method

Data were collected from both primary and secondary sources. Primary data were obtained through surveys of layer hen farmers using a two-part structural questionnaire (open-ended) on farm characteristics, production factors, management competencies, and health aspects. Stratified non-probability sampling (snowball sampling) was used, focusing on five prefectures, including Avé, Zio, Yoto, Vo, and Golfe as displayed in Figure 1. The survey, conducted in 2021, had formal authorization from CERSA/UL. The sample size, determined using Slovin's formula, was 88 table egg producers, with input from the Institute for Technical Support and Advice (ICAT/Togo) and the National Association of Poultry Producers of Togo (ANPAT/Togo). Primary data were collected using structured questionnaires through scheduled interviews with poultry farmers. Data collected included production, inputs, output, and input prices, major socio-economic characteristics, constraints faced by farmers, and the impact of COVID-19 on the input prices.

The survey form was designed using Sphinx software version 5.0, selected for its user-friendly interface. Physical forms were utilized for field data collection, enabling the gathering of additional on-site information and the expansion of the database with unforeseen variables relevant to the research topic. Upon completion of the survey, SPSS V23 and Stata 14 were used for data analysis. The stochastic frontier production was applied, followed by the prediction of efficiency scores, concluding with the Tobit analysis to fulfill all the study objectives.

Model for analyzing technical and allocative efficiency

There were two primary methods for analyzing economic efficiency, including the deterministic method using Data Envelopment Analysis (DEA) and the parametric stochastic method using Stochastic Frontier Analysis (SFA) estimation. Based on a review of previous studies, the parametric method was chosen for its robustness, consideration of unobserved variables, and realistic results. Empirical studies have applied stochastic frontier analysis to assess farm-level efficiencies, using these functions to predict performance levels (Coelli, 1995). Subsequently, predicted efficiency scores were regressed against the regressed specific farm variables, such as management experience and property characteristics, to determine factors contributing to efficiency variations (Coelli, 1995). The model can be specified by follows formula.

$$Y = f(X, \beta) + (v - u) \quad (1.1)$$

$u \geq 0; -\infty \leq v \leq +\infty$

In detail, the equation can be written as:

$$Y_i = \beta_0 + \sum \beta_j X_{ij} + \varepsilon_i \quad (1.2)$$

Où $\varepsilon_i = v_i - u_i$

In matrix form:

$$Y = X\beta + \varepsilon \quad (1.3)$$

Where:

Y represents production output, while X denotes production inputs. The parameter ß consists of fixed values to estimate, representing the elasticity of production with respect to input X. The term u_i corresponds to positive values of a random variable linked to producers' technical inefficiency. Additionally, v_i represents the error term associated with measurement errors and other random factors, such as climate, theft, luck, and neighborhood conflicts, all of which can influence production.

According to Panda (1996), $\mathbf{v_i}$ has a normal distribution with mean $\boldsymbol{\mu_v}$=0 and constant variance $\boldsymbol{\sigma_v^2}$; they are independent of $\mathbf{u_i}$, assumed to have a semi-normal distribution with mean $\boldsymbol{\mu_u}$=0 and constant variance $\boldsymbol{\sigma_u^2}$.

Under these conditions, the ratio of the observed output of the i^{th} producer to the potentially defined output by the production frontier, given the production inputs X_i, is used to calculate technical efficiency (TE_i).

$$TE_i = \frac{Y_i}{\exp(\beta \sum (lnxi))} = \frac{\exp((\beta lnxi) - u_i)}{\exp(\beta \sum (lnxi))} = \exp(-u_i) \quad (1.4)$$

Where exp(.) represents the exponential function.

Specification of the technical efficiency estimation model

In this study, the Cobb-Douglas production function is used, commonly employed in economics and econometrics as a model of production function. It represents the effects of technology on two or more production factors and on production itself. The function is presented as follows.

$$Y_i = X_i^{\beta_{i1}} \quad (1.5)$$

For the estimation, the natural logarithm is used to estimate the parameters β, which represent elasticities. This is commonly known in econometrics as a log-log model. The dependent variable, egg production, was specified as a function of five independent variables (i.e., building area, flock size, feed served until laying starts, hen weight at laying start, and expenditure per laying hen). The stochastic production frontier for poultry egg production is calculated as follows.

$$Y_i = X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} £_i \quad (1.6)$$

By linearizing the function for robustness, the formula becomes

$$LnY_i = Ln(\beta_0) + \beta_1 Ln(X_{1i}) + \beta_2 Ln(X_{2i}) + \beta_3 Ln(X_{3i}) + \beta_4 Ln(X_{4i}) + \beta_5 Ln(X_{5i}) + £_i \quad (1.7)$$

Where Yi represents production output, measured as the quantity of eggs produced per hen per cycle. X1 corresponds to the building area in square meters, while X2 denotes flock size, referring to the number of chicks. X3 represents the quantity of feed served before laying, specifically between the 16th and 19th weeks. X4 indicates the hen's weight at the start of laying, and X5 accounts for expenditure per laying hen, measured in FCFA. The parameter β consists of coefficients of the variables, representing their respective elasticities. v_i corresponds to random error, whereas u_i reflects technical inefficiency effects, indicating the gap a farmer must close to reach the production frontier. The u_i= technical inefficiency effects, representing what remains for the farmer to reach the production frontier.

Allocative efficiency is estimated by the cost frontier, similar to the technical efficiency specification. The cost frontier, derived from the dual relationship with the production frontier, measures allocative efficiency by assessing how effectively a farmer utilizes inputs in proportion to their respective costs (Khai et al., 2011). The model includes input prices (Px_{ik}) and total egg production Ln (Y_i*), adjusted for statistical noise. The model is specified as follows.

$$Ln(C_i) = \sigma_0 + \sigma_1 LnPX_{1i} + \sigma_2 LnPX_{2i} + \sigma_3 LnPX_{3i} + \sigma_4 LnPX_{4i} + \sigma_5 LnPX_{5i} + \sigma_6 LnPX_{6i} + LnYi + \varepsilon_i \quad (1.8)$$

Where,

Ci represents the total cost of egg production, measured in FCFA. PX1i corresponds to the cost of the building area per square meter, while PX2i refers to the price of chicks per unit. PX3i accounts for labor costs per subject, whereas PX4i captures the expenditure on feed served before laying, specifically between the 16th and 23rd weeks. PX5i represents the cost of veterinary treatments per subject, including the number of vaccines administered. PX6i denotes the cost of medication and vitamins, measured in FCFA per kilogram. Ln (Yi*) signifies table egg production adjusted for statistical noise. Finally, Ɛi represents the composite error term, and σ corresponds to the parameter to be estimated.

Verification of the existence of inefficiencies

The estimation procedure follows (Coelli, 1995), which involves maximizing the natural logarithm of the likelihood function and calculating the likelihood ratio (LR). The natural logarithm of the likelihood function can be mathematically expressed as follows.

$$Y = \boldsymbol{\delta_v^2} / \boldsymbol{\delta_u^2} \quad (1.9)$$

To test for the existence of technical and allocative inefficiency, Coelli (1995) suggested using the generalized likelihood ratio test.

According to the literature, the frequently used method to explain inefficiencies is a two-step process (Labiyi et al., 2012), including the first step estimates inefficiencies from a production function, and the second step involves regressing efficiency scores to determine factors influencing the performance of the Decision-Making Units (DMUs) considered. These models are also known as "censored regression models" or "truncated regression models." The choice of the Tobit model is justified by the continuous nature of efficiency indices, which take values between 0 and 1 (Labiyi et al. 2012). The model of inefficiency is as follows.

$$U = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + e \quad (2)$$

Where U represents inefficiency, while Z1 denotes the education level of the farmer, measured in years. Z2 corresponds to the presence of a disinfection footbath, recorded as a binary variable. Z3 indicates whether the farm is fenced, also represented as a binary variable. Z4 reflects cooperative membership status, Z5 captures access to credit, and Z6 measures the farm's proximity to the farmer's residence, all recorded as binary variables. Z7 accounts for veterinary support availability, Z8 represents sales blockage, and Z9 corresponds to the mortality rate, expressed as a percentage. Finally, δ denotes the vector of parameters to be estimated.

Statistical analysis

The study used STATA 15 software to perform the stochastic frontier analysis, examine the production frontier of table eggs, and predict both technical and allocative efficiency. Economic efficiency is then calculated from these predicted efficiency measures. Subsequently, Tobit analysis is conducted to identify the factors influencing breeders' technical efficiency beyond the effects of input usage in production.

RESULTS AND DISCUSSIONS

Technical efficiency of table egg farms

According to Table 1, the overall productivity of layer hens in the surveyed farms was 235.92 eggs. Given the low standard deviation (35.87), it can be concluded that the egg yields across different farms were close to the average value, which was low compared to yields in Cameroon, where the required productivity was 270 eggs. Farms owned by women have a relatively lower egg yield (192 eggs per hen) compared to those owned by men (238 eggs per hen). This finding indicated that women in Togo had not fully mastered poultry farming, unlike women in Benin, who achieved a yield of 236 eggs per hen, as reported by Siéwé et al. (2019).

The average cost of veterinary treatment was 218 FCFA per subject, which was relatively high compared to the standard set in projects, which was 100 to 150 FCFA per subject. The maximum cost of veterinary treatment (including vaccines, medication, and vitamins) was much higher than the report established by Traore (2014). This cost can be explained by the relatively small flock sizes, which still allocate the means to undergo all treatments.

Table 1. The stochastic frontier production variables' descriptive statistics of the table egg production

Variable	Average	Std. dt.	Min	Max
Laying cycle productivity per hen	235.92	35.87	120	285
Male producer	238.01	34.26	230	245
Female producer	192	46.21	228.31	243.52
Poultry house floor area	242.63	219.61	20	1000
Pre-laying feed consumption	9.63	1.90	3.54	13
Weight at the point of lay	1.51	0.19	1.3	2.2
Expenditure per laying hen	2286.38	471.72	1532	5103.75

Std. dt: Standard deviation, Min: Minimum, and Max: Maximum

Table 2. The stochastic frontier analysis for predicting technical efficiency in table egg production

Variables	Coef.	Std Err	Z	P>|Z|
LX_1 Poultry house floor area	-0.08394	0.0001366	-614.58	0.000***
LX_2 Number of birds	0.006573	0.0001236	53.17	0.000***
LX_3 Pre-laying feed consumption	-0.24665	0.0005997	-411.31	0.000***
LX_4 Weight at the point of lay	0.130336	0.0002364	551.26	0.000***
LX_5 Expenditure per laying hen	0.019259	0.0001015	189.77	0.000***
Inefficiency parameter				
σ_v^2	1.27E-17	0.0001		
σ_u^2	0.3328	0.02508		
$\sigma_s^2 = \sigma_u^2 + \sigma_v^2$	0.11078	0.02518		
$\gamma = \frac{\sigma u^2}{\sigma v^2}$	0.985	0.025089		
Logarithme de vraisemblance			41.43	

*** Significance at 1%, Coef: Coefficient, Std Err: Standard error, Z: Z-score

Estimation of technical efficiency

Table 2 shows that all variables in the function were significant at the 1% threshold, although two variables negatively impacted the production function. The estimated coefficients represented the partial elasticities concerning each corresponding variable. An increase of 10% in the poultry house area (LX1) without a corresponding increase in flock size will result in an 8%

decrease in egg production per hen. This finding can be explained by the energy wastage among laying hens due to the additional space, which distracted them from laying, as the hens spend more time running around and playing (Khan et al., 2022).

The feed given to laying hens (LX2) from the chick stage until the laying age was above normal, which explained the negative coefficient. A 1% increase in feed consumption before laying age will lead to a 20% reduction in egg production per hen. The variables, including flock size, weight at the onset of laying, and expenditures on a hen ready to lay, were positively significant at the 1% threshold. This means that a 1% increase in each of these variables will increase egg production per hen per cycle by 0.6% (LX3), 13% (LX4), and 1% (LX5), respectively.

The results of the stochastic model estimation show that all variables are significant, although some are negative, indicating a negative relationship between these variables and the production output. These results differ from those of Siéwé et al. (2019), who found a perfectly positive reaction. However, the three other variables show a positive relationship with the production output, confirming the findings of Dhehibi and Chemak (2010).

The maximum likelihood estimator (γ) of the stochastic frontier production model (LR) was statistically significant at the 1% threshold. Therefore, the null hypothesis of the absence of technical inefficiency was rejected. The variance value γ (0.985), significantly different from zero at the 1% threshold, indicated the presence of productive inefficiencies. Approximately 98% of the difference between observed productivity and potential productivity of laying hens within the studied farms is partly due to the inefficiency of the poultry farmers. Indeed, in this study, 2% of the differences were due to random effects, including measurement errors, which can arise from the nature of the data being averages at the farm level. The closer the value of (γ) is to 1, the smaller the difference between the results from a stochastic estimation and those from a deterministic estimation (Briec et al., 2005).

Table 3. Cross-table of technical efficiency score of farmers' table egg production in the Maritime region of Togo (2021)

	Average	Std. dt.	Min	Max
Technical efficiency of poultry farms	**72%**	**0.144**	**40%**	**90%**
Gender type				
Man as managers	75%	0.0153	70%	76%
Women as managers	57%	0.0853	30%	84%
Poultry farming training				
Yes	73%	0.0164	70%	76%
No	68%	0.041	60%	77%
Membership in a cooperative				
Yes	71%	0.020	66%	75%
No	74%	0.023	69%	79%

Std. dt: Standard deviation, Min: Minimum, and Max: Maximum

The surveyed farms have an average technical efficiency of 72%, which was relatively low compared to the average efficiency of poultry farms in Benin, standing at 92.38% (Siéwé et al., 2019).

Table 3 illustrates the technical efficiency of layer poultry farms in the Maritime region, along with a comparison based on gender, participation in training, and membership in a cooperative. It can be inferred that men exhibit higher technical efficiency at 75% compared to 57% for women. Furthermore, individuals who had received training demonstrated higher efficiency at 73% compared to 68% for those who entered the sector without formal training. However, regarding membership in a cooperative, there was an observed effect, with a technical efficiency of 71% for cooperative members and 74% for non-cooperative members. This disparity may be attributed to inter-cooperative conflicts.

Analysis of technical inefficiency

Table 4 presents the descriptive analysis of the variables used in the Tobit model. It shows how the table egg poultry farms are presented in the region. In Table 5, three variables are responsible for the technical inefficiency of layer poultry farms. The variable "level of education" indicated that individuals with higher levels of education struggle to undergo training and do not contribute to the technical efficiency of the operation. The chick price hurts efficiency, meaning that for every 1% increase in chick price, technical efficiency decreased by 22%. This may be attributed to a lack of resources to adequately feed and treat the layers once acquired. The mortality rate reflected farmer discouragement; an increase in chick mortality not only initiates technical inefficiency but also raises concerns and anxiety about resource scarcity. A 1% increase in mortality rate led to a drop in technical efficiency of over 50%. This variable was just at the 1% significance threshold, making it significant at the 5% default threshold.

A new variable in the model estimation was farm closure. The initial assumption for this variable was that it would be significant and positive, which was indeed the case; a fenced poultry farm increases technical efficiency by 5% at the 10% threshold.

The other variables were also significant and positive, and thus did not negatively impact technical efficiency.

Table 4. The statistics describing the tobit model variable that influences the technical efficiency of the table egg production

Qualitative variables	Percentage
Membership in a Cooperative	
Yes	56%
No	44%
Presence Of Footbath	
Yes	66%
No	34%
Credit Access	
Yes	37%
No	63%
Closed Farm	
Yes	32%
No	68%
Near Residences	
Yes	33%
No	66%
Training	
Yes	80%
No	20%

Table 5. The Tobit model output of the factors influencing the technical efficiency of table egg production of Togo (2021)

Variables	Coef.	Std. Dt.	Z	P>|Z|
Level of education	-0.0270234	0.0154466	1.75	0.084*
Number of personnel	0.0162859	0.0077546	2.10	0.039**
Presence of a footbath	0.070108	0.0261678	2.68	0.009**
Increase in chick price	-0.2236006	0.1037354	-2.16	0.034**
Mortality rate	-0.599072	0.1736052	-3.45	0.001**
Vaccine reminders	0.014632	2.79e-06	5243.75	0.000***
Closed farm	0.0532819	0.0275267	1.94	0.057**
Log-likelihood = 76.831277	LR chi2(14) = 67.08			
Probability > chi-square = 0.0001				

***Significance à 1%, ** Significance à 5% et * significance à 10%, Z: Z-score

Allocative efficiency of table egg production farms

The descriptive output of Table 6 shows that the average cost of the poultry house per square meter was quite high (10111.23 FCFA). The minimum cost registers as zero because some poultry houses were very old, while others were constructed by farmers over the years, with most materials sourced locally. The price of day-old layer chicks varied significantly, as evidenced by the standard deviation. This variance stems from the lack of regulation in chick imports, with numerous suppliers operating in the field and importing chicks from various sources. The standard cost of veterinary treatments typically falls within the range of 100 to 110 FCFA. However, the actual minimum observed is 82.2 FCFA, primarily influenced by product sales. Regarding vaccines, only doses of 500 and 1000 were available, leading smaller-scale operations with fewer than 500 layers to forego some vaccinations. Conversely, those undertaking all treatments, despite having smaller flocks, incurred higher costs (555.55 FCFA).

Table 6. The stochastic frontier cost variables' descriptive statistics

Variables	Moyenne	Std. dt.	Min	Max
Cost_ floor_area /m² (FCFA/m²)	10111,23	8384	50	31133,25
Price_Chicks FCFA	928.2443	118.1047	600	1100
Cost_labor/D/L FCFA	1.385094	2.56641	0	20.83333
Veterinary cost FCFA	218.0989	66.14408	82.26496	555.5556
Cost_hitness/L FCFA	73.39631	49.1308	3.555556	300
Cost_feed/L FCFA	38254,92	41204	2100	243000

FCFA: Franc communauté financière Africaine, D/P: Day per chicken layer, Std. dt: Means standard deviation, Min: Minimum, Max: Maximum

Table 7. Stochastic frontier cost analysis for the allocative efficiency prediction of table egg production

Variables	Coef.	Std. Err.	Z	P>|Z|
LPX_1COUT_floor_area/m² (FCFA/m²)	-0.038484	0.02231	-1.72	0.085*
LPX_2 Price_Chicks FCFA	0.736589	0.01213	60.7	0.000***
LPX_3 Cost_labor	0.2154071	0.0058	37.02	0.000***
LPX_4 Cost_Medecine	0.000595	0.0009	0.64	0.521
LPX_5 Cost_Vacination	0.141527	0.2179	6.49	0.000***
LPX_6 Cost_hitness	0.013449	0.0081	1.65	0.098*
LPX_7 Cost_Feed	0.5633576	0.0072	77.34	0.000***
LY Quantity of eggs produced	-0.00882	0.01172	-0.76	0.449
Inefficiency parameter				
σ_v^2	$1.6129E^{-15}$	$6.43E^{-7}$		
σ_u^2	0.000	0.011		
$\sigma_s^2 = \sigma_u^2 - \sigma_v^2$	0.0081	0.0017		
$\gamma = \frac{\sigma u^2}{\sigma v^2}$	0	0.0110723		
Log-likelihood		55.528		

*** Significance à 1%; **Significance à 5%; *Significance à 10% Coef : Coefficient, Std Err: Standard error, Z : Z-score

Estimation of the allocative efficiency

Table 7 shows that the maximum likelihood estimator (γ) of the stochastic production cost frontier model (LR) was statistically significant at the 1% level. However, its value is equal to zero (0). Thus, the null hypothesis (H0) of the absence of allocative inefficiency was accepted. The variance value of γ = 0.000 indicated that the inefficiency was technical, and it was also linked to random effects, including measurement errors. Based on the analysis of the stochastic production cost frontier, the last variable represents production cost, and its expected negative sign confirms the model's accuracy and robustness. This sign demonstrates the logical relationship between production and cost, as production costs increase, production naturally declines. The following variables, including chick cost, labor cost per layer, vaccine cost per layer, and pre-laying feed consumption, were highly significant at the 1% level. This implied that a 1% increase in the cost of each of the mentioned variables would significantly increase production costs by 73%, 21%, 14%, and 56%, respectively. The cost of the poultry house per square meter was negative; this variable was not included in the direct production cost estimation.

The analysis of technical efficiency among table egg farms revealed an average efficiency level of 72%, indicating substantial variations in effectiveness across different farms. While some farms demonstrated commendable efficiency levels, reaching up to 90%, others operate at comparatively lower rates, such as 40% and 50% (Table 3). Notably, factors such as poultry flock size and pre-laying feed consumption emerge as significant determinants of technical efficiency, with larger poultry houses and excessive feed consumption negatively impacting productivity. However, Khan et al. (2022) found the opposite effect, suggesting that optimal management of flock size and feed can improve the technical efficiency of enterprises. On the other hand, factors such as weight at the start of laying and cost per laying are favorably linked to efficiency. This highlights the critical role of strategic resource allocation and management in enhancing productivity (Dogan et al., 2018; Khan et al., 2022). The Tobit analysis of the factors influencing the technical inefficiency revealed a notable influence linked to socio-economic factors. In particular, the level of education among farm owners, the price of day-old chicks, and mortality rates within production farms all had significant impacts on technical efficiency. Farms operated by individuals with higher education levels tended to exhibit lower efficiency levels, suggesting potential barriers to effective management and resource utilization (Siéwé et al., 2019). Moreover, increases in day-old chick prices have a negative impact on efficiency, possibly due to constraints on investment in critical resources, such as feed and healthcare. Ezeano and Ohaemesi (2007) confirmed the present result, stating that the high price of day-old chicks negatively impacts the technical efficiency of poultry production. Additionally, higher mortality rates contributed to reduced efficiency, reflecting underlying challenges in disease management and overall farm health, as confirmed by Dogan et al. (2018). However, the allocative efficiency shows significant cost and efficiency dynamics in poultry farming. The average cost of poultry houses was high (10,111.23 FCFA/m2), while some older, locally constructed poultry houses incurred zero costs. Day-old layer chick prices vary due to unregulated imports, affecting cost stability. Veterinary treatment costs range widely, with smaller farms either skipping vaccinations or facing high costs due to limited vaccine dose sizes (Siéwé et al., 2019).

The stochastic production cost frontier analysis showed that there was little allocative inefficiency. At the 1% level, it is statistically significant but equal to zero, which means that technical inefficiencies are caused by random effects. The stochastic frontier production model confirmed an inverse relationship between production costs and output. Key cost drivers include chick cost, labor, vaccines, and pre-laying feed, all of which had a significant impact on overall production costs. Notably, direct cost estimations excluded the cost per square meter of the poultry house, indicating additional influencing factors. These insights offer a framework to tackle cost and efficiency issues in the sector, affirming the high efficiency in poultry production, evident in both technical and allocative efficiency (Dogan et al., 2018).

These findings underscore the multifaceted nature of farm efficiency, influenced by a complex interplay of technical, socio-economic, and economic factors. To enhance overall performance and sustainability in table egg production, targeted interventions addressing both technical and socio-economic challenges are essential. Strategies aimed at optimizing resource allocation, improving management practices, and supporting education and training initiatives can help mitigate inefficiencies and promote long-term viability within the sector.

CONCLUSION

The results revealed that, on average, the surveyed farms exhibit lower technical efficiency levels, despite demonstrating effectiveness in resource allocation. The mean economic efficiency index of 0.72, ranging from 0.40 (minimum) to 0.90 (maximum), reflects the varying degrees of efficiency within the poultry farming sector in Southern Togo. This region's poultry industry operates with high intensity and is characterized by abundant labor resources. However, despite having high-capacity poultry houses, farmers often lack the financial means to fully optimize their facilities. Furthermore, the absence of government regulation in the poultry input market contributes to fluctuating prices of feed ingredients and medical supplies, as well as shortages in stock availability. Further in-depth studies are necessary to comprehensively understand the economic efficiency of farms and devise effective solutions to address inefficiency factors. These studies should encompass a thorough examination of all facets of the poultry sector and allow for sufficient time to develop stochastic predictive models for allocative efficiency. By gaining a comprehensive understanding of the sector dynamics and implementing targeted interventions, stakeholders can work towards enhancing the overall efficiency and sustainability of poultry farming practices in the study region. Moreover, by addressing these underlying factors, stakeholders can work towards maximizing productivity and profitability while ensuring the long-term sustainability of table egg farming operations.

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Availability of data and materials

The data is available upon request from the corresponding author.

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Authors' contributions

Atsu Frank Yayra Ihou contributed to data collection, data analysis, and the write-up of the manuscript. Abbey Abbévi Georges conducted the design of the study and supervision. Aime Alayi conceptualized data collection and analysis. Paul Mansingh Jeyabalasingh contributed to the manuscript revision and formatting in English. All authors read and approved the final version of the manuscript.

Competing interests

All authors declare no conflict of interest.

Ethical considerations

Ethical issues, including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been checked by all authors.

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