VIRAL DISEASE CONTROL STRATEGIES EFFECT ON TECHNICAL EFFICIENCY OF LAYER FARMERS IN THE BONO REGION OF GHANA

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

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DECLARATION

I, Desmond Ayertey, the author of this thesis titled **"Viral Disease Control Strategy on Technical Efficiency of layer farmers in the Bono Region of Ghana"**, do hereby declare apart from the references duly citied, the research presented in this thesis was done entirely by me in the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon. The work has never been presented either in whole or in part for any other degree of this University or elsewhere.

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DEDICATION

I dedicate this thesis to Almighty God and to my parents.

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ABSTRACT

Viral diseases among layer chickens threaten income of small to medium holder commercial farmers in Ghana. Strict adherence to biosecurity measures aids in controlling the spread of these diseases and hence improves production efficiency thus increasing income. Limited knowledge, high cost of chemicals, irregular veterinary visits and negligence on the part of farmers constrain farmers from implementing good biosecurity practices. The study sought to assesses technical efficiency and biosecurity practices influencing technical efficiency levels of layer production in Bono Region of Ghana. A normalized Cobb-Douglas production function is employed using cross-sectional data of 161-layer producers in 2 districts (Dormaa Central and Dormaa East) in Bono Region. Inputs such as feed consumption, water consumption, vaccination and other medications and hired labour (man-days) were used and the output being crates of eggs produced per thousand birds. The study found that the quantity of feed and water consumption are the most significant factors negatively and positively affecting the egg levels of layer production. All the input variables respond positively to the output except feed consumption. Layer producers are about 92% efficient in terms of production. Majority of the farmers representing 53.3% were from the ages of 41 to 50 years with a mean age of 44 years. Layer farmers are largely dominated by males representing 81% of the sample size interviewed. However, Membership of farmer-based organizations, deworming, disinfection and rearing of other birds are the key factors that significantly explain the variations in production efficiency. Other biosecurity factors that were mentioned and mostly practiced were the use of footbath, litter disposal, deworming, frequent in-house cleaning and veterinary visits on farms. The findings suggest that irregular visits by veterinary officers to farms for increased education are important. This education should focus on the significance of practicing biosecurity measures on farms. Additionally, farmers need to be educated on the early detection of viral poultry diseases and its control mechanisms. Ensuring strict adherence to combinations of biosecurity practices by layer farmers is key. These actions can lead to an increase in efficiency levels, ultimately resulting in higher output. It is recommended that, there should be implementation of comprehensive vaccination schedules and timely vaccination of birds among these farmers.

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LIST OF ACRONYMS

APD: Animal Production Directorate

CRD: Chronic Respiratory Disease

DEA: Data Envelopment Analysis

DMU: Decision Making Units

FAO: Food and Agriculture Organization of the United Nations

GDP: Gross Domestic Product

IBV: Infectious Bronchitis Virus

ICLMPs: Integrated Crop-Livestock Management Practices

MLE: Maximum Likelihood Estimation

VSD: Veterinary Service Department

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Sub-Saharan Africa has a pressing issue. It needs to maintain its agrifood system. This is according to Pachauri et al., (2014). The population of Sub-Saharan Africa is expected to double by 2050. Because of this, it has the highest number of small-holder farmers globally. Crop farmers have few resources. Livestock farmers also have few resources. This makes them very vulnerable to the negative effects of climate change. Agriculture generates about 32% of the region's GDP. It also employs 65% of its labor force, according to the FAO (2015). Climate change is predicted to reduce agricultural production by 10–20%. This could worsen food insecurity and poverty.

The dominance of livestock production in Ghana, particularly poultry, is influenced by traditional farming practices and economic benefits. Traditional systems, such as free-range management, are prevalent, especially for poultry and small ruminants, providing essential income and non-pecuniary benefits like manure and social relations (Adams et al., 2021). Economic factors significantly influence the preference for poultry meat, as it is perceived as more convenient and affordable compared to other livestock.

The production of chicken alone saw more than 100% growth, that is from 20,000 tons to 50,000 tons within a period of ten years (Adzitey, 2013). It is well known that one of the easiest methods to quickly boost the availability of protein for the increasing global population is through poultry rearing (Castro et al., 2023). Every year, there is a noticeable increase in the production and consumption of chicken meat and eggs (Parlasca & Qaim, 2022). Both production and consumption of chicken have increased during the past few decades in Ghana (Amanor-Boadu, 2016). The supply of chicken grew from the year 1961 to 2011, from roughly 6,000 metric tons to nearly 200,000 metric tons (Amanor-Boadu, 2016).

This increase was attributed to government of Ghana's interventions put in place to encourage poultry farmers especially chicken farmers to alleviate the severe shortage of animal protein (Sarpong, 2021). The industry has benefited greatly over the years from measures like the elimination of duties on imported inputs such as feed, vaccine, day old chicks, a special 20% tax on the import of poultry products such as chicken and eggs, farmer training, the facilitation of broiler capitalization and marketing, government and non-governmental organization subsidies for day-old chicks and yellow maize, and the facilitation of better access to veterinary services (Yevu & Onumah, 2021).

Ghana's early independence and early implementation of structural adjustment initiatives, Ghana has led the way in African development and is currently a functioning multiparty democracy (Andam et al., 2017a). The Food and Drugs Authority and the Ghana Standards Authority provide technical assistance to the farmers through training workshops. The Animal Production Directorate and the district Veterinary Services Directorate also play a role by doing frequent visitation to layer farmers and giving technical advice on feed formulation (Nuvey et al., 2023).

The estimated chicken product consumed in Ghana is 12 eggs and 1.2 kilograms (kg) of meat per person per year and thus lower than the world's average of about 154 eggs and 10kg of meat per person per year(Blackie, 2014). Given its significant feed conversion rate advantages over beef and pork, poultry is a highly desirable and reasonably priced food option for African consumers (Andam et al., 2017a).

Ghana's layer production industry is notably active in three key regions: Bono, Ashanti, and Greater Accra. This order reflects the quantity of eggs and spent layers produced, from the largest to the smallest. Specifically, in Dormaa Ahenkro, layer production accounts for a significant 95 percent of all bird production (Andam et al., 2017). This high concentration is attributed to the growing demand for chicken and eggs from Ivory Coast, coupled with cross-border trade dynamics such as the flow of inputs (day-old chicks, feed, and vaccines) and Dormaa-Ahenkro's proximity to Ivory Coast (Obese et al., 2021a).

Over time, there has been recent increase in the population of layer chicken from 1.8 million to about 3 million within that community due to the demands of eggs and spent layers by both domestic consumers and foreign consumers nearby such as Ivory Coast and Burkina Faso (Andam et al., 2017a). Even though layer farmers in some communities within Dormaa East and Dormaa Central have experienced a wave of viral disease outbreak due to litter buyers actions on their farms from activities, such as using their trucks to enter one farm to the other without adhering to strict biosecurity practices such as traffic control and changing clothess as and when they enter different farms(Lendzele, 2021).

Infectious diseases caused by virus are of economic importance among livestock farmers since they have negative impact on animal productivity, animal health, farm income, food security and consumer trust within the meat industry (Ayim-Akonor et al., 2018). High mortality and high morbidity among the chickens are effects of infectious diseases from virus and these diseases include New Castle, Marek Disease, Avian Influenza and Infectious Bronchitis (Mpenda et al., 2019). More critically, there are no well-known treatment options for viral infections in chicken; management and prevention rely on effective vaccination delivery and on farmers' adopting biosecurity measures to prevent spread and transfer of illnesses across chicken flocks (Conan et al., 2012).

1.2 PROBLEM STATEMENT

Layer production in Ghana, particularly in the Bono region, has shown improvement, boosting employment and fostering international trade with neighboring countries like Ivory Coast and Burkina Faso through the sale of spent layers and eggs (Andam et al., 2017). The widespread nature of both broiler and layer chicken rearing across rural and urban areas contributes significantly to providing affordable protein sources for all income levels (Adesina et al., 2000). However, the Ghanaian layer farming sector has faced considerable challenges alongside its potential, especially in the wake of COVID-19 (Obese et al., 2021). The pandemic has highlighted the critical importance of biosecurity, production management, and disease control within the chicken industry (Obese et al., 2021), leading to decreased profit margins, feed availability issues, and supply chain disruptions for layer farmers (Yevu & Onumah, 2021).

A significant problem is that many poultry farmers begin production with the expectation of quick profits without adequate basic knowledge of production practices, particularly regarding viral disease management (Anang et al., 2013). While direct treatments for viral diseases are limited, adopting biosecurity measures can reduce their spread (Conan et al., 2012). These measures include routine vaccination, isolation and culling of sick animals, depopulation of overcrowded pens, controlled farm traffic, and proper sanitation to ensure sustainable layer production (Abdallah et al., 2023). The purchase of day-old chicks also presents a risk, as the absence of veterinary oversight at hatcheries can lead to the introduction of diseases against which the chicks have not been properly vaccinated (Etuah et al., 2019).

Furthermore, the local poultry industry has experienced production challenges negatively impacting egg production and farmer income (Abunyuwah et al., 2019). These challenges include increased feed costs (constituting about 60% of total production costs), low feed conversion ratios, and high input costs for vaccines and litter management. This raises concerns about the production efficiency of poultry farmers, as many lack the necessary techniques to maximize output through an appropriate combination of inputs and biosecurity management practices (Wongnaa et al., 2023). Notably, traffic control as a biosecurity measure is crucial in layer production, serving as both a preventive and management strategy against viral diseases (Oladipo et al., 2020). Therefore, this study seeks to understand the factors influencing the adoption of traffic control as a key biosecurity measure and overall viral disease control strategies in layer production.

This, therefore, leads to the following questions

1. What are the strategies that layer chicken farmers use to control viral diseases in the Bono Region?
2. What are factors affecting the practice of traffic control as a biosecurity measure in Bono Region?
3. What are the factors influencing the technical efficiency of layer chicken production in the Bono Region, particularly in relation to viral control strategies?

1.3 RESEARCH OBJECTIVES

The main objective of this research is to understand and assess the importance of viral disease control strategies and how we can relate them to an efficient level of poultry production. These specific objectives must be achieved to meet the main objective.

1. To identify viral diseases affecting farmers and identify biosecurity strategies that layer farmers use to control viral diseases in Bono Region.
2. To analyze factors affecting the practice of traffic control as a biosecurity measure in Bono Region.
3. To estimate the factors affecting technical efficiency of layer chicken production within the Bono Region.

1.4 SIGNIFICANCE OF THE STUDY

The findings from this study can inform policymakers, agricultural extension agents, and layer farmers about economically effective strategies for managing viral disease and its economic consequences.

Secondly, implementing biosecurity practices not only safeguards poultry health but also protects farmers' income by minimizing production losses. These practices ensure that the invested time, effort, and resources yield sustainable outcomes.

Overall, this research will contribute to existing scientific literature by providing empirical evidence regarding the effectiveness of specific viral disease control strategies on technical efficiency of layer farmers. The insights gained can offer some basis for further research and discussions in the fields of agriculture, animal health, and economics.

1.5 ORGANIZATION OF STUDY

This study is structured into five main chapters. Chapter one introduced the project topic which involves background of study, problems to be addressed, objectives generated and the justification of the study. Chapter two focuses on reviewing relevant literature on the study. Chapter three describes the methodology of study. It also shows the methods of analyses, the types and sources of data and the study area. Chapter four discusses and explains the results obtained from the various analyses. Chapter five presents a summary of the study, its main conclusions, and policy recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1. INTRODUCTION

Notable studies have been done in the layer chicken sector under viral diseases affecting the production of eggs and spent layer meat done by (Ayim-Akonor et al., 2018). The study was based on infectious bronchitis which affects the respiratory and urogenital tract of chickens. This disease is characterized by coughing, difficulty breathing and sneezing. Based on the symptoms experienced by the chicken, it is usually confused with Chronic Respiratory Disease (CRD) especially if post-mortem analysis and laboratory works are not done on birds suffering from such diseases. As such, it creates a major economic loss to the poultry sector, such reduced feed intake and drop in egg production which affects productivity and income of the farmer. Prevalence rate of birds that was not vaccinated against IBV was one hundred percent. This is due to not following vaccination routine specifically for IBV. According to a research study under the use of vaccination in poultry production by Marangon and Busani (2006), stated that, vaccination routine should be done based on factors perculiar to the community or region the poultry farm is located since this has an effect on the effectiveness of the vaccination programme and design. This was stated on an assumption that various sanitary practices are adhered to at the farm level. Factors that were considered in coming up with this statement were, vaccine availabilty, cost involved in vaccination, type of vaccine being used, density of the flock, disease history of the flock and also production type (that is, small scale, medium scale or larger scale production)(Marangon & Busani, 2006). They further stated that, when these facors are not considered together with sanitary farm practices, this affects egg production, quality of meat produced, reduced vaccine potency , increased morbitdity , increased mortality and thus increasing production cost, reduced profit and income which are detrimental to the farmers economically.

Ghana's poultry industry is largely dominated by layer and broiler production and raised mostly for their profitability both under the intensive and semi intensive system(Opoku -Mensah, 2016). There has been reduction in the growth of the poultry industry over a period of time and it was asserted that, this decline was as a result of high cost of feed and medication (antibiotics and vaccinations), access to credit, poor market structure, absence of processing facility and then outbreak of disesease especially viral diseases (Nimoh et al., 2011; Okantah et al., 2004).

2.1.1 BIOSECURITY

The aim of biosecurity in livestock farming is to preserve good health of the animals by protecting them from pathogens and also increase the production of safe and quality food(Lestari et al., 2019). Table 1 provides insights on the various biosecurity practices under sub-head two sub headings, these include; sanitation and traffic control.

Table 1: Biosecurity practices

Biosecurity	Components
Sanitation	Contamination of feed and equipement from feacal matter
	Routine sanitary evaluation on farm; weeding, sweeping around, routine disinfection
	Equipment cleaning
	Dip and footbath availability
Traffic control	Limiting number of visitors and movement of other animals on the farm
	Having a control strategy such as fencing
	Record keeping of visitors

Source :(Buhman et al., 2000; Lestari et al., 2019).

A study conducted by Goualie et al., (2020) on the practices of biosecurity measures and their consequences on poultry farms in Abidjan district revealed that farms that did not have any form of traffic control mechanism such as fencing which constituted of 45 percent of the farmer population promotes free movement of rodents of wild pest and birds which are carriers of infectious pathogens to increase the occurrence of viral diseases outbreak on farms thus affecting income and productivity negatively.

An article published by Pritchard et al., (2015) on cattle veterinarians' awareness and understanding biosecurity stated that, most farmers had knowledge in biosecurity measures and mostly try to have conversations with veterinary on biosecurity. This indicates awareness of biosecurity measures and then these farmers are likely to practice biosecurity measures on their farm (Pritchard et al., 2015). Despite the apparent benefits of biosecurity, a study by Pritchard et al., (2015) revealed that approximately 40% of 155 interviewed farmers admitted to neglecting its importance due to complacency, a lack of perceived evidence of its benefits, time constraints, and the associated costs. This indicates a significant issue where a considerable number of farmers disregard crucial biosecurity practices. Consequently, this neglect occurs even though it negatively impacts their income, as further explained by the farmers' reported challenges (Pritchard et al., 2015). This further explains that some farmers completely neglect the importance of biosecurity even though their income is affected negatively.

2.1.2 TRAFFIC CONTROL AS A BIOSECURITY MEASURE

According to (Buhman et al., 2000), stated that, biosecurity is in three parts, this includes, isolation, traffic control and sanitation. Hence when these components are effectively managed occurrence or risk involved in disease outbreak among livestock is reduced and level of contamination is reduced. Buhman et al., (2000) defined traffic control in livestock farming, traffic control is all about keeping your animals healthy and your farm disease-free. It is like managing the flow of people, vehicles and other animals on your farm to prevent or reduce transmission of diseases from an external agent from getting in and spreading to your animals. Activities which usually leads to traffic control breach may include bringing in feed from the mill using trucks which have not been thoroughly disinfected before getting on the farm where the animals can be found, when large trucks come around to load waste materials from animals and move to other farms(Buhman et al., 2000). Lestari et al., (2019) worked on the identification of biosecurity on beef cattle farms whereby various coping biosecurity measures were identified. Traffic control was measured in many ways, these include, record keeping on farm visits, limiting visitors to certain areas on the farm, presence of a dip, and footbath. Traffic control biosecurity measures exhibited an average adoption level of 61.7% among the studied farms. This rate falls between the adoption levels of vaccination 58.5% and sanitation 69%, indicating a moderate level of implementation and suggesting its perceived importance in mitigating biosecurity risks alongside other key practices. Based on a systematic review done by Conan et al., (2012) on the topic Biosecurity measures for backyard poultry in developing countries, findings from the literature suggested that results from several biosecurity measures risk factors are high, knowledge, attitude towards biosecurity are low and then practices by people in developing countries are not strictly adhered to. The search was conducted across three database systems, and these include google search, Pubmed and then Food and Agriculture Organization. The study also agrees with (Buhman et al., 2000) where it was based on the principle of segregation (isolation), traffic control in terms external human and or vehicle to animal contact reduction and sanitation. Thie study emphasized the importance of limiting the movement to reduce the effect of infectious disease outbreak on the farm especially among commercial farmers in developing countries. This study further iterated the importance of record keeping of visitors to enhance contact tracing anytime there is an outbreak and concluded that biosecurity is an important tool to mitigate the spread of infectious disease.

2.2 PERFORMANCE MEASURE OF LAYER PRODUCTION

To be able to measure the performance of an entity or a firm, basic analysis such as the use of efficiency analysis and then profitability can be utilized to see how well a firm is doing in terms of efficient use of resources to get the best output result. Another way production can be measured is through productivity. Productivity can be explained as the ratio of total output to quantity of inputs allocated in the production of a commodity (Gordon et al., 2015). This can be done in terms of average productivity and marginal productivity. This can be represented mathematically by:

$$AP = \frac{Q_i}{X_i} \quad 2.2.1$$

$$MP = \frac{\partial Q_i}{\partial X_i} \quad 2.2.2$$

Where Q represents the total output and X_i represents the level of input used in a production process.

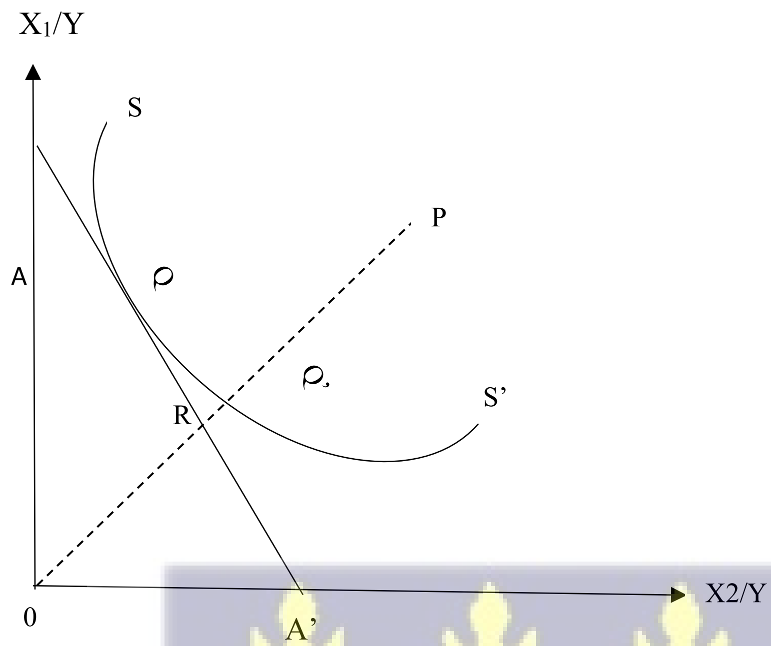
We can also talk about the Multiple Factor Productivity, which measures the performance ratio of quantity of output produced (Y) to the total quantity of inputs (Xi) used to produce that output. This can be expressed as;

$$MFP = \frac{Y}{\sum_{i=1}^{n} X_i} \quad 2.2.3$$

2.3 EFFICIENCY MEASUREMENTS

Measurement of efficiency was worked on years ago by Farrell, (1957). Upon his findings, other researchers worked on it extensively to add to the already existing information on efficiency measurements. Farrell (1957), segregated efficiency into technical efficiency and then allocative components.

He further described technical efficiency as the means to maximize output levels given a set of inputs whilst he described allocative efficiency as the optimum usage of inputs at their given prices. The diagram (**Figure 1**) below gives a better understanding of technical efficiency.



Source: (Farrell, 1957)

Figure 1: The technical and allocative efficiency graph

Farrell (1957) assumed a constant return to scale with the isoquant SS' describes the technology needed to combine inputs required to produce a unit of an output. This means that any point along the SS' isoquant is technically efficient whilst any point to the right of the isoquant, such as the point P, which means that point is technically inefficient. This means that more input would be required to produce a unit of output at that point. Hence, the technical inefficiency of P is measured along the distance Q'P. Technical efficiency at point P is expressed as [1-(Q'P/0P)].

Thus, when market prices of both the output and input are known, allocative efficiency can be derived from the isoquant of the diagram above. This is calculated as the relative distance indicated by the line (1- RQ'), where RQ' would be given as a ratio of (OR/OQ'). Efficient Frontier measurement approach is grouped into parametric or non-parametric approach (Farrell, 1957). The parametric method deals with estimations using the Stochastic Frontier model whereas the non-parametric approach employs the use of a linear mathematical programming known as the Data Envelopment Analysis (DEA) method.

He also described economic efficiency as the multiplication of technical efficiency and allocative efficiency.

$$EE = TE \ x \ AE \qquad 2.3.1$$

2.4 THE NON-PARAMETRIC APPROACH

Data Envelopment Analysis (DEA), as indicated early in the previous paragraph, is a non-parametric efficiency analysis approach worked on by (Farrell, 1957). Further additions to this method of efficiency analysis were done by Charnes et al., 1997). This was explained as a mathematical programming procedure applied to observational data gives a new avenue to acquiring empirical estimates of relations, some of these includes production functions and or efficient production possibilities surfaces which forms pillars of modern economics. DEA is a relatively new approach as compared to Decision Making Units (DMU) which transforms inputs to various yields since it is not specific when it comes to input transformations. DEA comes with some requirements based on some few priori assumptions as compared to other approaches requiring estimations of efficient frontiers in a regulated sector (Charnes et al., 1997). In DEA a smooth linear curve is constructed to like above observed values, and it can show relationships that most methodologies cannot show.

2.5 PARAMETRIC APPROACH

Utilizing either cross-sectional or panel data, the deterministic and stochastic frontier approaches are included in the parametric programming technique (Gordon et al., 2015). It is possible to estimate the deterministic frontier mathematically or stochastic frontier alone employs the econometric technique, whereas programing or econometric approach is used. For the parametric approach, the estimates are sensitive to outliers and measurements errors since the estimates are from a subset of observations. To curb that, econometric estimations are also employed in both deterministic and stochastic frontier approaches.

2.5.1 THE STOCHASTIC PRODUCTION FRONTIERS

Stochastic Production Frontier was worked on by several researchers and two of them were (Meeusen & van den Broeck, 1977). This method of analysis is set to aid in the explanation of the displacement of random components and inefficiency effects from possible high results that are caused by externalities other than the inefficiency of the production agent. Such externalities include weather, disease outbreak, institutional shocks, population growth and other uncertainties.

The stochastic frontier function can be written as;

$$Q_i = f(X_i; \beta).\exp(v_i - u_i) \qquad 2.5.1$$

Where:

Q_i= output of the i^{th} farm

X_i= the quantity of vector inputs for the i^{th} farm

β= the unknown coefficients to be estimated

v_i= the random effects

u_i= a non-negative error component that measures the endogenous sources of technical inefficiency effects on the parts of the producer.

The composed error term is $\varepsilon_i = v_i - u_i$, where v_i captures the effect of pure noise in the data attributed to measurement error, extreme weather conditions etc. and the one-sided inefficiency effects are denoted as u_i. A single firms' technical efficiency from the stochastic frontier is expressed as a proportion of the actual output to its own analogous stochastic frontier output, with respect to the input levels used by the firm. Therefore, a firm's technical efficiency using the function of the stochastic production frontier is given by;

$$TE = \frac{f(X_i;\beta).\exp(v_i - u_i)}{f(X_i;\beta).\exp(v_i)} = \exp(-u_i) \qquad 2.5.2$$

2.5.2 STOCHASTIC FRONTIER DISTRIBUTION ASSUMPTIONS

This aims to examine the different assumptions that underpins the estimating process for statistical analysis's use of the stochastic frontier. These are provided in the v_i and u_i distributional assumptions. It is expected that the v_i and u_i terms are uncorrelated with the explanatory variables, and that they are independent of each other. The random effects and non-negative error components are given as:

$E(v_i)=0$	(Zero mean)
$E(v^2_i)= \sigma^2_v$	(Homoscedastic)
$E(v_i v_k)=0$ for all i=k	(Uncorrelated)
$E(u^2_i)=$ Constant	(Homoscedastic)
$E(u_i u_j)= 0$	(Uncorrelated)

Estimates from the Ordinary Least Squares can be employed for the model based on the assumptions of the v_i and the u_i. However, given this, the least square estimator can be used to correct the intercept term's downwardly skewed coefficient. Under specific distributional assumptions of the two error factors, the maximum likelihood estimation method using iterative optimization methods provides a better answer. Presuming the random components v_i and u_i are distributed as any of the following independent pure noise and the random components v_i are independently and identically distributed with a zero mean and constant variance:

$U_i \approx iidN^+(0, \sigma^2_u)$ (Half Normal)

$U_i \approx iidN^+ (\mu, \sigma^2_u)$ (Truncated Normal)

$U_i \approx iidG (\lambda, 0)$ (Exponential)

$U_i \approx iidG (\lambda, m)$ (Gamma)

At times, computational simplicity dictates the distributional specification with regard to the user interfaces. With the Frontier 4.1 program, which has a built-in statistical package, the half-normal and truncated-normal models can be estimated. A greater range of distributional shapes can be achieved with the truncated normal and gamma models,but doing so comes at the expense of computational complexity because there are more parameters to estimate and because the probability distributional functions for vi and ui may have similar shapes, making it challenging to discern between inefficiency effects and random noise.

The log likelihood of the farm output is expressed as;

$\sigma^2 = \sigma_u^2 + \sigma_v^u, \; \lambda = \frac{\sigma_u^2}{\sigma_v^2}$ (Aigner & Chu, 1968). The variance σ^2_u, rather than the variance of the truncated half normal model, refers to the variance of the truncated random variable, which places limitations on this variation.

The maximization of the relevant log-likelihood function yields the estimates for the frontier model. These approximations are helpful in verifying whether the inefficiency model is suitable. Under the supposition that inefficiency is half-normally distributed, or $U_i \approx iidN^+ (\mu, \sigma^2_u)$, data regarding the Ui's is dependent on the error term that was created. This was applied to obtain the U_i predictor, and $1 - E(U_i | V_i - U_i)$ was then utilized to forecast the i-th farm's technical efficiency. If the one-sided error term had an exponential distribution, the Ui's were also calculated.

Fortunately given the value of the random variable, Ei 〽Vi ∘Ui, the conditional expectation of

exp (- ui) is the best way to estimate the technical efficiency of the i-th farm, given as TE=exp(-u_i), since it is consistent with the concept of the technical efficiency. In contrast to the half-normal distribution, (Coelli & Battese, 1995)reported their results on the truncated distribution with mean, ui dependent on the exogenous variables and the input variables.

2.5.3 FUNCTIONAL FORM REVIEW

The Cobb-Douglas and trans log functional forms are the primary choices for researchers estimating production frontiers. Each form has its own merits and limitations, and the decision on which to use in a study depends on finding the best fit. The Cobb-Douglass stochastic frontier production that assumes the egg production inputs among layer chicken farmers is as follows:

$$InY_i = \beta_0 + \sum_{k=1}^{N} \beta_i InX_i + \varepsilon_i \qquad 2.5.3$$

This model is suitable for analysis and usually requires estimating less information than other production models. Given its intrinsic benefits, the Cobb-Douglas model is the one that is chosen for study. One of these benefits is that it can handle a variety of econometric estimating issues more easily and successfully, including serial correlation, multicollinearity, and heteroscedasticity (Ogunniyi & Oladejo, 2011). One downside of this approach is the assumption that all firms share identical production elasticities and that substitution elasticities are uniformly set to one.

2.5.4 TRANSCENDENTAL LOGARITHMIC FUNCTIONAL FORM

Below is the functional form and it is specified as:

$$In\, Y_i = \beta_0 + \sum_{k=1}^{N} \beta_k InX_k + \frac{1}{2}\sum_{k=1}^{N}\sum_{j=1}^{N} \beta_{kj} In\, X_k In\, X_j + \varepsilon_i \qquad 2.5.4$$

This translog function is also known as the flexible functional form or the Cobb Douglas production function due to its importance among all the production functions. (Gordon et al., 2015). There are less restrictions on the substitution and production elasticities and also provides a second order derivatives of the underlying production function even though this same translog function requires a large sample size for analysis (Farrell, 1957). There is also a high level of multicollinearity which also affects the precision of the estimates of the model.

2.6 FARM SPECIFIC FACTORS

According to Yevu & Onumah (2021), it was identified that factors such as farmer age, gender, level of education, experience, farm size, extension service availability and accessibility, proximity of farmers residence to farm, accessibility to credit and accessibility to roads had significant effect on technical efficiency levels of farms. A study done by Akolgo (2020), indicated that hired labor had a positive effect on the efficiency technical efficiency level across various farms and this is due to the highly skilled nature of these type of labour. The reliance on family labor, while offering a degree of on-farm assistance, presented certain inefficiencies. The unskilled nature of this labor, coupled with the concentration of a large workforce on small landholdings, resulted in relatively high labor expenses and reduced efficiency, ultimately contributing to diminishing marginal returns to labor. It has also been identified that, older farmers and female farmers are inefficient due to inefficiency attributed to age and due to inaccessibility to farm inputs respectively (Yevu & Onumah, 2021).

Technical efficiency in chicken production is heavily influenced by several farm-specific factors in Ghana. These variables include input use as well as management techniques that have an immediate impact on output and cost effectiveness.

Inputs that are necessary to improve technical efficiency include feed, water, and flock size. Research shows that these inputs have a positive correlation with output levels in broiler and layer production (Ahiale et al., 2019; Yevu & Onumah, 2021).

Training in poultry management, regular extension visits, and farmer experience are essential. By addressing inefficiencies in production methods, increased extension contact and training have been demonstrated to improve technical efficiency (Ahiale et al., 2019; Yevu & Onumah, 2021).

2.7 Empirical Results of Previous Technical Efficiency Studies

A study conducted by (Djokoto, 2012), on the topic technical efficiency of agriculture in Ghana; a time series stochastic frontier estimation approach, the Cobb-Douglas production was fitted to time series data from 1961 to 2010. Aside land and seeds, all production factors had a priori signals, and every variable was significant at the 1% level. Every capital variable exhibited output inelasticity. Labor had an elasticity of 1.28 with respect to production. The total elasticities estimated was 1.74, indicating increasing agricultural output returns in Ghana over the time frame. Technical efficiency estimates ranged from a low of 59% to a maximum of 96%, with a mean of 82%. There are still efforts to use the available technologies to offset the 18% inefficiency, and this is based on the negative relationship between land and agricultural productivity as well as the growing population's demand for non-agricultural land usage.

Ahiale, Abunyuwah, & Yenibehit (2019) undertook a study using cross-sectional data from the most recent production in 2017. This study used the stochastic frontier model to evaluate the technical proficiency of broiler producers in the Mampong Municipality. Utilizing the Cobb-Douglas functional form, it was discovered that variables including feed, flock size, and water all had a positive impact on the technical efficiency of the broiler producers in the research region were significant. The technical efficiency of each farmer's operation varied from 42% to 99%, with an average of 87%. This indicates that soon, chicken farmers may still be able to optimize resource utilization by 13% on their farms. Factors such as age, education, experience level, and frequency of extension visits were found to be associated with technical inefficiency among chicken farmers. A high ranking of challenges for the broiler production industry included worries about the prevalence of predators and competition from imports. Broiler chicks need to consume more feed and water in order to enhance efficiency and output, even while farmers are being encouraged to increase their stocking capacity. Farmers also need to engage with extension staff more frequently and be introduced to non-formal education.

(Asante et al., 2017) conducted a study on integrated crop-livestock management practices. A meta-frontier production function model is used to estimate the mean technical efficiencies and meta-technology ratios of farmers in each district using farm-level data taken from a sample of 510 farmers from the Atebubu-Amantin, Nkoranza South, and Ejura-Sekyedumase districts. At least one of the three districts' inputs—herd size, capital, labor, feed, and veterinary expenses—had a major impact on the farmers' small-ruminant outputs as well as the meta-frontier function. Additionally, increased pasture, the storage of crop leftovers, and the use of pigeon pea, ash, or neem all had a significant and positive impact on the outputs of small ruminants. In addition, the crop-livestock farmers' age, gender, and level of education, as well as their involvement in projects, off-farm income, market knowledge, and availability to extension guidance in one or more of the three districts, all had an impact on their technical efficiency. The findings show that the three districts' approaches to small-ruminant production differ significantly from one another, with Nkoranza South district employing a more advanced production system than the other two. The findings highlight the necessity of funding research and extension activities to create and distribute pertinent ICLMPs and supplemental training that improves the productivity of small-ruminant production and, as a result, raises farm profitability.

In the framework of profit maximization as the incentive for optimal production, the study conducted by Tuffour & Oppong (2014) looks at profit efficiency and its factors in the broiler industry. The Cobb-Douglas profit function is applied in the study together with the stochastic frontier technique. The study's findings showed that while the cost of day-old chicks increased profit, the cost of labor dramatically decreased profit. The outcome also showed that, on average, broiler growers were able to obtain 54% of their border profit. It was discovered that farms run by sole proprietors were less economically efficient, while farms with years of experience producing broilers reduced inefficiencies.

2.8.1 Kendall's Coefficient of Concordance

Kendall's ranking system is used to compile ordinal rankings into a collective one even though there could be variation in preferences of selection which might be objective to each respondent based on criteria of selection. This ranking system is usually known as the compromising ranking (Franceschini & Maisano, 2021). One main advantage of the Kendall rank correlation coefficient is that, the data can be non-numeric but can be grouped using selected criterion which can be calculated easily and then we do not necessarily have to make any hypothesis.

The ratio of the observed variation of the ranked entities' total rankings to the highest possible variability of the potential total ranks is represented by Kendall's statistic. This would be the variation of the overall ranks divided by the greatest variance that might exist in the overall ranks(Field, 2005).

A test of significance level can be estimated to attain the validity of the ranking method using the chi-square statistics (n-1) degree of freedom.

2.8.2 The Classical Coefficient of Concordance

Let X = (x_1, …… x_n) denote a finite universe of discourse, that is, a finite set of factors to rank. The factors would be ranked based on preferences of number of sample size and these factors are ordered. The data is presented in the form of a two-way matrix M, with k x n with designated to be row and columns respectively, whereby R_{ij} (I =1…, k and h=1…., n) represents the rank given by the ith observer to the jth factor, that is,

$$M = \begin{bmatrix} R_{11} \; R_{12} \; ...... \; R_{1n} \\ R_{21} \; R_{22} \; .... R_{2n} \\ .... \; .... \; .... \; .... \\ R_{k1} \; R_{k2} \; .... \; R_{km} \end{bmatrix}$$

It is simple to notice that every row is a different combination of numbers. Additionally, we have a collection of ranks that each observer has assigned to the factor in the jth column. For instance, all rankings in the jth column will be the same if each of the k observers believes that has the same preference in comparison to all other things. As such, the agreement among observers is indicated by the ranks in each column. The coefficient W is a number between 0 and 1, where 0 denotes no agreement or sample independence and 1 represents perfect agreement (or concordance). There is more unanimity among observers as W rises. Additionally, Kendall's coefficient of concordance is invariant and commutative under all transformations that preserve order. As with most other nonparametric techniques, the standard procedure for handling tied observations is to assign equal ranks to indistinguishable observations, should they also occur.

2.8.3 Empirical Results of Previous Kendall's Coefficient of Concordance Studies

The purpose of this research done by (Melkamu & Singh, 2015) was to use Kendall's coefficient of concordance approach to determine frequent coping techniques in Northern Rajasthan. After a multistage random sampling procedure in the study region, 300 homes provided primary data for the study. The research discovered that the standard order in which all households employ coping mechanisms is determined by the assets they possess, and the order in which these methods are selected is consistent with one another. In Northern Rajasthan, the three most popular coping strategies among all sampled households are looking for subsidies, selling livestock, and finding wage work. Kendall’s 'W' of 0.856 shows that 85.6 percent of respondents agreed on the ranking of coping strategies among households. Low-income families have three most common coping mechanisms are to work for a wage, rely on less desirable foods, and control meal quantity. With six degrees of freedom, the coefficient of concordance for the ranking of poor households is 0.879, indicating an 87.9 percent agreement among respondent ranks of the coping mechanisms used by poor households to maintain a constant standard of living. The top four coping techniques selected by non-poor households to maintain a constant level of wellbeing were looking for subsidy prices, selling livestock, buying food on credit, and working for pay. With six degrees of freedom, Kendall's coefficient of concordance for non-poor households is 0.943. The score of W indicates that 94.3 percent of the non-poor families in the sample agreed with the coping techniques' ranking order.

Research conducted by Hailu et al., 2015) on participatory assessment of trade limiting diseases of small ruminants export market chain utilized Kendall’s coefficient of concordance to measure the degree of agreement amongst informant groups. Approximately 72.2% of pastoralists sell shoats to satisfy their immediate needs at any time of year. Most producers (51.9%) do not have a defined goal in mind for selling their products. Just 7.6% of the producers were aware of the health, quality, and other requirements related to animals that importers expect. The Afars' sheep are the most sought-after by importers, second only to Somali black head, however just 20% of all the shoat offered for sale are sheep. Most producers (40.9%) said they offered young male shoat for sale, while 28.2% said they offered culled female shoat for sale. Pastoralists pointed out that the diseases that had the biggest effects on livelihoods were PPR, Pasteurellosis, sheep pox, external parasite, ovine fasciolosis, and CCPP. The most significant diseases that affect enterprises in shoat are PPR, pasteurellosis, CCPP, sheep pox, and external parasites, according to quarantine institutions. Most of the diseases that quarantine centers report as serious illnesses are likewise the main illnesses that affect producers.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This chapter introduces the conceptual framework, theoretical framework, study area and model specifications that address the study's objectives. It also describes the variables used to estimate the models, data collection, sampling methods and data sources as well as the software utilized in the analysis.

3.2 THEORETICAL FRAMEWORK

The concept of technical efficiency centers on the optimal utilization of resources to maximize output, a principle often quantified through efficiency indexes. The increasing adoption of these indexes can be attributed to advancements in estimation tools and techniques (González & Álvarez, 2001). While a robust theoretical explanation for technical inefficiency has historically been elusive, it is increasingly being understood through the Resource-Based View (RBV). This perspective connects a firm's resources and capabilities to its efficiency outcomes (González & Álvarez, 2001). Complementing this, production theory provides a foundational understanding of the relationship between inputs and outputs in the production process, detailing how firms can optimize their processes to enhance efficiency and productivity, a critical aspect of technical efficiency assessments (González & Álvarez, 2001).

According to Battese et., (2004), the stochastic frontier function is useful because it helps to measure both the technical efficiency sources and the impact of measurement errors or factors that are not inherently related to production. By using the stochastic frontier model, the error term (e_i) is used to estimate technical efficiency. The stochastic model for a cross-sectional is specified as:

$$Y = f(Xi; \beta)\exp(\varepsilon i) = f(Xi; \beta)\exp(Vi - Ui), i = 1, \ldots N \qquad 3.1$$

Where the error term $(\varepsilon_i) = V_i - U_i$

Where Y is the output (crates of eggs sold) by the i^{th} layer chicken farmer, f(Xi,ß) represents a production functional form (such as Cobb-Douglas) and (εi=vi-ui) denotes the composite error term. Technical efficiency is the ratio of the observed mean production output of the i^{th} poultry farmer with inputs $X_{i.}$ (these include quantity of feed, water consumption, vaccination, Deworming and other drugs, and labour). Biosecurity practices as factors that affect technical efficiency include depopulation of birds, litter change, rearing of other birds, disinfection routine, deworming routine, footbath use, traffic control and in-house cleaning. There are some socio-economic characteristics that influence technical efficiency and it include age, gender, education, layer farming experience, district of the respondent, membership of farmer-based organization and use of family labour) to the Meta frontier production output. V_i and U_i are elements of the decomposed error term εi.

$$TE = \frac{Yi}{Y*} = \frac{f(Xi;\beta)\exp(Vi-Ui)}{f(Xi;\beta)\exp(Vi)} \qquad 3.2$$

Whereby:

TE= technical efficiency value of the layer chicken farmer

$X_{i.=}$ quantity of feed consumed in the production year per 1000 birds, quantity of vaccines used per production year per 1000 birds, quantity of water consumed, quantity of dewormer and other drugs used per 1000 birds and labour used in man hours.

Y= represents the observed output level (crates of eggs produced)

U_i = accounts for unobservable factors that affect the farmer's inability to achieve maximum output

V_i = represents the composite error term

When technical efficiency is equal to one, it means it is efficient or otherwise if it is less than one. Understanding the technical efficiency of layer production concerning viral disease control strategies is essential for improving overall production processes. Efficiency improvements can directly impact profitability, income, and cost reduction, reducing wastage of resources, and optimizing outcomes which translates to improved standards of living and livelihood among poultry farmers (Yevu & Onumah, 2021).

The Cobb-Douglass stochastic frontier production that assumes the egg production inputs among layer chicken farmers is as follows:

$$InY_i = \beta_0 + \beta_i InX_i + \varepsilon_i \qquad 3.3$$

whereby:

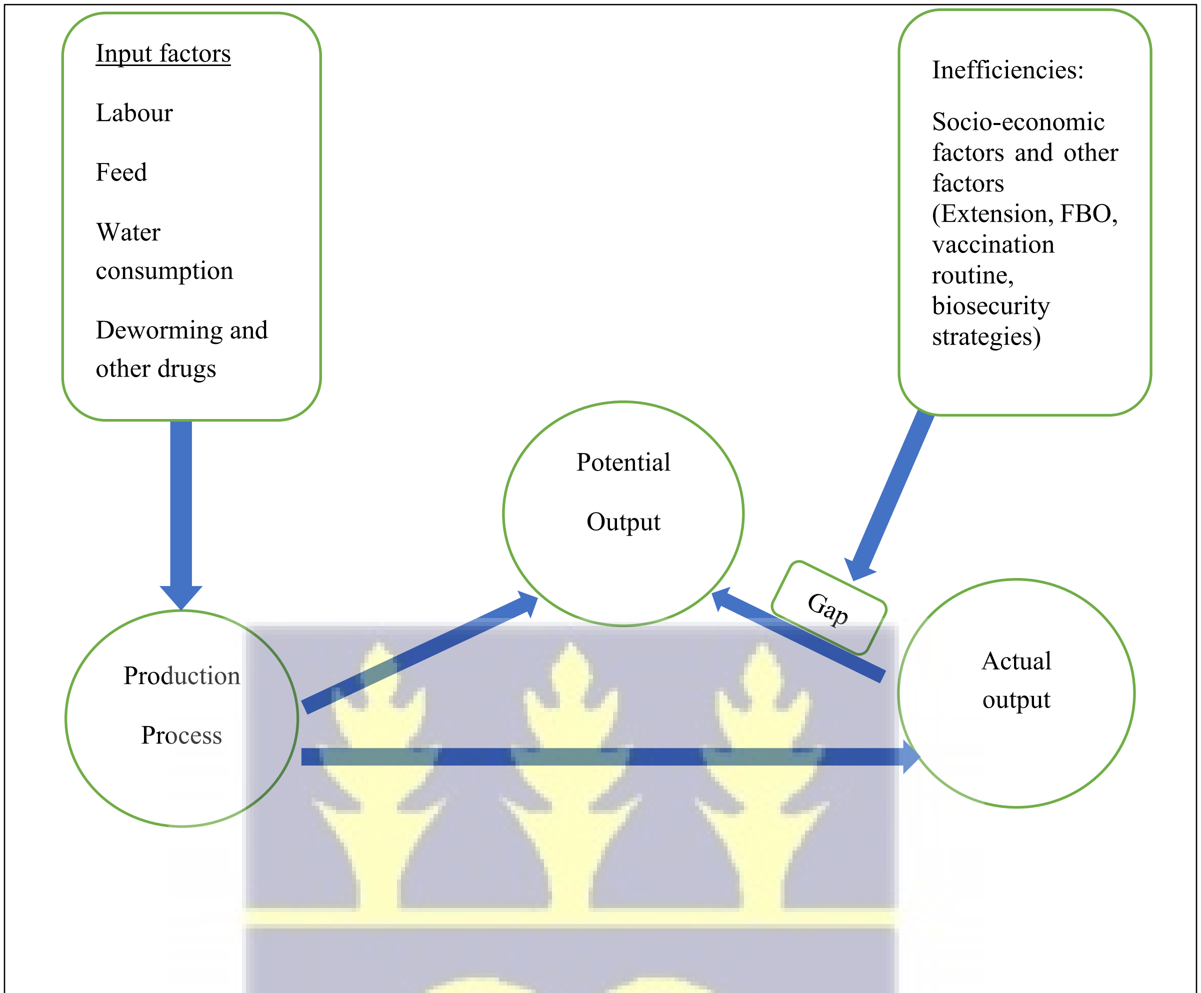
InY_i = natural logarithm; Y_i is output (crates of eggs produced) of the i^{th} farmer

β= parameters to be estimated

X_i = represents vector inputs which include cost of feed, ration, biosecurity measures (cost of vaccination per bird, frequency, and cost of litter management, and other socioeconomic characteristics such as age, experience, membership of Farmer Based organization, extension services, land ownership, mortality rate of the layer chicken, and housing type.

3.3 CONCEPTUAL FRAMEWORK

When factors are combined under a production process given a particular technique, an actual output is achieved. Management practices on the farm which includes biosecurity practices and adherence to vaccination routine and biosecurity practices provided by the Veterinary Services Department and Animal Production Directorate. Differences in the practices stated above bring about the variations existing between the actual output and potential output. This is explained by the inefficiencies on the part of the farmers and other risk factors such as disease outbreak, weather conditions and many others and this study focuses only on the inefficiencies. Figure 2 presents a diagram showing conceptual framework in this section. The conceptual framework presented here illustrates the relationship between input factors, the production process, and the resulting output. Input factors such as labor, feed, water, and other resources are transformed through the production process to yield an actual output. However, due to various inefficiencies, including socio-economic factors and inadequate implementation of best practices like extension services, vaccination, and biosecurity measures, the actual output often falls short of the potential output. By identifying and addressing these inefficiencies, producers can move closer to their potential output, thereby improving technical efficiency levels in the production of eggs.



Source: Ayertey (2024)
Figure 2: Conceptual Framework

3.4 STUDY AREA

The study is based on farm level data on layer production in the Bono Region. This region has a population of 1.2 million and a population density of 108.8 per km^2 (Ghana Statistical Service, 2021) . Agricultural activities dominate the economic environment of the area, especially in livestock, that is layer production is most dominating in the region. Some of the districts such as Sunyani West and Berekum Districts are in the semi-deciduous forest zone, which satisfy the weather requirements for maize production and most importantly poultry production in the region.

This makes the region more conducive for poultry activities because maize forms the major component of poultry feed. Dormaa Central and Dormaa East are the most dominant areas in the region for poultry production (Yevu & Onumah, 2021).

The Bono Region together with Ashanti Region and Greater Accra Region were the selected study area for the Marek Disease project. This also had influence in the selection of the study area and region for this project. The study area was selected based on project being conducted by International Livestock Research Institute on the topic socioeconomic impact modelling of Ghana's poultry value chain under the combined influence of imperfect vaccines, host genetics, non-genetic drivers on virus transmission and virulence (Marek's Disease project). Layer production dominates in this region, and it is the highest in layer producing districts in Ghana and employs a high proportion of the labour force in the region.

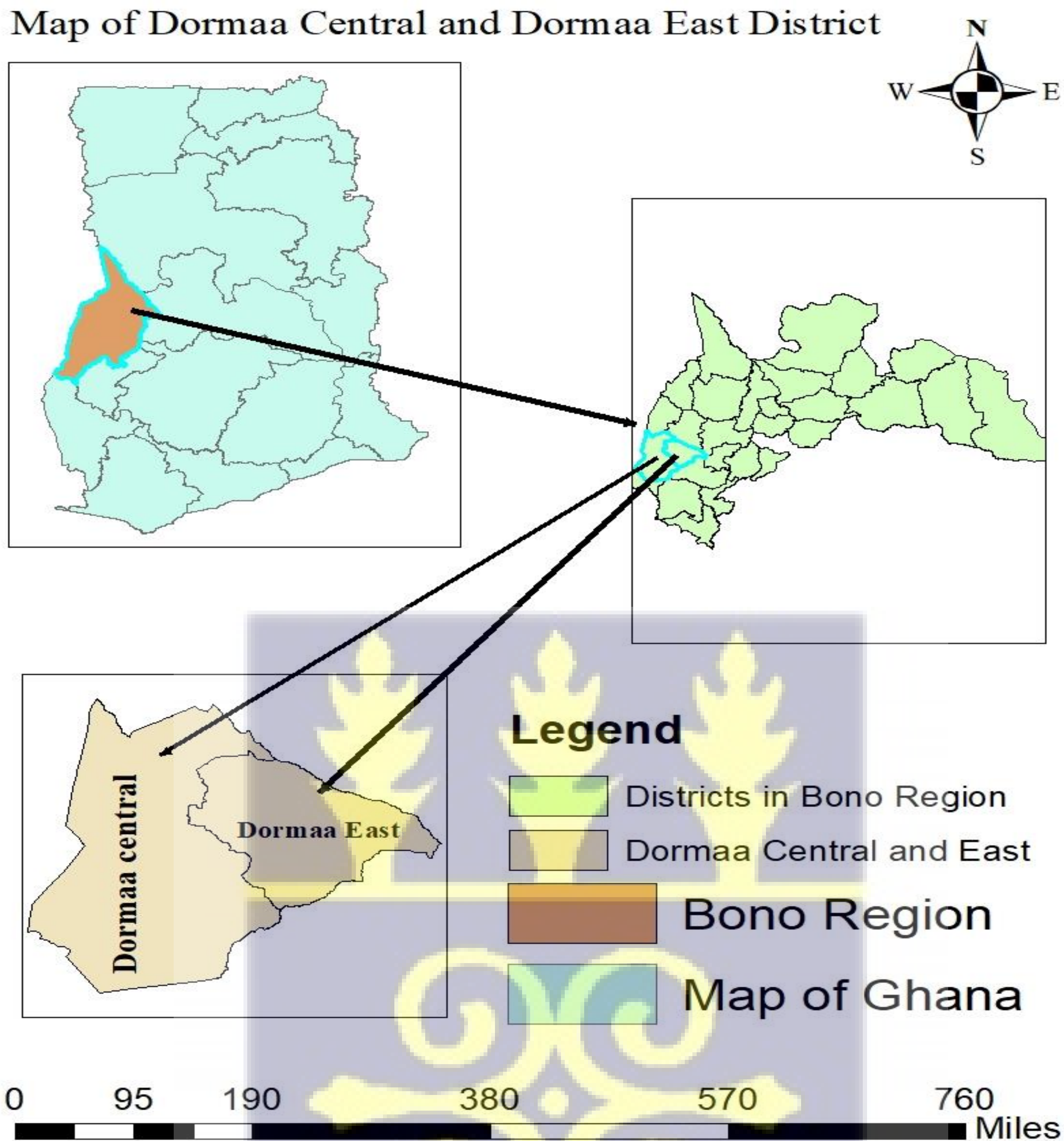


Figure 3: Map of study area

3.5 SAMPLING TECHNIQUE AND SAMPLE SIZE

Layer producers in the Bono Region were selected using a multi-stage sampling technique. Initially, purposive sampling was employed at both regional level and district level, focusing on areas with a substantial population of layer farmers. This approach was informed by the prior involvement of some farmers in focus group discussions and in-depth interviews related to the

Marek Disease project. Subsequently, within the selected districts of Dormaa East and Dormaa Central, purposive sampling was again utilized to identify key communities with a high concentration of layer producers. Specifically, the four communities with the highest number of layer farmers in Dormaa Central were Dwen, Suromani, Kofiasua, and Kyeremasu. Similarly, in Dormaa East, the four leading communities with the most layer farmers owning 10,000 birds or fewer were Ampenkro, Akontanim, Asuhhyia, and Asutiano. While these were primary sites, other communities were also visited to comprehensively enumerate layer farmers across both districts. However, precise figures for the current active layer farmer population were challenging to ascertain due to business attrition linked to the COVID-19 pandemic and other factors, as indicated by records from the Dormaa Central and Dormaa East Veterinary offices. These districts were strategically chosen due to their heterogeneity in farmer educational levels, experience in layer farming, production practices, and access to extension services. The adoption of a non-probability sampling procedure in this study was necessitated by the prior selection of farmers for the Marek's Disease project [Reference to Marek Disease Project] and the study's focus on farmers with layer bird holdings between 500 and 10,000. The targeted sample size for this study was 161-layer producers within the Bono Region, a figure determined based on existing literature and the population of layer producers with 500 to 10,000 birds, to ensure the inclusion of both small-scale and medium-scale producers. The majority of the selected farmers were categorized as small-scale producers, with the remainder being medium-scale, based on farmer lists obtained from the veterinary offices in both districts and pretest conducted in these selected districts. This sample size was achieved using the Cochran's formula (Cochran, 1977),

$$n = \frac{z^2 p(1-p)}{e^2} \quad 3.4$$

Where:

n= sample size

p= is the estimated proportion of the population that exhibits the characteristic of interest. This is often based on prior knowledge or pilot studies. To be conservative value used was 0.5.

Z= Z-score corresponding to the desired confidence level. The Z-score is a critical value from the standard normal distribution that corresponds to the chosen level of confidence. Z-score was valued at 1.96 at 95 % confidence level.

e= margin of error value was 0.077

3.6 DATA COLLECTION

Data collection was done by interviewing farmers with the aid of a well-structured questionnaire. This procedure was done in two districts, Dormaa East and Dormaa Central in the Bono Region. The survey was pretested to adhere to field conditions, also inconsistencies were corrected before dispensing. The pretest was conducted in Dwen and Kyeremasu of the Dormaa Central district and Kobedi and Wamnafo of the Dormaa East district. The pretest was conducted in the month of November 2023. Irregularities and mistakes were corrected before questionnaires were deployed in the month of February 2024. Enumerators used were trained on how to use the Kobol tool app to deploy the questionnaires to the respondents prior to the month of data collection. Consent forms were given out and were well explained before respondents were allowed to participate in the survey.

3.7 RANKING OF THE VIRAL DISEASES THAT AFFECT LAYER FARMERS IN BONO REGION OF GHANA

To rank the various viral diseases that affect layer farmers based on their severity of occurrence on their farm, Kendall's coefficient of concordance was used. This ranking system was used currently by Okata & Al-Hassan (2023) on the constraints affecting poultry farmers vaccination routine. This forms an aspect of objective one which seeks to rank viral disease affecting layer farmers and identify their biosecurity strategies. The viral diseases include, Infectious Bronchitis, Infectious Bursal virus (Gumboro), New Castle, Fowl pox, Avian Influenza and Marek disease. The model is specified by:

$$W = \frac{12[\sum T^2 - \frac{\sum(T)^2}{n}]}{m^2(n^3 - n)} \quad 3.5$$

Where m = number of respondents doing the ranking

W = is the coefficient of concordance. The value of the Kendall's coefficient is between 0 and 1, which indicates the degree of agreement , 1 indicates perfect agreement in the ranking and 0 means a perfect disagreement in the rank.

n = number of diseases to be ranked

T= respondents ranking of the disease

The coefficient of concordance, (W), was tested for significance in terms of F-test distribution: it is given as:

$$Fcal = \frac{\frac{[m-1]}{W}}{1-W} \quad 3.6$$

Hypothesis:

H_0= There is no agreement among the respondents in the rankings

H_1= There is an agreement among the respondents in the rankings

Decision rule: If the calculated F_{cal} is greater than the F_{crit}, it implies that we reject the null hypothesis.

3.8 ELASTICITY OF INPUTS

The estimated parameters β1 β2 β3...... βk for the Stochastic Frontier Production model describe the output elasticities of the respective inputs employed in the analysis. Regarding the production. The Cobb-Douglas production function is given as:

$$InY_i = \beta_0 + \sum_{k=1}^{N} \beta_i InX_i + \varepsilon_i \quad 3.7$$

In production function analysis, the elasticity (ε) estimates are inherently derived from the first-order parameters. However, for the translog production function, the elasticities associated with individual inputs are not constant and depend on the specific levels at which these inputs are employed. These input elasticities are typically expressed as;

$$\frac{\partial InE(Y_i)}{\partial InX_{ki}} = \{\beta_0 + \sum_{k=1}^{N} \beta_i InX_i + \varepsilon_i\} \quad 3.8$$

As the input and output variables are normalized, divided by their respective means—the first-order coefficient can be seen as the output's elasticities with respect to the various inputs. The returns to scale (RTS) are obtained by adding up these input elasticities to assess how changes in the input variable affect the outcome. One can say that the returns to scale are increasing, constant, or diminishing.

When (ε) > 1, it means increasing returns to scale (ε) = , it means constant returns to scale

(ε) < 1, it means decreasing returns to scale

3.8.1 HYPOTHESIS FORMULATION

I. H_0: $\beta_{ij} = 0$; the null hypothesis that Cobb-Douglas production function is a statistically accurate representation of the data of the technical efficiency frontier function. The alternative hypothesis is stated as; H_A:$\beta_{ij} \neq 0$

II. $H_0 : \gamma = 0$; inefficiency effects are non-stochastic. The alternate hypothesis is H_A: $\gamma \neq 0$

III. $H_0 : \delta_6 = 0$ states that, there is no district effect on technical efficiency of layer production. The alternative hypothesis is $H_A\ \delta_6 \neq 0$

The hypothesis was validated based on the generalized likelihood-ratio test, (LR), which is specified as:

$$LR = -2[In\{L(H_0)\} - In\{L(H_A)\}] \quad 3.9$$

$L(H_0)$ and $L(H_A)$ represent the values of the likelihood function based on the null (H_0) and alternate hypothesis (H_A). The log likelihood ratio (LR) makes use of the Chi-square distribution with the degree of freedom representing the number of parameters assumed to be zero based on the assumption of the null hypothesis (H_0)(Sverdrup, 1986; Garcia, 1986). The Chi-square distribution table used to attain the critical values can be found in an article published by Kodde & Palm, (1986).

IV. To make sure the dataset and results are robust and reliable for making references, the estimated model to test for multicollinearity used was the variance inflation factor or tolerance test and for homoscedasticity, white test was used. White test and tolerance test were utilized by (Birau, 2012) and Prempeh et al., (2018) respectively. Multicollinearity occurs when two or more independent variables in a regression model are correlated with each other (Farrar & Glauber, 1967). For multicollinearity a variance inflation factor that is greater than 10 or a tolerance level equal to 1/VIF which is less than 0.1 indicates the presence of multicollinearity. For the heteroscedasticity, we test for the residual term or error term (ε_i) being constant. White test was developed by Halbert White in the year 1980 and it is one of the most used heteroscedasticity tests since it is unrestricted and robust. The null hypothesis for this is stated as; H_0: $b_1 = b_2 \ldots\ldots b_n = 0$, this indicates that the variance of the residuals is homoscedastic, the alternate hypothesis H_A: $b_1 \neq b_2 \ldots\ldots b_n \neq 0$.

3. 9 BINARY LOGISTIC REGRESSION ON THE PRACTICE OF TRAFFIC CONTROL

The logistic regression model is frequently used to identify the elements that affect dichotomous dependent variables. Many other researchers have also employed the model, and they include Adesina et al., (2000); Bonabana-Wabbi, (2002); Odendo et al., (2009); Thangata & Alavalapati, (2003). Maximum Likelihood Estimation (MLE) is a more suitable method for estimating logistic models than the Ordinary Least Square approach, according to (Morris & Doss, 1999). The Maximum Likelihood Estimation is unbiased and provides efficient estimates.

Farmers' decision to adopt or not to adopt a practice is assumed to be the outcome of a complex set of factors related to the farmers' objectives. Logistic regression models are perhaps best viewed as instances of generalized linear model (McCullagh & Nelder, 1989) where the response variable follows a Bernoulli distribution, and the link function is the logit function. Assuming one wants to estimate the effect of explanatory variables on the observed economic phenomena uses linear model:

$$y = \alpha + \sum_{i=1}^{n} b_i X_i + e \qquad 3.10$$

Where y is a continuous random variable $x=x_1....x_n$ are the variables that explain y, α is a constant and $b= b_1...b_n$ are the parameters that ultimately describe the effect a change in x has on y, i denotes the i-th individual and n is the number of observations. But for biosecurity practices such as traffic control strategy, the random variable y is not continuous. Instead, it can be discrete or dichotomous. When dichotomous:

$$P = P(Y = \frac{1}{X}) \quad 3.11$$

Where the probability that $Y = \frac{1}{X}$ and $1 - p = P(Y = \frac{0}{X})$ 3.12

For instance, Y=1/X might represent the practice of traffic control as a biosecurity practice, whereas $Y = \frac{0}{X}$ would indicate non-practice of traffic control X_i. The judgments made by farmers based on economic theory ultimately led to its acceptance. An economic unit, in this example a layer farmer, makes logical choices to maximize predicted utility. The potential outcomes of implementing this control strategy determine the utility associated with the strategy thus:

$$U_0= f(b/X_o) \quad 3.13$$

$$U_1= f(b/X_1) \quad 3.14$$

Where u_0, u_1 are the expected utility levels with and without the practice of traffic control, X_0, socioeconomic and other characteristics of layer farmers, $b= b_1...b_n$ are parameters that describe the effect of farmers' characteristics on utility. When $U_1> U_0$, then a farmer practices traffic control or simply that Y=1/X . Now by substituting equation 3.11 into equation 3.12 it becomes

$$p = P(\alpha + \sum_{i=1}^{n} b_i X_i + e) \quad 3.15$$

For Y= 1/X equation 3.11 can be expressed as

$$y = \alpha + \sum_{i=1}^{n} \beta_i X_i + e \quad 3.16$$

The outcome of a continuous random variable, y is replaced by P the probability of traffic control practice. But equation 3.13 is linear, hence would show probability of < 0 and >1 at low levels and high levels of X respectively. To ensure that P is positive and restricted to the (0,1) range, then equation 3.13 $P\left(Y = \frac{1}{X}\right) = \frac{e^{\alpha} + \sum \beta x + e}{1 + e^{\alpha} + \sum \beta x + e}$s 3.16

Where p(.) is Probability that traffic control is practiced, α is constant term, β is a vector of unknown parameters and e is disturbance term. Reformulation of equation 3.16 yield is:

$$\frac{P\left(Y = \frac{1}{X}\right)}{1 - P\left(Y = \frac{1}{X}\right)} = e^{\alpha} + \sum \beta x + e \qquad 3.17$$

This is odds ratio or the probability of traffic control measure divided by the probability of non - practice of traffic control hence transforming equation 3.9.2 into a logistic function:

$$In\left[\frac{P\left(Y = \frac{1}{X}\right)}{1 - P\left(Y = \frac{1}{X}\right)}\right] = \alpha + \sum_{i=1}^{n} \beta_i X_i + e \qquad 3.18$$

When B>0, the probability of adoption increases as the levels of factors (X) increases, When B=0, the binary response is independent of X.

Equation 3.17 is also known as the logit (p). By defining $\frac{p}{1-p}$ as the odds of adoption and modelling p with the logistic function above, it is equivalent to estimating a linear regression model where the continuous outcome y has been replaced by the logarithm of the odds of adoption. Thus, the logit model is linear in the explanatory variables. One major limitation with logistic regression is that the parameter estimates are difficult to interpret, as the coefficients do not have a direct interpretation. For instance, equation 3.19 is not the change in probability per unit change in the independent variable. One way to ease this interpretation issue is to calculate the marginal (effects) probabilities for each parameter estimates not the change in probability per unit change in the independent variable. Explicitly, it helps in the interpretation of the effect of a change in an explanatory variable on the dependent variable by measuring the direct percentage change in a dependent variable when an explanatory variable changes by one percent ceteris paribus. Equation 3.16 above allows the determination of a change in farmer's adoption behavior if the independent variables change by a given amount and is measured by taking

the first derivative of equation 3.16:

$$\frac{\partial \mathrm{P}\left(\mathrm{Y} = \frac{1}{\mathrm{X}}\right)}{\partial X} = \left[\frac{e^{\alpha} + \sum \beta x + e}{1 + e^{Xb + e}}\right]\left[\frac{X}{Y}\right] \qquad 3.19$$

Which is;

$$\beta p\left(Y = \frac{1}{X}\right)[1 - p\left(Y = \frac{1}{X}\right) \qquad 3.20$$

Thus the marginal probability for the logistic distribution is the parameter estimate for the logit multiplied by a standardization factor. The standardization factor is the probability of traffic control practice multiplied by the probability of non-traffic control practice and it is given by:

$$\frac{\exp(X\beta)}{[(1 + \exp(X\beta)]^2} \qquad 3.21$$

This change in probability of practicing traffic control is not constant but increases or decreases depending on the value of X. Thus, for a continuous variable X, at relatively high values, a large change will give a relatively smaller change in the probability of adoption (McCullagh & Nelder, 1989). A convenient measure is to evaluate the change in probability at the sample means of the explanatory variables.

However, for this study the independent variable for the empirical models come from the categories of traffic control practice determinants where:

$$In\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{j=1}^{n} \beta_j X_j \qquad 3.22$$

In table 2, it provides all the variables used in the logit model.

Table 2: Description of Variables used in the Logit Model and their Expected Signs

Variable	Description	Measurement	Expected Sign
Dependent Variable			
Traffic Control	Controlling the number of people who enter the farming.	Dummy (1 =Yes, No=0)	
Explanatory variables			
Age of farmer	Age of layer farmers	Years	+/-
Member of Farmer Based Organizations	Farmers belong to farmer based organization or not	Dummy (1 =Yes, No=0)	+
District of the farmer	Selected districts in the Bono Region, Dormaa Central and Dormaa East	Dummy (1 =Dormaa central , 0= Dormaa East)	+/-
Gender of the farmer		Dummy (1= Male, 0= Female)	+
Years spent formal in education	Level of formal education attained in years	Years	+
Total Eggs Produced in the production cycle	Total number of eggs quantified in crates	Crates of eggs	+
Production scale	500 to 5000 birds is small scale, 5,001 to 10,000 birds is medium scale	Dummy (0= Small scale, 1= Medium scale)	+

Source: Author's own construct 2024

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This chapter presents the results from the study and the discussions of the results. It begins with a discussion on the socio-economic characteristics of the respondents of chicken layer farmers in the Bono Region interviewed. The various viral diseases that affect the layer chicken, the biosecurity measures these farmers put in place, their technical efficiency levels, factors affecting the technical efficiency levels and factors affecting the practice of traffic control.

4.2 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF FARMERS

The socio-demographic characteristics of the layer farmers in the Bono Region interviewed are summarized in Table 3. Each characteristic is further discussed in the subsequent headings.

4.2.1 AGE DISTRIBUTION OF THE LAYER FARMERS

The result of the age groupings of the layer farmer indicated that 33% were between the ages of 41 to 50 years, with the mean age being 44 years, this suggests that the middle-aged group dominates the layer production sector, this was also observed by Yevu and Onumah (2021). This is followed by a bracket age group from 31 to 40 representing 27%, age bracket group from 51 to 60 years represented 25%. The figure below gives a complete representation of the age bracket group of the layer farmers in the Bono Region of Ghana.

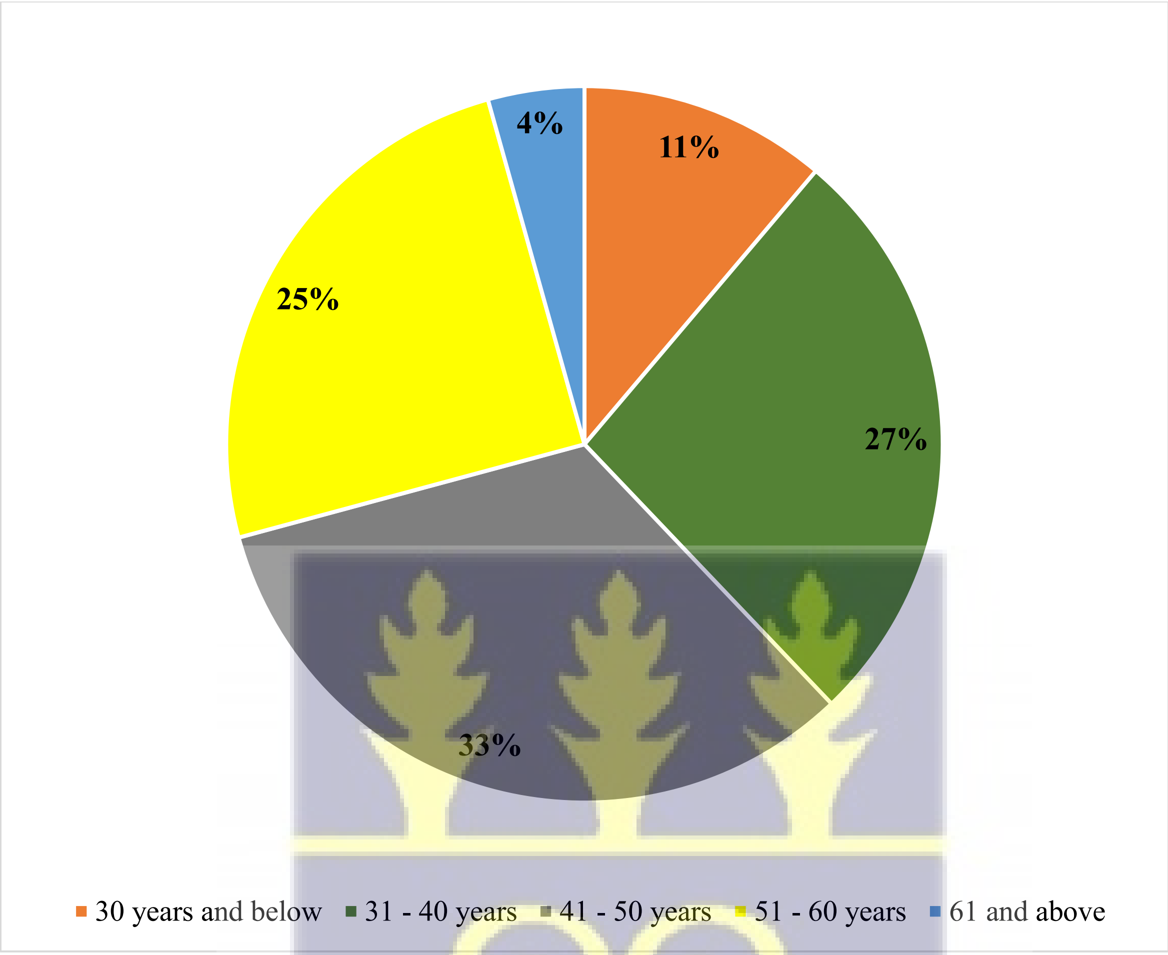
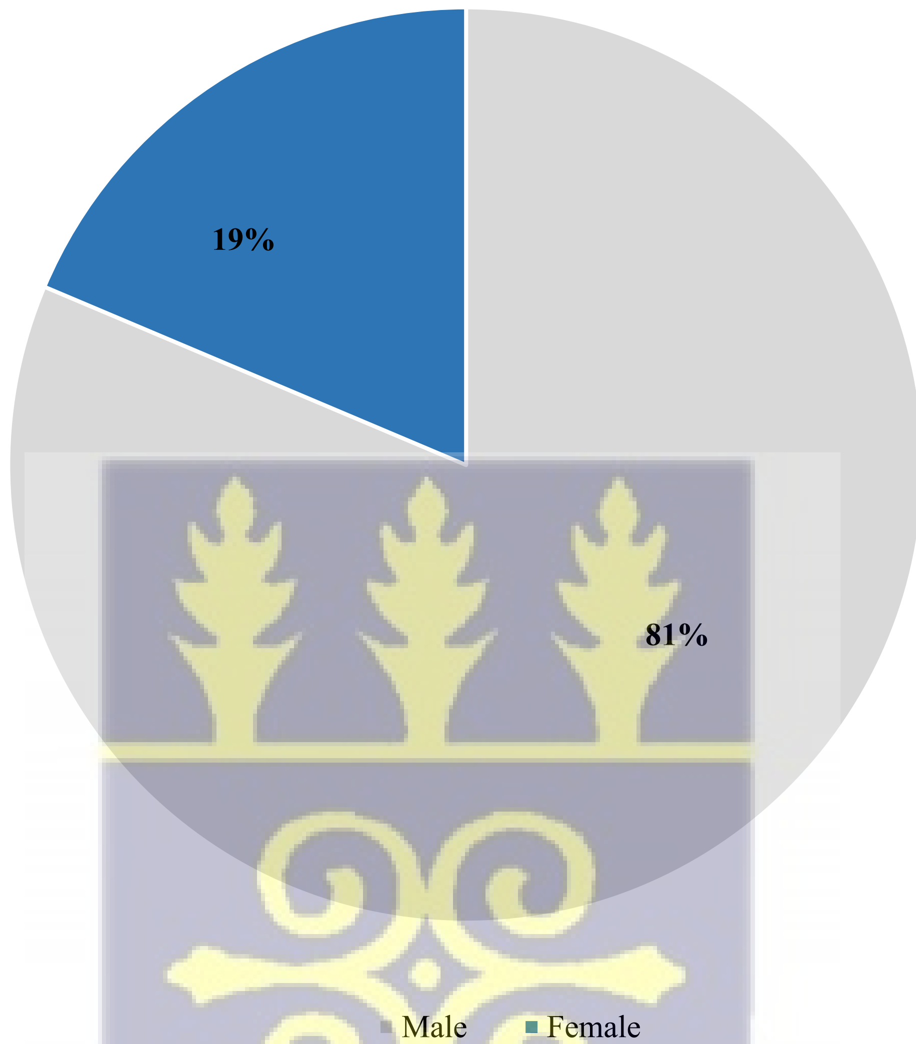


Figure 4: Age of layer chicken farmers
Source: Ayertey (2024)

4.2.2 GENDER OF LAYER FARMERS IN LAYER CHICKEN PRODUCTION

Based on 161layer chicken farmers interviewed in the Bono Region of Ghana, 30 of these respondents were females and 131 were males representing 19% and 81% respectively. This is due to the nature of the production scale, and the ability of males to have access to resources to aid in their production according to Yevu and Onumah, (2021). In terms of the resource to aid in production, based on the interaction with the farmers, it was revealed that layer farming in general is capital intensive and hence majority of these female farmers are unable to raise such capital and are unable to go into such ventures.



Source: Ayertey (2024)

Figure 5: Gender of layer chicken farmers

Table 3: Descriptive Statistics of variables in the Production Frontier Model

Variable	Unit of measurement	Mean	Std. Dev.	Min	Max
Age of farmers	Years	44.006	10.426	21	75
Experience in layer farming	Years	10.578	6.711	2	46
Years spent in education	Years	11.099	4.117	0	16
Gender of layer farmer	Dummy (1 = male 0 = female)	0.814	0.391	0	1
Farmer Association Member	Dummy (1= Yes 0=No)		.464	0	1
District	Dummy (1= Dormaa Central 0= Dormaa East)		.482	0	1
Length of production cycle	Weeks	89.727	8.239	60	100
Egg Produced weekly per 1000 birds	Crates	208.77	12.428	140	231
Feed consumed per thousand	Kilogram (kg)	58640.354	11678.952	17975	84900
Total water consumed per 1000 birds	Litres (l)	27014.84	181370.33	58205	1301230
Vaccinating drugs per 1000 birds	Litres (l)	12.855	0.697	10.417	14.108
Deworm and other drugs per 1000 birds	Kilogram (kg)	13.768	3.058	8.333	24.74
Labour	Man hours	24.711	26.625	0	184
Traffic control	Dummy (1= Yes 0=No)		0.485	0	1
Depopulation of the birds	Dummy (1= Yes 0=No)		0.380	0	1
Monthly In-house cleaning	Dummy (1= Yes 0=No)		0.440	0	1
Protective clothing	Dummy (1= Yes 0=No)		0.369	0	1
Monthly litter change	Dummy (1= Yes 0=No)		0.331	0	1
Footbath use	Dummy (1= Yes 0=No)		0.440	0	1

Monthly veterinary visits	Dummy (1= Yes 0=No)	0.440	0	1
Monthly disinfection	Dummy (1= Yes 0=No)	0.492	0	1
Rearing of other birds	Dummy (1= Yes 0=No)	0.469	0	1

Source: Ayertey (2024)

Table 3 provides all the parameters used in estimating the technical efficiency level of the viral control strategies on layer chicken production and analyzing factors affecting the practice of traffic control as a biosecurity measure respectively.

4.3 VIRAL DISEASES THAT AFFECT LAYER CHICKEN IN THE BONO REGION

Majority of the farmers stated that they have at least experienced one of the diseases in Table 4. The most predominant one they have experienced based on the negative effect it has on their flock was Infectious Bronchitis. According to the farmers, this disease affects the layer's egg production. An article published by Hoerr, (2021) stated that this disease affects the nasal and tracheal mucosa of the chicken. It also does affect the egg production ability of the birds when the birds mature to the laying stage and thus cause economic loses to the farmers (Hoerr, 2021). According to Ayim-Akonor et al., (2018), stated that infectious bronchitis vaccination is not done or considered among layer farmers in Ghana.

Another disease that also raised concern and affects the chicken through high mortality rate according to the farmers was Infectious Bursal Virus also known as Gumboro. This disease affects the chickens in their grower stage especially within the weeks of 6 to 12. According to Dey et al., (2019), Gumboro increases mortality rate among young chickens by making the chicken susceptible to other infections which interferes with vaccinations against other diseases. This is known as immunosuppression in chickens. Prevalence of Gumboro is very high in Ghana according to a study done by Ayim-Akonor et al. (2018) in Ghana. Their study concluded that Gumboro affects layer chickens more than other poultry. The remaining viral diseases followed suit in same manner in terms of how they affect the farmers, that is based on mortality rate and egg production rate. The layer farmers responses were subjective.

Based on the interview done under this study, farmers do not vaccinate against Marek Disease on the farm even though revaccinations are done for some of the viral diseases among layers. Viral diseases that fall under the category of revaccination is Newcastle and Gumboro. Marek Disease is done at the hatchery, that is at the day-old stages of the birds before they are sold to farmers.

In Table 4, the study revealed that 65.30 % of the respondents agreed to this ranking and it was significant under 1%, thus rejecting the null hypothesis based on the Kendall's coefficient of concordance.

Table 4: Ranking of viral diseases that affect layers in the Bono Region

Viral Diseases	Observations	Mean Rank	Disease Ranking
Infectious Bronchitis	161	1.53	1st
Infectious Bursal virus (Gumboro)	161	2.55	2nd
New Castle	161	3.28	3rd
Fowl Pox	161	3.49	4th
Avian Influenza	161	4.17	5th
Marek Disease	161	5.97	6th
N			161
Kendall's W[a]			0.653
Chi-Square			525.535
Df			5
Asymp. Sig			0.000

Source: Ayertey (2024)

4.4 BIOSECURITY MEASURES PRACTICED BY LAYER FARMERS IN THE BONO REGION

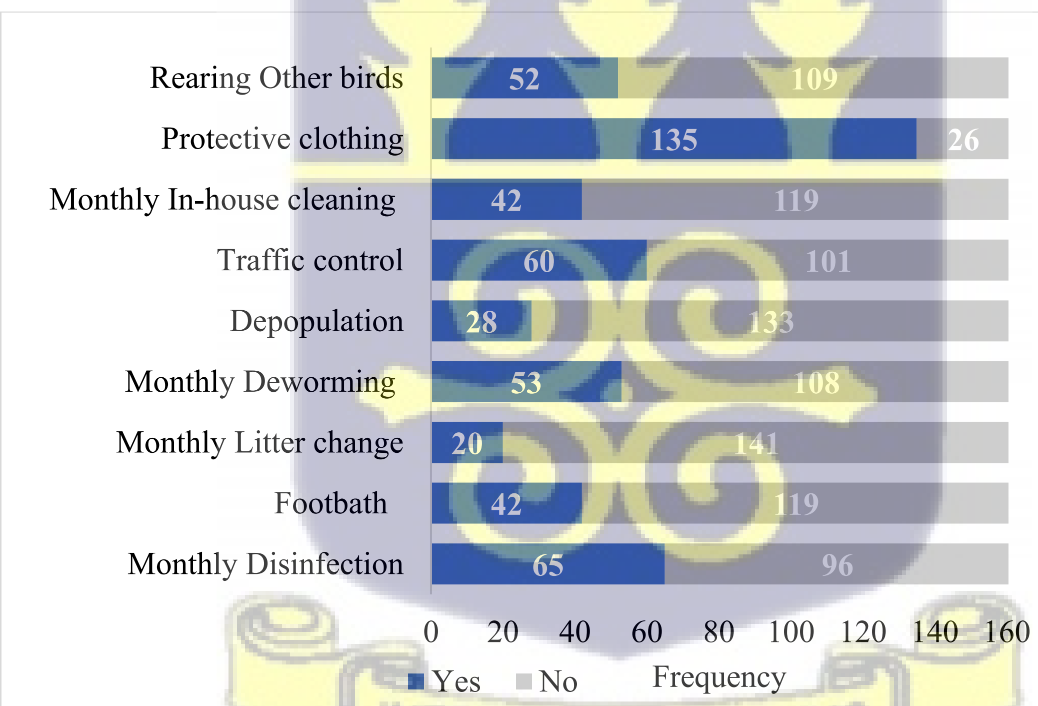
This study categorized these practices into two components. This was based on observation on the field. These parts include in-house biosecurity measures and personal biosecurity measures. The personal biosecurity included, use of footbath, traffic control (reducing external people to animal contact on farm), use of protective wear and rearing of other birds on the same farm. In-house biosecurity practices include monthly disinfection of the pen, in-house cleaning of equipment, depopulation of birds, footbath use, monthly deworming of the birds and monthly litter change (Dewulf & Van Immerseel, 2019). All the nine biosecurity measures were answered by each, and every farmer interviewed. Based on figure 5, the study identified that the most practiced biosecurity was the use of protective clothing or protective wear. This includes farmers with one foot ware per pen or use of one specific cloths per pen. This means that if the farmer has three pens, that farmer has footwear or cloth for each pen. The farmers stated that this helps in reducing the transmission of diseases from one pen to the other, especially when there is an outbreak on the farm or from other farms. Moreover, this also prevents the farmers from wearing pen clothes outside the farm which also influences disease transmission. Study conducted by Akpabio et al., (2023) on assessment of biosecurity measures of poultry farmers in commercial poultry farms mentioned a biosecurity practice that is changing room. This feature measures the fact that farmers put on farm wear before they visit the flocks thus reducing transmission of diseases on the farm.

The next measure mostly practiced by farmers is monthly disinfection through spraying of the whole farm using disinfectants. Use of disinfectants for in-house is an important biosecurity practice and the study done by Akpabio et al., (2023) also made mention of such an important practice among farmers.

Traffic control as biosecurity measure also plays a role, that is reducing the number of people that are allowed onto the farm. This reduces the spread of diseases from other farms. The farmers stated that they normally practice this when they are getting rid of the litter (saw dust mixed with chicken fecal matter). They normally do the removal of the litter themselves together with their workers and bag it outside of the farm for buyers to pick it a few meters away from the farm. These buyers come from other farms with their trucks to pick up the litter and can potentially be carriers of viruses from other farms.

Rearing other birds could also pose a threat to the layer chicken. The study revealed that 109 layer farmers were not rearing other birds on the same farm they use for layer production. Based on the conversation with these farmers, they claimed that some of the birds have resistance to some of these viral diseases and are mostly carriers since it does not affect such birds. Layer chickens are at risk if these birds are put on the same farm. Similar findings were established by (Akpabio et al., (2023).

The monthly litter change was the least practiced biosecurity. According to the farmers, they believe that frequent changing of the litter stresses the birds due to constant movement of the birds anytime they need to clear the old litter. This stress affects birds' egg production ability. These farmers believe that it takes time for the layers to adjust before they start laying again. Some farmers also believe that the longer the litter stays in the pen, they get high prices for that. This is because the litter is rich in fecal matter and serves best as an organic fertilizer to crop farmers. Some farmers prefer to keep their litter for a period beyond one month, this could be in space of three months or six months depending on the manure buyer's choice (Bolan et al., 2010).



Source: Ayertey (2024)

Figure 6: **Biosecurity measures practiced by layer farmers**

4.4.1 BIOSECURITY MEASURES PUT IN PLACE BY LAYER FARMERS IN THE BONO REGION.

This information was extracted by summing up the number of biosecurity practices utilized by these farmers. There were farmers who were basically doing just two biosecurity practices whilst others did the nine that were listed in figure 5. In figure 6, this shows a graphical representation of the number of farmers practicing several of the biosecurity practices. At least, there are 28% of layer farmers implementing four biosecurity practices in no order. This is followed by farmers implementing two biosecurity practices constituting 26% of layer farmers. For farmers implementing six and seven biosecurity practices were 1% each of total layer farmers. Farmers implementing eight and nine biosecurity practices were 7% and 2% respectively. Farmers implementing five biosecurity practices were 11%. Farmers implementing three biosecurity practices were 24% of total layer farmers.

Source: Ayertey (2024)

Figure 7: Number of biosecurity practices done by layer farmers

4.5 SUMMARY STATISTICS OF VARIABLES OF THE STOCHASTIC FRONTIER MODEL

Table 5 presents the summary statistics of the output and input variables of the stochastic frontier model. The summary statistics are then discussed in subsequent paragraphs under this sub-heading.

The result of the study indicated that the average crates of eggs per production cycle of 1000 layer chicken was 13,359.28 crates. These outputs range from a minimum of 6,300 crates to a maximum output of 17,556 crates. The average egg production of the birds also means that a layer chicken produces 400.78 eggs in its production cycle with other studies suggesting 18% less of the average egg production by a single layer bird (Amanor-Boadu, 2016). That means, it produces for about 57 weeks before the birds are sold off, taking into consideration all factors of production, breed of the bird, biosecurity practices and management practices. This study indicates an improvement in the layer production in the Bono Region of Ghana. This could be because of factors of production, breed selection of the birds, management practices in terms of decision making, biosecurity practices and length of production cycle Amanor-Boadu (2016) revealed that, the average production cycle was 80 weeks, with a minimum and maximum of 52 weeks and 130 weeks respectively. This study indicated an average production cycle of 89 weeks, with a minimum and maximum of 60 weeks and 100 weeks respectively.

In terms of inputs, the minimum and maximum quantity of total feed consumed per 1000-layer chicken in a production cycle were 17,975kg and 84,900 kg respectively. The average feed consumed per 1000-layer chicken was also found to be 13,359.28kg. A single layer bird consumes 0.0932 kg or 93.2g of feed per day during it average production period of about 89 weeks based on this study. According to a study conducted by Fraooq et al., (2002), the study estimated that, a layer chicken averagely consumed 102.17g of feed per day based on 52 weeks of data collected. This estimate includes all the growth stages of the bird, that is day old chick stage, grower stage and layer stage, with recorded days of 42 days, 84 days and 241 days respectively.

Average vaccines given to 1000-layer chicken as and when the birds arrive on the farm as day old chicks till the birds are sold in a production cycle was estimated to be 12.86 litres, and with a minimum and maximum value of 10.41 litres and 14.1075 litres respectively. These vaccines include, Gumboro intermediate, first New Castle (HB1), Gumboro Intermediate Plus, Fowl pox, Lasota (second Newcastle), and third Newcastle vaccine. After 16 weeks, third Newcastle vaccine given to the birds on the 16 week is repeated every 90 days according to the vaccination schedule provided by the district veterinary service. It was also noted that, every vial of vaccine contains 1000 dose or 1000 ml which caters for 1000 birds.

Table 5: Summary statistics of the variables in the Production Frontier Model

Variable	Unit of measurement	Mean	Std. Dev.	Min	Max
Egg Produced per 1000 birds in a production cycle	Crates	13,359.28	2045.653	6.300	17,556
Total Feed consumed per 1000 birds	Kilogram (kg)	58640.354	11678.952	17975	84900
Total water consumed per 1000 birds	Litres (l)	27014.84	181370.33	58205	1301230
Total Vaccines given per 1000 birds	Litres (l)	12.855	0.697	10.417	14.108
Deworm and other drugs per 1000 birds	Kilogram (kg)	13.768	3.058	8.333	24.74
Hired labour	Man hours	24.711	26.625	0	184

Source: Ayertey, 2024

Average water consumed for every 1000-layer chicken in a production cycle was estimated to be 27,0140.80 litres. The minimum and maximum water consumed were 58,205 and 130,1230 litres. These estimations were generated from collecting the birds water intake at the different growth stages, that is from day old chick stage (first two weeks), grower stages (from four weeks to the birds are 15 to 16 weeks) and the layer stage (from week 16 till they are sold off on the farm). Water plays an important role in egg production, especially the weight, size and cholesterol level of eggs. A good egg contains about 90% water and 10% protein (Zaheer, 2015). To attain that, good amount of water should be given to the birds to increase egg production rate and its quality too is impacted positively.

The average drugs taken to deworm 1000-layer chicken together with other drugs such as vitamins was estimated to be 13.77 kg. The minimum and maximum values were 8.33 kg and 24.74 kg respectively.

The last input is the hired labour used on the farm. It was calculated in Man-days and the average man-days estimated was 24.71. The minimum and maximum value estimated were 0 and 184 respectively. This study measured labour as man-days according to the rule that one adult male, one adult female and one child (less than 18 years old) worked for one day (8 hours) is equal to 1, 0.75 and 0.5 respectively (Onumah et al., 2018). After, the individual man-days were summed as a single variable as hired labour. The minimum man-day value could be as a result of a farmer not having any form of labour at all, hence operation is done by that farmer.

4.5.1 TESTING OF HYPOTHESIS

Table 6 presents the various hypothesis tests on the statistical validity of the set of data and specified model. Table 6 represents the outcome of the hypothesis test, the validity of the data set and the adequacy of the Cobb-Douglas functional form of the stochastic frontier model using the generalized likelihood ratio test.

The Cobb-Douglas functional form representing the first hypothesis test was used for objective two. This decision was made by failing to reject the null hypothesis at 5% significance level. This choice is reinforced by various studies which includes a study done by Kleyn et al., (2017). They demonstrated the robustness and applicability of the Cobb-Douglas production function across different contexts. Secondly, the rejection of the null hypothesis on the test that specifies the technical inefficiency effects are not stochastic indicates that the ordinary least square estimation technique does not adequately represent the data. That is, the ordinary least square estimation method does not capture the complex nature of the data. The third hypothesis test indicates that there are no district level effect on technical efficiency hence the study rejects the null hypothesis. This means that variations in where layer farmers are located has no effect on technical efficiency. This could be because of veterinary officers' effective ways of giving out services and quick response to farmer needs across different locations (Fidelis et al., 2023). The fourth hypothesis that has been categorized into two parts; the first part that tests homoscedasticity. The decision made is to fail to reject the null hypothesis since the variance of the residuals is constant or homoscedastic. The second part is about multicollinearity. Based on the variance inflation factor value, which is 1.71 and tolerance level of 0.58, we fail to reject the null hypothesis, indicting that, there is absence of multicollinearity. A study conducted by Miles, (2014) stated that a variance inflator factor above 10 or tolerance level below 0.1 is signifies some level of multicollinearity.

Table 6: Hypothesis Test for Model Specification and robustness check

Hypothesis	Test statistics	Critical Value	Decision
1. H_0:β_{ij}=0	16.040	24.996	Fail to reject H_0
2. H_0: λ=0	13.550	3.841	Reject the H_0
3. H_0: δ_6	41.070	27.587	Reject the H_0
4. a. H_0: $b_1 = b_2$	7.494	24.587	Fail to reject H_0
b. H_o: $\varepsilon_i = 0$	VIF = 1.71, Tolerance Level = 0.58		Fail to reject H_0

Source: Ayertey (2024)

4.5.2 PRODUCTIVITY LEVELS OF LAYER PRODUCTION IN BONO REGION

Table 7 shows the productivity responses of the total egg produced per production cycle per 1000 birds, with respect to individual inputs, such as, hired labour, vaccine per 1000 birds per production cycle, total water consumed per 1000 birds per production cycle and feed consumed per 1000 birds per production cycle. The estimates from the Cobb Douglass functional model show that a percent increase of the aforementioned factors of production leads to output (total eggs produced) which is 0.811. This means, a one percent increase in factors of production leads to 0.811 increase in output . This suggests that the firm is better off producing at small scale. Unlike Yevu and Onumah, (2021), that reported something different. The study revealed an increasing returns to scale estimated to be 1.56 indicating that the layer farmers considered in that stage were operating stage on production that suggests more than a proportionate increase in layer output when factors of production are increased by 1%.

Table 7: Productivity Estimates and Return to Scale of Production

Quantity of eggs (crates)	Parameters	Coefficient	p-value
Total feed consumed per 1000 birds	β_1	0.288 ***	0.000
Total Vaccines given per 1000 birds	β_2	0.318**	0.035
Total water consumed per 1000 birds	β_3	-0.058***	0.002
Deworming and other drugs per 1000 birds	β_4	0.229***	0.000
Labour	β_5	0.007	0.342
Constant		0.076***	0.000

****, **, * are significant at 1%, 5%, 10% levels, respectively*

Source: Field Survey 2024

In Table 7, the results show that all the input variables were significant except labour. The significant variables include, total feed consumed per 1000 birds, total vaccines given per 1000 birds, total water consumed per 1000 birds and deworming and other drugs per 1000 birds. These significant inputs means that, these inputs have effect on layer production in the Bono Region of Ghana. The input total vaccines per 1000 birds indicated that, a percentage increase in the use of vaccine increases the output level in terms of egg production by 0.318 percent and hence the most important input in the production. It was significant at 5 percent. This is followed by total feed consumed per 1000 birds, a percentage increase of this input results in 0.288 percent in egg production in the layer production and the result was statistically significant at 1 percent. Deworming and other drugs as an input also had an impact on production by 0.229 percent and the result was statistically significant at 1 percent.

Total water consumed per bird was significant but had a negative influence on egg produced by the layers. This is counterintuitive which usually does not align with the understanding of poultry farming in general. There could possibly be reasons why this effect. The reasons may include some level of infrastructural limitation with respect to the water delivery system. Observations made on the field were that majority of the layer farmers were not using the automated drinker system. Most of these farmers had manual drinkers which might be inefficient as compared to the automated drinkers. The birds could possibly stand on the manual drinkers and drop their fecal matter into the drinkers which contaminates the water and hence affects the egg production. The water might be contaminated with pathogens from the main water source and hence if the layer farmers give such water to the birds. This thus affects the egg production of the birds. An article published by Delpla et al., (2009) described water quality based on three parameters, these include, physio-chemical properties (include oxygen levels and temperature of the water), micropollutants (include metal particles and pharmaceuticals) and biological parameters (include pathogens and microorganisms). Water quality defined under the biological parameters whereby harmful pathogens and microbes increases the risk of health impact among livestock, that is morbidity of the animal increases thus affecting it potential production benefits (Delpla et al., 2009). In table 8, it contains the variables used in estimating factors affecting technical efficiency.

Table 8: Technical Efficiency Model Estimates

Variable	Parameter	Coefficient	p-value
Age of farmer	δ_1	-0.0002	0.946
Gender of farmer	δ_2	-0.4390	0.459
Farmer Based Organization member	δ_3	1.0950*	0.094
Years spent in education	δ_4	0.0070	0.901
Experience in poultry farming	δ_5	0.0277	0.386
District of farm	δ_6	-0.8991	0.198
Production Scale	δ_7	0.8999	0.155
Traffic control	δ_8	-0.5053	0.391
Footbath use	δ_9	-0.0434	0.940
Depopulation	δ_{10}	-1.1866	0.203
Monthly litter change	δ_{11}	-2.6470	0.146
Monthly deworming	δ_{12}	-1.8887*	0.067
Monthly disinfection	δ_{13}	-2.9351**	0.002
Monthly in-house cleaning	δ_{14}	1.1003	0.258
Rearing of other birds	δ_{15}	1.6545**	0.062
Protective clothing	δ_{16}	-0.9632	0.381
Doing at least five practices	δ_{17}	1.4373	0.164
Constant		-3.9543**	0.032

****, **, * are significant at 1%, 5%, 10% levels, respectively*

Source: Author's own construct (2024)

Table 8 presents the results of the technical efficiency factors. From Table 8, the coefficient of being a member of Farmer Based Organization is positively significant at 10% indicating that, layer farmers in the Bono Region are technically inefficient when they are members of Farmer

Based Organization. This could be as result of farmers not utilizing information efficiently and or not adhering strictly to information on farm practices which include biosecurity measures based on this study (Huber et al., 2022). This may be a reason for having a negative impact on their technical efficiency.

Monthly deworming was estimated to have a negative influence on technical inefficiency such and was significant at 10%. Frequent deworming reduces the rate of morbidity among the layer birds and reduces the ability of the birds from getting other diseases which might affect the technical efficiency levels of layer production. This statement confirms a study conducted by Nigar & Nushrat, (2023) that stated that regular deworming reduces the risk of layer birds getting hit by diseases and hence improves productivity through egg production if frequent deworming is practiced.

The coefficient of monthly disinfection also has a negative effect on technical inefficiency and was significant at 5%. This study established the importance of frequent disinfection among the layer birds to improve the bird's health and technical efficiency in layer production. Regular disinfection reduces the occurrence of Newcastle disease based on a study conducted by Boamah and Agyare, (2016) on the topic practices and factors influencing the use of antibiotics in selected poultry farms in Ghana. This supports the importance of disinfection as a biosecurity practice.

Rearing of other birds together with layer chicken also had significant effect on technical inefficiency the result was statistically significant at 5% and had a positive influence. That is, rearing other birds or livestock according to this study indicates that technical inefficiency levels increase, and production becomes unproductive. This might be because of the high risk of disease outbreak or transfer from other birds to layer chicken. This might or may lead to decline in egg production and thus affect technical efficiency level of layer production.

4.5.3 TECHNICAL EFFICIENCY LEVELS OF LAYER FARMERS IN BONO REGION

The results revealed that technical efficiency for layer farmers in the Bono Region of Ghana range from 56.4 percent to 99.58 percent in figure 8. This study conforms to the study conducted by Ahiale et al., (2019) who gave similar range of 46 percent to 99 percent but that was for broiler chicken.

Biosecurity practices and management practices do contribute to the variation in the technical efficiency scores across the two districts in the Bono Region. Most of the layer farmers are operating above 90 percent with a mean technical value of 92.50 percent indicating that these farmers are technically efficient in terms of production. This could be because of good farm practices which could be good biosecurity practices which were identified under this study. The other reasons could be breeding selection and other managerial decisions

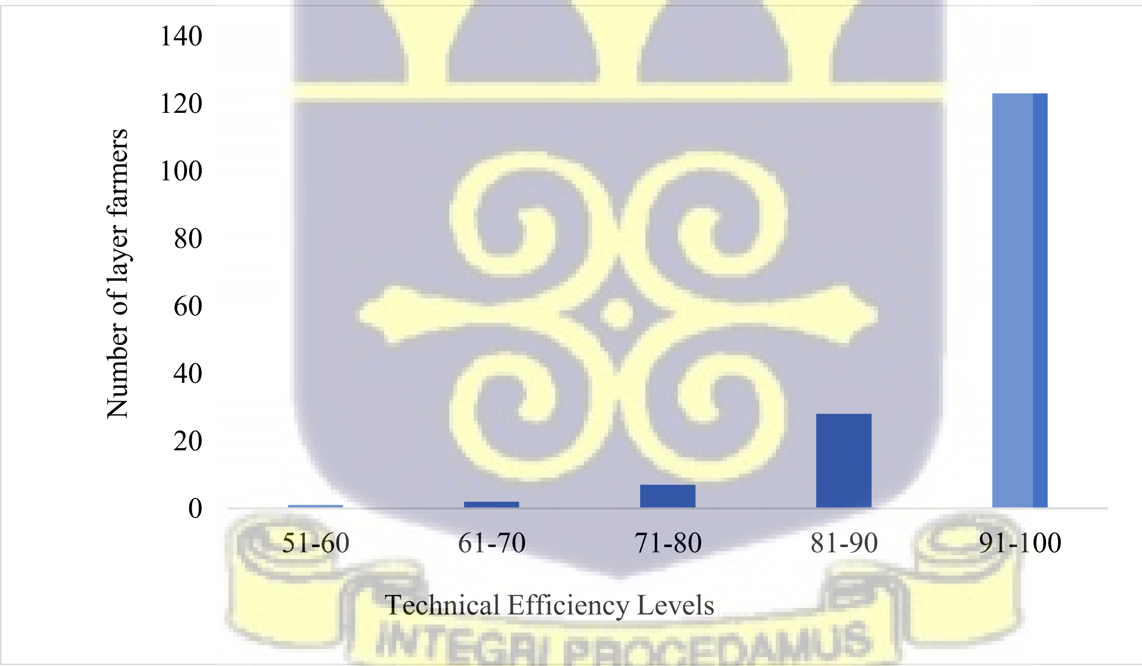
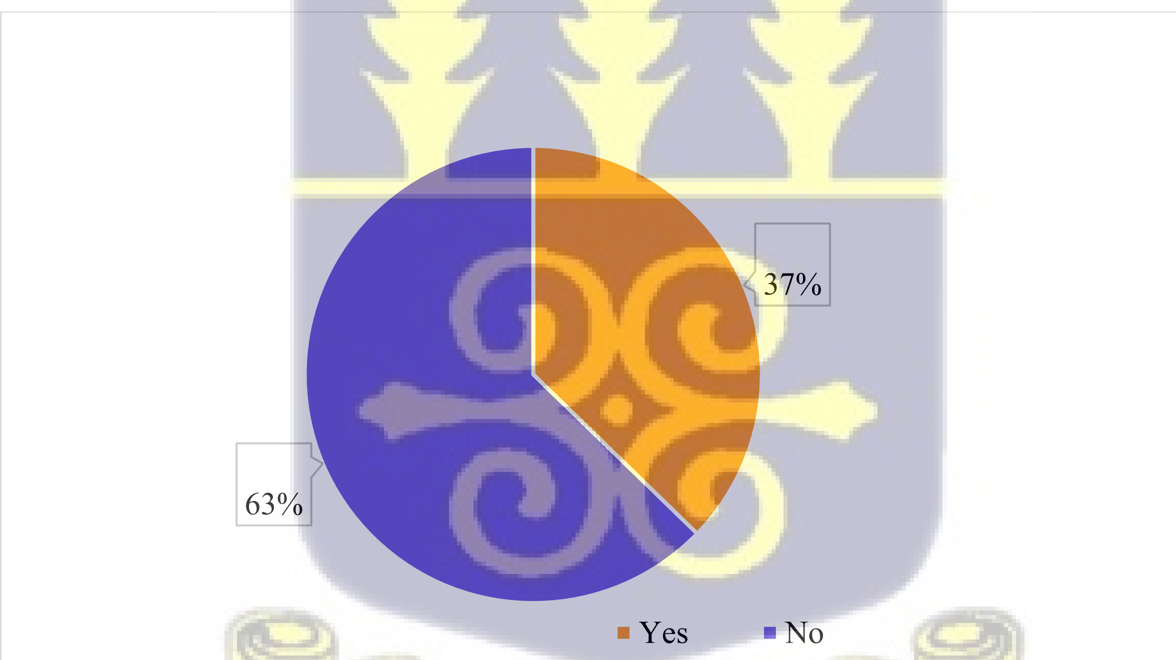


Figure 8: Technical Efficiency Levels of Layer Farmers
Source: Ayertey (2024)

4.6 FACTORS AFFECTING THE PRACTICE OF TRAFFIC CONTROL AMONG LAYER FARMERS IN BONO REGION

The figure below (Figure 8) shows responses of 161-layer farmers in the Bono Region who practice traffic control as a biosecurity practice. The result shows that 63% of the respondents were not practicing traffic control and that represents 101 respondents as compared to 60 layer farmers practicing traffic control that represents 37 percent of the respondents. This result indicates that the practice of traffic control is very low in this region. This could be because most of these farmers do not have their farms fenced. This study agrees with the findings of Kouam et al., (2019), who also reported pig farmers who have a fencing system were 11.83 percent of the total pig farmers interviewed.



Source: Ayertey, (2024)

Figure 9: Traffic Control as a Biosecurity practice among layer farmers response

Table 9: Traffic control responses of layer farmers at the district level

		District	
		Dormaa East	Dormaa Central
Responses	Yes	36	24
	No	22	79
	Total Responses	58	103
	Probability of practicing traffic control	0.62	0.23

Source: Ayertey (2024)

Table 9 further explains the responses of the layer farmers that is district specific and also determines the probability of practicing traffic control as a biosecurity measure in Dormaa East was 62% compared to those in Dormaa Central with 23%. This indicates a high a hire compliance of traffic control among farmers from Dormaa East as compared to Dormaa Central.

4.6.1 MARGINAL EFFECTS OF FACTORS INFLUENCING THE PRACTICE OF TRAFFIC CONTROL AMONG LAYER FARMERS IN THE BONO REGION

The marginal effects from the binary logistic regression show that the major factors influencing a farmer's decision to practice traffic control as a biosecurity strategy were district the farmers were located, total eggs produced by the birds and production scale of the farmer in the Bono Region of Ghana (Table 10).

The marginal effect of districts the layer farmers were in had a negative relationship with the practice of traffic control as a biosecurity practice and the result was statistically significant at 1 percent. This means that, per the 1 percent increase in population of farmers in Dormaa East 1.797 percent practice traffic control. From table 9, it was estimated that layer farmers in the Dormaa East ratio of practicing traffic control as a biosecurity measure is 0.62 of respondents interviewed in Dormaa East as compared to layer farmers in Dormaa Central with a ratio 0.23 of total layer farmers in Dormaa Central. This result could be attributed to reasons such as varying levels of education received with regards to biosecurity practices, access to timely biosecurity information when there is an outbreak of viral disease or any other diseases and irregular field visits by veterinary officers to regulate safe and hygienic biosecurity practices on the farm at district level. These reasons conform to factors identified by Buckel et al., (2024) based on a study conducted to understand the factors influencing biosecurity adoption on poultry farms in Ghana.

The quantity of eggs produced by the layer birds had a positive influence on the practicing of traffic control as a biosecurity practice. This result was statistically significant at 1 percent. This means that when egg production increases by 1 percent, the probability of practicing traffic control increases by 0.019 percent. These further states that an increase in the practicing of biosecurity measure especially traffic control increases egg production since it reduces the risk of contracting diseases from other agents outside the farm premises. This conforms the study conducted by Oladipo et al., (2020). The effect of high egg production calls for reduction in outbreak of viral diseases and this conforms to study undertaken by Yalcouye, (2021) in Mali.

Production scale plays a major role among all the significant variables, such that the population of birds being reared plays a role in whether layer farmers should invest in traffic control practices. This result was statistically significant at 5 percent and was positively correlated with the practice of traffic control. The production scale was in two categories, that is the small scale (bird population from 500 to 5000) and medium scale production, that is (bird population from 5001 to 10000). Layer farmers within the medium scale production tend to practice traffic control more as compared to small scale farmers according to the results from this study which signifies that, the more the number of birds the higher the chances of practicing traffic control.

Table 10: Logistic regression on traffic control measures by layer farmers in the Bono Region

Traffic control	Coefficient	Standard Erorr	P-values	dy/dx	Standard Error	P- values
Age of farmer	0.011	0.019	0.562	0.002	0.004	0.562
Farmer Based Association	0.748	0.486	0.123	0.167	0.106	0.118
Experience of farmer	-0.019	0.031	0.538	-0.004	0.007	0.538
District of farm	-1.797	0.445 ***	0.000	-0.400***	0.099	0.000
Gender of farmer	-0.027	0.515	0.959	-0.006	0.114	0.959
Years in education	0.042	0.049	0.402	0.009	0.011	0.401
Quantity of eggs	0.019	0.005***	0.000	0.004***	0.001	0.000
Production scale	2.112	0.919**	0.021	0.471**	0.203	0.020

Mean dependent var	0.373	SD dependent var	0.485
Pseudo r-squared	0.281	Number of obs	161
Chi-square	46.292	Prob > chi2	0.000
Akaike crit. (AIC)	184.344	Bayesian crit. (BIC)	212.077

****, **, * are significant at 1%, 5%, 10% levels, respectively*

Source: Ayetey (2024)

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the summary, main conclusions and policy recommendations of the study. Section 5.2 presents a summary of the study whiles the conclusions from the study are presented in section 5.3. Finally, section 5.4 presents the recommendations from the study.

5.2 SUMMARY

This study analyses viral disease control strategies effect on technical efficiency of layer farms in the Bono Region of Ghana. This study also helped in identifying the various viral diseases that these layer farmers have faced or experienced and was ranked based on how these diseases affected them in terms of egg production. Various biosecurity strategies were identified based on what each individual layer farmer practiced. Thirdly, technical efficiency levels of the layer farmers were estimated and factors that affected the technical efficiency levels were estimated which includes the various biosecurity practices these farmers put in place on their farms. Finally, traffic control as biosecurity was identified as an important biosecurity practice and hence factors that hindered the practicing of it were determined.

The study interviewed 161 respondents in total, 81 percent of these respondents were males and 19 percent being females. The average age of these farmers was 44 years with a minimum and maximum age of 21 years and 74 years respectively. The study revealed that the mean number of years spent to attain some formal education is 11 years, indicating that at least a farmer has attained middle school or senior high school level education. The study identified that the average experience a farmer has in layer farming is 10 years with minimum and maximum experience being 2 years and 46 years of experience respectively.

The study identified viral disease these farmers have experienced in one way or the other and biosecurity measures these farmers put in place. Most farmers experienced at least one disease, with Infectious Bronchitis being the most prevalent, negatively impacting egg production. While Marek Disease was less common, farmers avoided vaccinating against it on their farms, opting for hatchery vaccinations.

The study found that farmers generally agree on the importance of biosecurity measures. They prioritize personal protective equipment, such as dedicated clothing and footwear for each pen, to prevent disease transmission. Other commonly practiced biosecurity measures include monthly disinfection and traffic control. These practices are crucial for maintaining a healthy flock and preventing disease outbreaks.

The study also analyzed the egg production and input usage of layer chickens. Key findings include average egg production of 13,359 crates per 1000 chickens, feed consumption of 13,359 kg per 1000 birds, vaccine usage of 12.86 liters per 1000 chickens, and water consumption of 27,014 liters per 1000 birds. These results offer valuable insights into the resource requirements for layer chicken farming.

Furthermore, the study examined the relationship between various factors of production and egg production in layer farming. Moreover, specific inputs such as vaccines, feed, and deworming drugs were found to have a significant positive impact on egg production. Surprisingly, the study also discovered that increased water consumption could negatively affect egg production due to potential infrastructure issues or water contamination, highlighting the complex interplay between inputs and egg production in this industry.

Additionally, the study analyzed the factors affecting technical efficiency among layer farmers. It was found that membership in Farmer-Based Organizations can negatively impact technical efficiency due to inefficient information use or non-adherence to best practices. Regular deworming and disinfection were found to be crucial for improving technical efficiency by reducing disease risk and enhancing productivity. Additionally, co-housing layer chickens with other poultry can negatively impact technical efficiency due to increased disease transmission. Overall, these findings emphasize the importance of effective management practices and biosecurity measures for improving technical efficiency in layer farming.

Finally, the study investigated the factors influencing the adoption of traffic control as a biosecurity measure among layer farmers. It found that only 37% of farmers practiced traffic control, likely due to a lack of farm fencing. Farmers in Dormaa East were more likely to adopt traffic control than those in Dormaa Central. Additionally, higher egg production and medium-scale production were positively correlated with the practice of traffic control. These results emphasize the importance of district-specific interventions and the potential benefits of traffic control for improving biosecurity and egg production in the region.

5.3 CONCLUSION

The study examined viral diseases affecting layer chickens in the Bono Region of Ghana. Infectious Bronchitis and Gumboro were the most prevalent and impactful, causing reduced egg production and high mortality rates.

Biosecurity practices were categorized into in-house and personal measures. Protective wear, monthly disinfection, and traffic control were the most common practices. However, litter change and deworming were less frequent due to perceived negative impacts on egg production.

The study found that feed, vaccines, water, and drugs significantly influenced egg production, while labor did not. Technical efficiency was in a normal range with most farmers operating above ninety percent. The study examined the relationship between various inputs (labor, vaccines, water, and feed) and egg production. Using a Cobb-Douglas model, researchers found a diminishing return to scale, indicating that increasing inputs led to proportionally smaller increases in egg output. This suggests that operating at a smaller scale might be more efficient for these layer farmers.

Factors affecting traffic control practice included district, egg production, and production scale. Farmers in Dormaa East were more likely to practice traffic control than those in Dormaa Central. Larger-scale farms were more likely to implement this biosecurity measure.

Overall, the study highlights the challenges faced by layer farmers in the Bono Region due to viral diseases and biosecurity practices not taken seriously.

5.4 POLICY RECOMMENDATION

Based on the findings provided by this study, the following recommendations are proposed. Farmers identified in this study were found to have experienced at least one of the viral diseases identified and thus affect them economically. Hence there is a need for the implementation of comprehensive vaccination schedules aligned with prevalent diseases and their epidemiological patterns and are to be strictly adhered to by the layer farmers. Ensuring timely vaccination and booster doses to maintain flock immunity. To safeguard the health and productivity of layer chicken, it's essential to establish and follow detailed vaccination plans against common viral diseases in the area and their patterns of spread. By strictly adhering to these plans and providing timely vaccinations and booster shots, layer farmers can create and maintain herd immunity within their layer flock. This preventative strategy substantially lowers the chance of disease outbreaks, reduces financial losses, and ultimately promotes the overall well-being of the birds and the long-term viability of the poultry industry.

Secondly, to effectively prevent and manage viral diseases on layer farms, strict adherence to biosecurity protocols is paramount. By implementing robust traffic control measures, such as limiting access to the farm and disinfecting vehicles and personnel, farmers can significantly reduce the risk of disease introduction. Regular disinfection of farm equipment, tools, and facilities is essential to eliminate pathogens and minimize their spread. Additionally, effective rodent control programs should be implemented to prevent these pests from carrying and transmitting diseases. Beyond these core biosecurity practices, it's crucial to provide farmers with practical guidance and support to help them implement effective disease management strategies. This includes training on early disease detection, rapid response plans, and proper cleaning and disinfection procedures. By empowering farmers with the knowledge and tools they need, they can proactively identify and address potential disease outbreaks, minimizing their impact on flock health and productivity.

To end with, to effectively control and manage poultry diseases, a strong surveillance system is crucial. This system should be designed to quickly identify disease outbreaks and initiate rapid responses to curb the spread of infection. By using advanced diagnostic tools and having clear response plans, authorities can swiftly detect and isolate affected flocks, minimizing the impact of disease outbreaks.To further improve disease prevention and control, the Animal Production

Directorate and Veterinary Service Department should create and deliver specific training programs for poultry farmers. These programs should cover a variety of topics, including poultry health, nutrition, management practices, and record-keeping. By including practical demonstrations and hands-on learning experiences, these training programs can provide farmers with the knowledge and skills necessary to identify and address potential health problems in their flocks. Additionally, building strong relationships between farmers and extension agents can promote knowledge sharing, encourage best practices, and facilitate early detection and reporting of disease outbreaks.

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APPENDIX

Questionnaire of the study

(A) Firmographics & Demographics

1. Farm ID: ……………………………………………
2. Location of Farm: [Town]……………………………. [District] ……………………………
3. Sex of farmer: Male ☐ Female ☐
4. Farmer's year of birth ………………… (YYYY)
5. Farmer's highest level of formal education (schooling) completed

   No formal education ☐ Primary ☐ Junior high ☐ senior high ☐ Tertiary ☐
6. Farmer's ownership position of respondent in the poultry farm

   sole owner/proprietor☐ joint owner/proprietor ☐ household member of owner ☐

   employee ☐ Other ☐ Please indicate ……..
7. Extent of participation in poultry farm decision making

   little to no input☐ input into some decisions☐

   input into most/all decisions☐
8. Size of farm : …………………………………
9. Year operation started: …………………………………
10. Nature of the poultry business entity?

    sole proprietorship (registered)☐ partnership (registered☐ private/public

    company (registered) ☐ non-registered sole proprietor☐ non-registered

    partnership☐ Other ☐ Please indicate ……..
11. Main purpose: Layer production ☐ Broiler production☐

12. Do you switch to broiler production within a calendar year? [if layer production is selected]

    Yes ☐ No ☐

13. List the main production facilities on the farm

    ……………………………………………………………………………………………

14. What is the size of your poultry pen in m^2? ………………………

15. How many poultry pens do you use to house birds?..

16. How many birds do you keep per pen (on average) in a production cycle?

    …………………………..

17. What factors influence the number of birds you keep in a production cycle?

    Number demanded by buyer(s) ☐ Pen size (capacity) ☐

    cost of labour ☐ cost of feeds health inputs ☐ Other ☐ Please indicate

18. Which breed(s) of chicken do you raise on your poultry farm? [select all that apply]………..

    ISA brown ☐ Shaver ☐ Hisex ☐ Warren ☐ Babcock ☐ Bovans ☐ ISA Brown

    ☐ISA White ☐ White Leghorn ☐ Brown Leghorn other (name) ☐

19. Why do you prefer the selected breed(s)?

    high growth rate ☐ high survival rate/resistance to disease ☐

    ☐high quality of products (eggs/meat) ☐ Availability at the moment

    ☐ Agent recommendation Other ☐ Please indicate ……...

20. Do you mix these breeds in the same barn? Yes ☐ No ☐

21. Which production scheme do you adopt?

    a. Cohort production scheme (all-in, all-out) ☐

    b. Systematic production scheme (reserve some of the chicks for next production cycle)

       ☐

(i) If a systematic production scheme is adopted, what number of birds in each cohort are not sold in a production cycle? ……………

22. How many cycles do you produce in a calendar year?

1 ☐ 2 ☐ 3 ☐ 4 ☐ more than 4 ☐

23. How do you stock your farm? Day-old chicks ☐ Point of lay ☐

24. How do you ensure that the new flocks coming into the farm are healthy?

Proof of vaccination certificate from seller☐

Vaccinating the flock when they come in ☐

Farmer trust in Importing agent or Impoter☐

Other ☐ Please indicate …….

(B) Production Data

Variable cost

25. Where do you get (or buy) your day-old chicks?

Self-production ☐ Imports ☐ Local hatcheries (within Ghana) ☐Gift (friends/relatives) ☐

26. How many day-old chicks do you usually buy (get) on average from these sources for a production cycle?

Imports ……………………

Local hatcheries (within the region) …………………..

Local hatcheries (outside the region) …………………..

Gift ……………………………….

If self-production is selected, how many eggs do you hatch on average in a production cycle? ……

27. What do you do when there is low supply from your main source for day-old chick? ………..

28. How often do you buy day-old chicks annually?

Imports ……………………

Local hatcheries (within the region) …………………...

Local hatcheries (outside the region) ………………….

Gift ……………………………….

Agents……………………………

29. How much is a day-old chick sold?

Imported day old chicks………..

Local day-old chicks ………………

30. How often does the price usually change?

Weekly ☐ Fortnightly ☐ Monthly ☐ Biannually ☐ Annually ☐ Biennially ☐

31. What are the factors that influence the change in the price of day-old chicks?

……………………………………………………………………………………………..

32. How do you get your feed?

Self-formulation ☐ Local market ☐ Farmers' association ☐

(Imported)Outside market ☐ other (specify) …….

33. Feed details

Feed	Growth Stages	Price per tonne GHC	Quantity needed per week (Tonne)	Number of birds	Week Range
Self-formulation	DOC				
	Grower				
	Layer				
	Spent layer				
Purchase from Markets	DOC				
	Grower				
	Layer				
	Spent layer				

34. What factors influence changes in the feed prices?

Exchange rate ☐

Availability of raw materials ☐

Availability of the feed ☐

Seasonality ☐

Other ☐

35. What is the weekly water ration (in litres) required for the birds at the different growth stages?

	Quantity of birds	Quantity in litres

Day-old chicks		
Grower		
Layer		
Spent layer		

36. What factors will make you change the quantity of feed?

…………………………………………………………………………………………………

37. What factors will make you change the quantity of water you give to the birds?

…………………………………………………………………………………………………

38. How much do you spend on transportation per month on transportation of feed?

……………………………………………………………………………………………………

…………………………

39. How many workers support your production activities?

Permanent ……………. Temporary ……………. Family labour …………..

40. How much is each temporary worker paid daily? ……………………………

41. For how many days are the employed on the farm?..

42. How much is each permanent worker paid on average every month?

……………………………..

43. Energy consumption

Energy type	Cost per month	Cost per year
Electricity		
Charcoal		
Generator		
Other		

Vaccination routine

44. Do you perform the vaccination yourself?

Yes☐ No☐ Sometimes ☐

45. Do you use veterinary services in your production?

Yes☐ No☐

46. Which veterinary service do you use ?

District veterinary services ☐ Private Veterinary services ☐ Both ☐

47. How much do you pay the veterinary per week or month?

…………………………………………………………

48. After day old chicks arrive on the farm, at what weeks do you vaccinate the birds?

……………………………………………………………………………………………

49. Kindly fill the table below:

Services	Week	Type of Vaccine	Cost per 1000 dose (1000 birds)	Number of birds
Gumboro Intermediate	1			
HB1	2			
Gumboro intermediate plus	3			
Lasota	4			
Coryza	4			
Gumboro Intermediate	5			
1st Fowl Pox	8			
Lasota	10			
2nd Fowl Pox	12			
3rd New Castle	16			
Lasota	Every 30 days after 16 weeks			
New Cavak (for NewCastle) Done every 3 months after 16 weeks	Every 90 days if there are no symptoms of NewCastle			

50. Challenges faced during vaccination routines. (1= means most pressing constraints, 5= least pressing constraints)

Constraints	Rank
Availability of vaccine	
Cost of vaccine	
Availability of veterinary to do the vaccination	
Potency of the vaccine	
Number of birds available	

51. Administrative costs and other cost

Item	Unit cost GHC	Cost per week	Cost per month

52. Fixed cost items

Item	Availability (Yes/ No)	Quantity	Year of Purchase	Unit price	Cost
Truck					
Wheel barrow					
Feeder					
Drinker					
Boots					
Bucket					

shovel					
Head pans					
Heater					
Other					

53. Do you have any other facility?

Yes ☐ No ☐

54. What are they? (facilities)

……………………………………………………………………………………………

55. How much did these facilities cost?

……………………………………………………………………………………………

56. At what age (in weeks) would a layer produce eggs?...

57. How many eggs would a layer produce (weekly) at the start of its productive phase?

……………………………………………………………………………………………..

58. Which factors influence the number of eggs that a chicken lays?

……………………………………………………………………………………………

59. At what age (in weeks) does a layer reach the peak of its productive phase?

…………………………………………………………………………………………………

(C) Revenue

60. How many eggs would it produce (weekly) during its peak period?

…………………………………………………………………………………..

61. How many eggs would it produce (weekly) during the less-productive phase?

…………………………………………………………………………………..

62. What is the average weight of an expended layer?.....................

63. Revenue generated from sale of eggs in previous production year

Grades of eggs	No of crates sold per week	Prices at which it is sold (GHC)
Small		
Medium		
Large		
Unsorted eggs		

64. Revenue generated from sales of spent layer for the production year.

Quantity sold per month ……………………………….

Price at which spent layer is sold ……………………

65. Revenue generated from sales of by product per production cycle

Poultry Waste	Quantity (kg)	Unit price	Total Cost
Litter			
Other (specify)			

(D) Income

66. Are you only into poultry production?

Yes ☐ No ☐

67. If yes, what other occupation (s) are you into?

……………………………………………………………………………………………

68. What is your monthly income from the other occupation?..............................

(F) Control Strategies

69. Aside the vaccination what other control strategies (biosecurity measures) do you utilize.

	Biosecurity Practices	Responses		
		Yes	No	Frequency per production cycle
Personal biosecurity	Footbaths			
	Visitor's record book			
	Farm restrictions (traffic control)			
	Hand washing			
	Wearing of protective gears			
Drinking water source	Farm dam			
	Borehole			
	Pipe born water			
	Depopulation of birds			

In- house biosecurity measures	Frequent litter replacement			
	Cleaning of feed and water trough			
	Disinfect other equipment used in the farm			
	Well-ventilated pen			
	Quarantining day-old chicks			
	Do you have isolation pens for diseased birds			
	Random checks by veterinary to check animal health			
	Deworming			
	Rearing of other birds			

70. Frequent diseases that affect you on the farm.

Diseases	Scale of 1-5	Mortality of rate of birds per1000 birds.
Newcastle		
Avian Influenza		
Gumboro		
Fowl Pox		
Infectious Bronchitis		
Marek Disease		

71. Rank the constraints of the faced on the farm when practicing some of the biosecurity measures. (1= means most pressing constraints, 5= least pressing constraints)

Constraints	Rank (1-5)
Negligence of workers to adhere strictly to biosecurity measures on farm	
Cost of chemicals for disinfecting equipment and for footbaths	
Frequent rains affecting the use of foot bath	
Cost of Protective gears for visitors	
Tedious process in changing litter	
Difficulty in getting veterinary on the farm for routine checks on animal health	

Test for Multicollinearity for the variables

Table A.1: OLS Regression on Determinants of egg production among layer farmers in the Bono Region

In Total Eggs	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
In Total feed consumed	0.364	0.051	7.19	0	0.264	0.464	***
In Vaccine	0.405	0.194	2.09	0.039	0.021	0.788	**
In Water consumed	-0.039	0.024	-1.59	0.115	-0.087	0.01	
In Dewormer	0.254	0.049	5.22	0	0.158	0.35	***
In Labour	0.004	0.016	0.28	0.781	-0.027	0.036	
Age of respondents	0	0	0.69	0.493	0	0	
Gender of respondents	0.023	0.029	0.81	0.421	-0.034	0.08	
Farmer Association membership	-0.021	0.025	-0.84	0.4	-0.071	0.029	
Years spent in Education	-0.002	0.003	-0.64	0.524	-0.007	0.004	
Experience of respondents in layer production	-0.002	0.002	-1.35	0.179	-0.006	0.001	
District of respondents	0	0.029	-0.00	0.999	-0.057	0.057	
Traffic control	0.04	0.028	1.45	0.15	-0.015	0.095	
Footbath use	-0.023	0.026	-0.88	0.379	-0.073	0.028	
Depopulation	0.026	0.036	0.70	0.485	-0.047	0.098	
Monthly litter Management	0.057	0.044	1.29	0.2	-0.03	0.143	
Monthly deworming	0.019	0.032	0.60	0.549	-0.045	0.083	
Monthly disinfection	0.091	0.025	3.72	0	0.043	0.14	***
In house cleaning	0.019	0.03	0.63	0.531	-0.041	0.079	
Rearing other birds	-0.071	0.036	-2.00	0.048	-0.141	-0.001	**
Protective clothing	0.062	0.042	1.49	0.138	-0.02	0.145	
Practicing at least five biosecurity practices	-0.072	0.047	-1.53	0.128	-0.165	0.021	
Production scale	-0.029	0.025	-1.13	0.259	-0.078	0.021	

Constant	-0.041	0.077	-0.53	0.599	-0.194	0.112

Mean dependent var	-0.013	SD dependent var	0.164
R-squared	0.477	Number of obs	161
F-test	5.713	Prob > F	0.000
Akaike crit. (AIC)	-185.338	Bayesian crit. (BIC)	-114.466

*** *p<.01*, ** *p<.05*, * *p<.1* (Author's own construct, 2024)

Multicollinearity (A VIF > 10 or a tolerance level = 1/VIF < 0.1 indicates the presence of Multicollinearity)

Table A. 2: Variance inflation factor

	VIF	1/VIF
Practicing at least five biosecurity practices	3.809	0.263
Rearing other birds	2.733	0.366
Protective clothing	2.347	0.426
Monthly deworming	2.296	0.436
Monthly litter change	2.083	0.48
District of respondents	1.913	0.5023
Depopulation	1.894	0.528
Traffic control	1.789	0.559
In house cleaning	1.748	0.572
In Labour	1.458	0.686
Monthly disinfection	1.448	0.691
In water consumed	1.428	0.7
Experience of respondents	1.36	0.735
Farmer Association Membership	1.344	0.744
Age of respondents	1.306	0.766
In total feed consumed	1.288	0.777
Gender of respondents	1.256	0.796
Footbath use	1.25	0.8
Production scale	1.212	0.825
Years spent in education	1.155	0.866
In Dewormer	1.107	0.904
In vaccine	1.101	0.908
Mean VIF	1.697	.

Source: Author's own construct (2024)

A mean VIF of 1.697 indicates the absence of multicollinearity in the model

Test of Adequacy of specified models

The use of the generalized likelihood ratio statistic; $LR = -2[\text{In}\{L(H_0)\} - \text{In}\{L(H_1)\}]$, where the Cobb-Douglas is the restricted model (H_0: $\beta_{ij} = 0$) and the Translog (H_1: $\beta_{ij \neq} 0$) is the unrestricted. The calculated log likelihood ratio (LR_{cal}) is equal to 16.040 with a critical value of 24.996 indicating that, we should fail to reject the null hypothesis of Cobb-Douglas model (H_0: $\beta_{ij} = 0$) at degree of freedom of 15.

To test for if there is variation in the technical efficiencies of the farmers, the log likelihood ratio was utilized to test for that. The null hypothesis indicates that there is no variation in the technical efficiency of the layer farmers; hence, H_0: $\delta_1 = \delta_2 = \ldots \delta_{15}$ and the alternate hypothesis indicates that the is variation in the technical efficiency levels of the layer farmers. The calculated log likelihood ratio (LR_{cal}) is equal to 36.49 and the critical value is 27.587 indicating that the null hypothesis should be rejected and hence there is variation in the technical efficiency of the farmers.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
(1) ln Total eggs	1.000																				
(2) ln Total feed consumed	0.399	1.000																			
(3) ln Vaccine	0.086	-0.062	1.000																		
(4) ln Water consumed	-0.120	0.081	-0.125	1.000																	
(5) ln Dewormer	0.348	0.080	0.083	-0.028	1.000																
(6) ln Labour	0.112	-0.006	-0.095	-0.002	-0.068	1.000															
(7) Age of respondents	0.021	-0.128	0.093	-0.053	-0.021	0.113	1.000														
(8) Gender of respondents	0.138	-0.049	-0.018	-0.023	0.107	0.117	-0.062	1.000													
(9) Farmer Association membership	0.048	-0.005	0.091	-0.354	0.090	0.143	0.067	0.024	1.000												
(10) Years spent in Education	-0.027	0.006	0.101	-0.044	0.002	-0.042	0.103	-0.047	0.078	1.000											
(11) Experience of respondents in layer production	-0.064	-0.155	0.061	-0.076	0.080	0.260	0.360	0.001	0.142	0.036	1.000										
(12) District of respondents	-0.057	0.218	-0.088	0.421	-0.034	-0.094	-0.093	-0.127	-0.364	-0.231	-0.076	1.000									
(13) Traffic control	0.083	-0.037	0.020	-0.211	-0.087	0.224	0.101	0.072	0.240	0.116	0.091	-0.385	1.000								
(14) Footbath use	-0.006	0.194	0.053	-0.094	-0.027	-0.023	-0.018	-0.043	0.185	0.103	-0.007	-0.202	0.127	1.000							
(15) Depopulation	-0.052	0.245	0.007	0.043	0.004	-0.034	0.030	-0.243	0.060	0.033	-0.022	0.140	0.121	0.063	1.000						
(16) Monthly litter Management	0.125	-0.132	0.055	-0.245	0.025	0.278	0.177	0.084	0.212	0.124	0.029	-0.423	0.411	-0.009	-0.024	1.000					

(17) Monthly deworming	0.051	-0.064	0.059	-0.185	-0.074	0.147	0.055	0.064	0.099	0.179	-0.023	-0.383	0.362	0.126	-0.147	0.498	1.000				
(18) Monthly disinfection	0.203	-0.148	0.004	-0.200	-0.003	0.266	0.268	-0.126	0.169	-0.014	0.094	-0.253	0.125	-0.028	-0.077	0.304	0.232	1.000			
(19) In house cleaning	0.049	0.039	0.036	-0.155	-0.030	0.072	-0.031	-0.006	0.093	0.044	-0.024	-0.261	0.186	0.259	-0.123	0.248	0.517	0.203	1.000		
(20) Rearing other birds	-0.096	0.204	0.105	-0.134	0.053	0.004	0.109	-0.283	0.148	0.045	0.010	-0.090	0.182	0.164	0.489	0.223	0.308	0.136	0.255	1.000	
(21) Protective clothing	0.092	-0.222	-0.106	0.077	-0.028	0.069	-0.002	0.267	-0.003	-0.022	0.083	-0.224	0.094	0.030	-0.556	0.165	0.236	0.017	0.107	-0.491	1.000

Table A.3: Matrix of correlations of all variables