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Research article

Modelling of vertical integration in commercial poultry production of Ghana: A count data model analysis

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A B S T R A C T

Poultry production has significant potential to reduce protein deficiency, food insecurity and poverty in Ghana. However, limited vertical integration and high cost of production in the sector have stifled growth and exposed poultry farms in the country to many risks, leading to poor business performance. This study uses cross-sectional data from 102 commercial poultry farms to assess the determinants of vertical integration in the Ghanaian poultry industry by employing zero-inflated Poisson (ZIP) and Zero-inflated Negative Binomial (ZINB) models. The results show that one in every four poultry farms in the country are vertically integrated, either partially or fully. The ZINB model, which best fits the data, reveals that the degree of vertical integration in the poultry business is significantly influenced by a set of personal (education, occupation, and farming experience) and farm level (land tenure, flock size, production cost, and farm revenue) characteristics as well as institutional factors (credit access, extension access and membership of association). The paper discusses the implications of these findings and provides appropriate recommendations for strengthening the poultry industry in Ghana.

1. Introduction

Poultry, widely termed as the "cow" of the poor, has the potential to improve nutritional security and ensure poverty reduction across sub-Saharan Africa (SSA) [1]. In Ghana, poultry production makes a significant contribution to the economic growth of the country [2, 3]. The sector accounts for about 34% of domestic meat production and employs nearly 2.5 million people in the country. The majority of the poultry-dependent households are women, who subsist on poultry and other related products for livelihood and sustenance [4, 5]. Despite its contribution to the growth of the economy, the Ghanaian poultry industry particularly broiler production, over the past decades, has declined from 60% to 20% [7]. The sharp fall in poultry meat production culminated in an increase in imports from 13,900MT to over 155,000MT between 2002 and 2016 [7], representing a more than 1000% rise within the 14 years. The less competitive nature of the broiler industry forced many poultry farmers to focus essentially on egg production [10, 67]. For instance, nearly 90% of poultry farms in Ghana are into raising layer birds for egg production with an estimated 10% annual growth [65].

Even though the layer industry has experienced remarkable growth, the recent hike in the cost of production mainly from feeding, medications, marketing risks and production inefficiencies has led to a substantial reduction in returns to farmers [66]. According to the Netherlands Enterprise Agency (RVO.nl) [67], the overall cost of poultry production in Ghana has increased by 40% from 2012 to 2019 with feeding costs accounting for over 70% of the total variable costs. In response, the average egg price per crate (30 pieces) sharply rose from Gh₵15 (US$3.1)[1] in 2018 to Gh28 (US$5.0) in 2020, representing a more than 60% increment [69]. This price rise led to a substantial fall in egg demand and broiler meat, which, in turn, forced many poultry farms to shut down and discouraged potential investors in the sector.

Like most agricultural markets in developing economies, the poultry input and output markets in Ghana are more competitive; farmers do not have control over prices and as such, are price takers. Therefore, a management strategy that tends to reduce production costs at the farm level will be critical for improving productivity, profitability and returns to investment [19, 20]. One of such important business approaches that have frequently been mentioned to significantly influence the cost of

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[1] US$1= Gh₵4.8 in 2018 and US$1= Gh₵5.6 in 2020 (oanda.com).

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production at the firm level, but has received little attention in poultry production is *vertical integration* [19]. In Ghana, reasons such as limited empirical data on the implications of vertical integration in poultry farming are adduced to this apparent lack of consideration in poultry development programs in the country [3]. This study presents an empirical analysis of the extent and determinants of vertical integration of poultry production in Ghana. A thorough understanding of the implication of vertical integration in poultry farming is a prerequisite to guide policy intervention that will improve the efficiency and competitiveness of the poultry sub-sector of the country.

Empirical studies on vertical integration as a key catalytic operation to expand and improve the competitiveness of firms have been well-documented [12, 13, 15, 16]. In a poultry study for Nigeria, Bamiro [21] observed decreasing cost of production which is augmented by high revenue for highly vertically integrated poultry farms. It was observed that vertical integration of poultry farms is a feed and labour savings strategy because the production of key poultry feed ingredients including maize and soybean are carried under the same management unit. Similarly, the vertically integrated farms do incur lesser labour costs on the maize and soybean farms since labourers from the same poultry farm unit work on the crop farms. In such a situation, vertical integration does not only lower transaction costs such as searching and marketing costs, but also helps to minimise risks and uncertainties to overcome production and market failures. Thus, the general motive for firms to integrate vertically is to reduce the overall cost of production, which in turn, improves firms' performance and consumer welfare [11].

Despite this, there are only a few studies [e.g. 19; 20, 21] across sub-Saharan Africa that consider vertical integration of poultry farms as a conduit to increase the competitiveness and efficiency of the sector. Moreover, the findings of these limited studies have generally been mixed and inconclusive [e.g. 19, 20, 21]. This is so because the use of the value-added ratio to measure the vertical integration of poultry farms in these studies is weak [22]. The constructions of the value-added ratio are based on two economic variables (sales and purchases) which are highly influenced by other factors such as production techniques and staff competencies rather than vertical integration [23]. This study contributes to the literature by computing a vertical integration index based on available data to capture the extent of vertical integration of poultry production in Ghana. Furthermore, we examine the key determinants of vertical integration by paying particular attention to an important farmer, farm-level, and institutional factors. The rest of the study is organized as follows. First, the theoretical concept of vertical integration and its measurement are reviewed in Section II. The research method is presented in Section III before the results and discussions in Section IV. Conclusions and recommendations of the study are also outlined in Section V.

2. Vertical integration and its measurement

The concept of vertical integration has been popular in economics literature since the era of Adams Smith, and the division of labour theory propounded by Young [24] and Stigler [25]. Yet to date, there is no universally accepted definition of the concept [see, for instance, 12, 13, 26, 27]. Despite the diversity in the definitions, a common understanding as adopted in this study suggests that firms are vertically integrated when they partially or wholly internalised their operations without the involvement of external agents. Thus, in a vertically integrated firm, two or more production stages occur under one management where all upstream production activities serve as inputs for downstream activities and vice versa [23]. As a result, the product developed is not transmitted via the market and, hence, does not reflect market prices [23]. In summary, Barrera-Ray [22] contends that the stages of production in a vertically integrated firm should be contiguous without intermediaries and no market exchanges. There are two basic types of vertical integration: backward and forward vertical integration [16, 21, 22]. A firm engages in backward integration when it produces its input instead of relying on external stakeholders. In the case of forward integration, firms take ownership of upstream activities that include distribution, processing, or supply of the firm's final product to consumers. Therefore, to accurately measure the full implication of vertical integration on a firm, both backward and forward integrations have to be sufficiently captured.

The measurement of vertical integration across industries is complicated and poses several practical and theoretical hurdles, which limit the ability of researchers to examine the extent of vertical integration on firms' performances [23]. Nonetheless, two distinct measures of vertical integration can be identified in the literature. These include measures determined from financial statements and the use of multidimensional constructs such as the computation of indices based on available data [28].

In terms of financial measures, the Value Added to Sales (VAS), proposed by Adelman [29], is the most widely used approach to proxy a firm's degree of vertical integration. The VAS is mathematically friendly and has a strong theoretical foundation because it is defined by two economic variables [13]. Despite its simplicity, the VAS has many drawbacks, which makes it near impossible to be applied in firms that operate in the informal sector such as poultry production in developing economies. First, the approach measures monetary values, which can be influenced by other factors such as efficiencies of production techniques and employees [23], and not by physical activities/transactions that contribute to the degree of vertical integration [22]. Similarly, the measure is criticised as not being symmetric concerning production stages, as it favours upstream activities [22, 30]. Lastly, not only is the VAS dependent on financial indicators that are sensitive and confidential but records on these indicators are poorly kept, especially for informal firms in developing countries [31]. However, the VAS is the dominant approach used in the few existing studies that consider vertical integration of poultry production across sub-Saharan Africa [19, 20, 21].

In this study, we adopt the index approach (vertical integration indices) that permits the use of reliable and readily available data from poultry farms to measure the extent of vertical integration. The indices proposed by Chapman and Ashton [32], and Gort [33] based on the number of equipment and employees respectively used in different stages of production within the firm were adopted and modified to calculate the extent of vertical integration of the Ghanaian poultry industry. Chapman and Ashton [32] calculated an index from the inventories of equipment employed in two production stages including weaving and spinning. On the other hand, Gort [33] used the number of assignments given to employees besides the core activities of the firms to determine the degree of vertical integration. Both studies used indices that did not capture internal transfers because there is no production transfer from one stage to the other. However, this current study modified this approach by separating the poultry farm's main activity (i.e., production of eggs and meat) from its auxiliary activities and values assigned to each activity in the poultry value chain. There is transfer of data since all the auxiliary activities are linked in a chain that finally improve performance of the firm. Empirically, six (6) major auxiliary activities are performed along the value chain. These include ownership of crop farms (mainly maize), feed mill, hatchery, delivery van, processing plants and retail outlets [34]. The number of activities engaged in by each poultry farm is expressed as a ratio to the number of major activities in the value chain. Mathematically, the degree of vertical integration adopted in this study is expressed as in Eq. (1):

$$V_i = \sum_{n=i}^{k} \left(\frac{n_i}{N}\right) \times 100\% \tag{1}$$

where, V_i the extent of vertical integration expressed in percentage, n is the number of activities engaged in by the i^{th} poultry farms and N represents the number of major auxiliary production stages in the poultry value chain.

This approach is similar to the index employed by Hamdaoui and Bouayad [23] to measure the extent of vertical integration in the Moroccan textile industry. The following criteria as defined by Misund [35] are used to categorise the poultry farms based on the extent of vertical integration, which was used in the further econometric analysis (see Table 1a).

Table 1a. Benchmark for the Levels of integration.

Ratio (Percentage)	Level of vertical integration
Less than 20%	Non-integrated
20%–65%	Partially integrated
Greater than 65%	Fully integrated

Source: Adopted from [35].

Table 1b. Districts and communities of data collection.

Districts/Muncipal	Communities	Number selected
Dormaa Municipal	Nsesereso	10
	Dormaa Ahenkro	35
Dormaa West	Nkrakwanta	30
	Wamfio (Nyamebekeyere)	5
Dormaa East	Asuotiano	10
	Kyeremasu	12
Total		**102**

3. Methodology

3.1. Study area

The study was conducted in the three Dormaa districts *viz:* Dormaa East, West and Municipality located in the Bono region of Ghana. The three districts have a total land area of 1,704.20 km^2 with a population of 210,660 representing 0.84% of the national population [35]. The three districts have an agrarian economy that employs nearly 68.4% of their total population. All three districts are found within the wet semi-equatorial climate with two rainfall seasons. The annual mean rainfall vacillates between 124cm and 175cm; the minor season spans from May to June and the major season starts from September to October for all the districts. Soil types generally mimic the Nzema-Bekwai association, which is moderately well-drained and suitable for the cultivation of cocoa, oil palm, plantain, citrus, cashew, cassava and maize. About 73% of the population is located in rural communities. Crop and livestock framings are the major agricultural activities in the area. The districts are well noted for the production of poultry, which constitutes more than 50% of the total livestock production of the three Brong Ahafo regions (Bono East, Bono, and Ahafo) [70]. The three districts are located in the western part of the Bono region which contributes to the largest commercial poultry farms in the entire three Brong Ahafo regions [6, 9]. Though there are two major poultry production lines; broiler and layer, nearly 90% of the poultry farms in Dormaa and its environs are engaged in layer production [2]. Domestic broiler production is only carried out to meet demands during festival periods including christmass, the Islmaic idil-fitr and Easter celebrations [6]. Therefore, the unit of analysis in this study is limited to layer production.

3.2. Study design and data collection procedure

3.2.1. Study design area

The study uses both qualitative and quantitative approaches with a descriptive survey as the key research design. The adoption of the survey design helps to quantify or provide a numeric description of respondents' opinions or attitudes by drawing inferences from a sample study to a population. The design is suitable for cross-sectional studies that allow the use of questionnaires or structured interviews for data collection (71). Hence, both structured questionnaires and interviews were used to help to improve the reliability and validity of the data collected through data triangulation. Qualitative methods such as focus group discussions and key informant interviews were conducted with leaders of the poultry associations and the Municipal agricultural officers. The focus group discussion comprised seven (7) participants consisting of four (4) male and three (3) female poultry farm owners. In total, 4 focus group discussions were conducted with one each in the 3 selected poultry producing districts. Key qualitative data collected included farmers' perception of vertical integration, bottlenecks to practicing vertical integration as well as general production and marketing information. The seven (7) farms selected for the pretesting of the questionnaires were excluded from the final data collection.

On the other hand, the structured questionnaire was developed and used to solicit quantitative information on the poultry farms (i.e., size of farms, production cost, revenue, upstream and downstream poultry activities, among others), producers' demographics, and access to relevant institutions such as the veterinary services.

The study employed cross-sectional data collected between February and March 2020. The data collected was based on the 2019 production year. Prior to the data collection, the survey questionnaire was pre-tested in one community in the study area to assess the appropriateness of the statements for meeting the objectives of the study. Seven (7) poultry farmers were randomly selected and used in the pre-testing.

A multi-stage sampling procedure was adopted for the study. At stage one, Dormaa East and West, as well as Dormaa Municipality were purposively selected from Bono due to their significant contribution to poultry production in Ghana. In stage two, two communities were randomly selected from each district for data collection. In each of the three districts, the Department of Agriculture was contacted for the list of poultry farmers in the selected communities. All 137 contacts for commercial poultry farms comprising small-, medium- and large-scale farms were provided. However, only managers and owners of 102 poultry farms were available for data collection within the survey period. Table 1b illustrates the distribution of farms by districts and communities in which data was collected.

3.3. Analytical approach

Descriptive tools including frequency tables, pie charts and measures of central tendencies and dispersions were used to summarise key farm level and personal characteristics. The zero-inflated Poisson (ZIP) and negative binomial (ZINB) regression models were used to examine the precursors of the extent of vertical integration in the poultry business. The zero-inflated models were chosen for the study because less than half of all poultry farms in Dormaa were found to be vertically integrated; leading to the situation/problem of excess zeros in terms of the extent of integration [3]. The ZIP and ZINB models were compared and the model that best fitted the data was selected for further discussion. In addition, a Two-Part Fractional (2-PF) regression is estimated and the result is compared to the best fit model as a robust check. The comparison helps to produce results that are robust because the dependent variable (extent of vertical integration) was also measured in fractions.

3.3.1. Zero-inflated Poisson and negative binomial models

In socio-economic studies, outcomes of interest are sometimes counted data with excessive zeros [36]. While these zeros are important and meaningful, most researchers often treat them as missing values or delete them. In other cases, the data is either transformed into a linear model (which violates the normality assumption) or coded as a categorical dummy variable where all zeros are considered as 'absent' and those observed as 'present' [37]. Under such circumstances, the analysis becomes less useful and less informative if the interest is to determine the number of occurrences [38].

A zero-inflated model can distinguish between the two processes causing the excess zeros [38, 39]. A common feature of the zero-inflated model is its ability to simultaneously produce two outcomes in count data models by i.) examining the effects of covariates on the extra/inflated zeros and, ii) generating the Poisson or negative binomial aspect of the model [36, 37, 39].

Table 2. Model comparisons and selections.

Test	Model	Decision rule
AIC	$AIC = -2\,x\,In(likelihood) + 2\,x\,K$	Choose model with smallest AIC value
BIC	$AIC = -2\,x\,In(likelihood) + In(N)\,x\,K$	Choose model with smallest BIC value
Voung test	-	Significant test statistic implies the data fits ZIP and ZINB against standard Poisson and Negative Binomial model, respectively.

Source [48]:

Zero-inflated Poisson and zero-inflated negative binomial models are specialized types of Poisson regression models that are widely employed in count data analyses with inflated zeros [36, 39, 40, 41]. Lambert [40] first developed the zero-inflated Poisson after the standard Poisson regression model failed to produce efficient estimates with excess zeros in count data variables. Similarly, modelling a zero-inflated count data that has over-dispersion problems with ZIP also produces coefficients that are consistent but inefficient [36, 42]. Fameye [43] therefore, proposed the use of ZINB to account for the over-dispersion problem under such circumstances. Over-dispersion in count data models arises when the variance of the count dependent variable is larger than its mean [38].

In the ZIP model, the count dependent variable $(Y_1, Y_2 \ldots Y_n)$ is independent and the assumption behind the model is that given a probability (p_i), there are two possible outcomes; 0 and the probability of $(1-\pi)$ which leads to the generation of a Poisson random variable (λ_i) in Y_i [14]. The distribution of Y_i is given Eq. (2):

$$Y_i = \begin{cases} 0, \textit{with probability } p_i + (1+\pi)e^{-\lambda_i} \\ Y_i, \textit{with probability } (1-\pi)\dfrac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i}, y_i = 1,2,3\ldots n \end{cases} \tag{2}$$

The variance and mean of the zero inflated Poisson distribution are specified in Eqs. (3) and (4), respectively;

$$V(Y_i) = (1-\pi)\left(\lambda_i + \lambda_i^2\right) - ((1-\pi)\lambda_i)^2 \tag{3}$$

$$E(Y_i) = (1-\pi)\lambda_i \tag{4}$$

Similar to ZIP, the ZINB also has two possible outcomes. Assume π as the probability for the occurrence of zero (0) and $(1-\pi)$ as the probability for success. If $(1-\pi)$ occurs, the counts (including zeros) generated are in line with negative binomial model. In this case [44], defined the probability of the ZINB random variable, Y_i as specified in Eq. (5);

$$Y_i = 0 \text{ with probability } \pi \tag{5}$$

$Y_i \sim$ negative binomial (λ_i, k) with probability $(1-\pi)$

This implies that,

$$\Pr(Y_i = 0) = \pi + (1-\pi)(1 + k_i\lambda_i)^{-1/k} \tag{6}$$

$$\Pr(Y_i = y_i) = (1-\pi)\frac{\Gamma\left(y_i + k_i^{-1}\right)}{\Gamma\left(k_i^{-1}\right)\Gamma(y_i+1)}\frac{(k_i\lambda_i)^{y_i}}{(1+k_i\lambda_i)^{\lambda_i + \frac{1}{k_i}}}, y_i = 1,2,\ldots \tag{7}$$

From Eqs. (6) and (7), the mean and variance of y_i specified in Eqs. (8) and (9):

$$V(Y_i) = (1-\pi)\lambda_i(1 + \lambda_i(\pi + k_i)) \tag{8}$$

$$E(Y_i) = (1-\pi)\lambda_i \tag{9}$$

where λ_i denotes the mean of the negative binomial distribution with k being the over-dispersion parameter. As $k_i \to 0$, the ZINB distributions reduces to the ZIP. Meanwhile, λ_i is expressed as a function of linear predictor:

$\lambda_i = exp(X_i{'}\beta)$, where $\boldsymbol{\beta}$ is a vector of unknown parameters to be estimated from the covariate vector $X_i{'}$ that would include farm and non-farm related factors that influence the extent of vertical integration of poultry farms. The main estimation procedure for (6) is using the method of maximum likelihood. As noted earlier, both ZIP and ZINB generate two models; first, the count model used to predict the response variable; and second, the inflated model used to predict the occurrence of the excess zeros.

3.3.2. Model comparisons and selection

Three tests of model fits were performed to compare and select the model that best explained the data Table 2. First, the Akaike Information Criterion (AIC) [47] and Bayesian Information Criterion (BIC) [63] tests

Table 3. Description of explanatory variables used for both ZIP and ZINP models.

Acronym	Variable Codes/Description	Expected sign
SEX	Sex of poultry farmer, measured as a dummy variable (1 = if farmer is male and 0 = otherwise)	+
EDUL	Educational background of poultry farmer, measured as a categorical variable (1[a] = No formal education, 2 = Basic, 3 = Secondary, 4 = Tertiary and above)	+
AGE	Age of poultry farmer, measured as a continuous variable in years	+
HHSIZE	Number of persons in the household of poultry farmer, measured as a continuous variable	+
FEXP	Poultry farmer experience, measured as a continuous variable in years	+
TEMP	Number of employees of the poultry farm, measured as a continuous variable	+
NATOC	Nature of occupation of farmer, measured as a dummy variable (1 = Full-time, 0 = Part-time)	+
MFBO	Membership of poultry association, measured as a dummy variable (1 = member, 0 = otherwise)	+
TCOST	Total cost of poultry production, measured as continuous variable (Gh'/layer)	-
TFSize	Total flock size, measured as a continuous variable (number of birds)	+
TR	Total revenue of poultry farm, measured as a continuous variable (Gh'/spent layer and egg)	
LANDOWN	Land ownership, measured as a categorical variable (1[a] = family/inheritance, 2 = Individual ownership 3 = Lease arrangement)	+/-
FOWN	Type of farm business ownership, measured as categorical variable (1[a] = sole proprietorship, 2 = family farm, 3 = partnership arrangement)	+/-
TBIRDS	Types of birds managed, measured as categorical variable (1[a] = layer only, 2 = broiler, 3 = layer & broiler)	+/-
EXTCON	Contact with extension agent measured as a dummy variable (1 = yes, 0 = otherwise)	+
ACCRT	Access to credit/facilities and received loan, measured as dummy variable (1 = Have access, 0 = Otherwise	+
NONINC	Access to non-farm income sources, measured as a dummy variable (1 = Access, 0 = Otherwise)	

[a] base category.

Table 4. Responses of poultry farms participating in auxiliary poultry activities.

Production stages	Frequencies	Percentage
Own maize farm	16	18.40
Feed mill	27	31.00
Processing house	2	2.30
Hatchery	1	1.10
Delivery van for marketing	23	26.40
Retail outlet	18	20.70
Total	87	100

Source: Field data (2020).

were performed to score and select the appropriate model. However, while the AIC is asymptotically efficient but inconsistent, the BIC is consistent but not asymptotically efficient [48]. In both instances, the model with the smallest value is considered the better fit. The Vuong test was also performed on the two models against the standard Poisson regression and negative binomial models.

3.3.3. Two part-fractional regression

Ramalho [75] argued that fractional regression could be used to model simple decision-making problems in which the dependent variable has large volumes of zeros. However, if the decision-making involves two-step decision-making to explain (1) the decision to participate or not and (ii) determine the extent/magnitude of participation, the two-part fractional regression is most appropriate. In this study, therefore, we adopt the two-part fractional regression model to complement the zero-inflated models given the excess zeros and the fractional (ratio) nature of the dependent variable, that is, vertical integration ratio [76, 77]. According to Ramalho [75], the first part of the two-part fractional regression is to be reduced into a binary outcome model to determine the probability of a poultry farm's decision to participate in vertical integration (1) or otherwise (0) (eq. 10).

$$Y^* = \begin{cases} 0 \text{ for } Y = 0, \\ 1 \text{ for } Y \in (0,1) \end{cases} \tag{10}$$

where the probability of success is state as captured in Eq. (11):

$$Pr = (Y^* = 1 \mid X) = \Pr(\, Y \in (0,1) \mid X) = F(X\Theta) \tag{11}$$

where Θ is the vector of explanatory variables and $F(.)$ is the cumulative logistic or normal distribution functions. The logit or binary model could be specified from this distribution and estimated by the maximum likelihood method.

The second component of the two-part fractional model deals with positive choices which includes estimating the extent of participation. A $H(.)$ similar to the one specified above is also true for this specification shown in Eq. (12):

$$E = E(Y \mid X, \in = (0,1)) = H(X\gamma) \tag{12}$$

Where $H(X\gamma)$ could be estimated by Quasi Maximum Likelihood with data from producers who have positive vertical integration ratios. Note that the $E(Y|X)$ could be decomposed into:

$E(Y|X) = E(Y|X, Y = 0).\Pr(Y = 0|X) + E(YX, Y \in (0,1]).$ $Pr(Y \in (0,1]|X)$, the first term of the expression on the right-hand side is almost zero. Therefore, the two-part fractional model is specified in Eq. (13):

$$E(Y \mid X) = E(Y \mid X, Y \in (0,1]).\ \Pr(Y \in (0,1] \mid X) = H(X\gamma).\ F(X\Theta) \tag{13}$$

where the two components are to be estimated separately. The coefficients γ and Θ are not the same and the explanatory variables influence the decision to participate or not and the magnitude of participation.

3.3.4. Empirical model specifications

Following the theoretical review of both the ZIP and ZINB, the empirical model guiding this study is specified in Eq. (14) as:

$$\begin{aligned} Y_i = {} & \beta0 + \beta1\ (\text{SEX}) + \beta2\ (\text{EDU}) + \beta3\ (\text{POCC}) + \beta4\ (\text{FEXP}) \\ & + \beta5(\text{AGE}) + \beta6\ (\text{HHS}) + \beta7(\text{EXTCON}) + \beta8(\text{LANDOWN}) \\ & + \beta9(\text{MFBO}) + \beta10(\ \text{TFSize}) + \beta11\ (\text{TCOST}) + \beta12\ (\ \text{BTYPES}) \\ & + \beta13(\ \text{FOWN}) + \beta14\ (ACCRDT) + \beta15(\text{TEMP}) + \beta16(\text{NONINC}) \\ & + \beta17(\text{TR}) + \mu i \end{aligned} \tag{14}$$

where Y_i denotes the degree of vertical integration measured by the number of upstream and downstream activities (non-negative integer

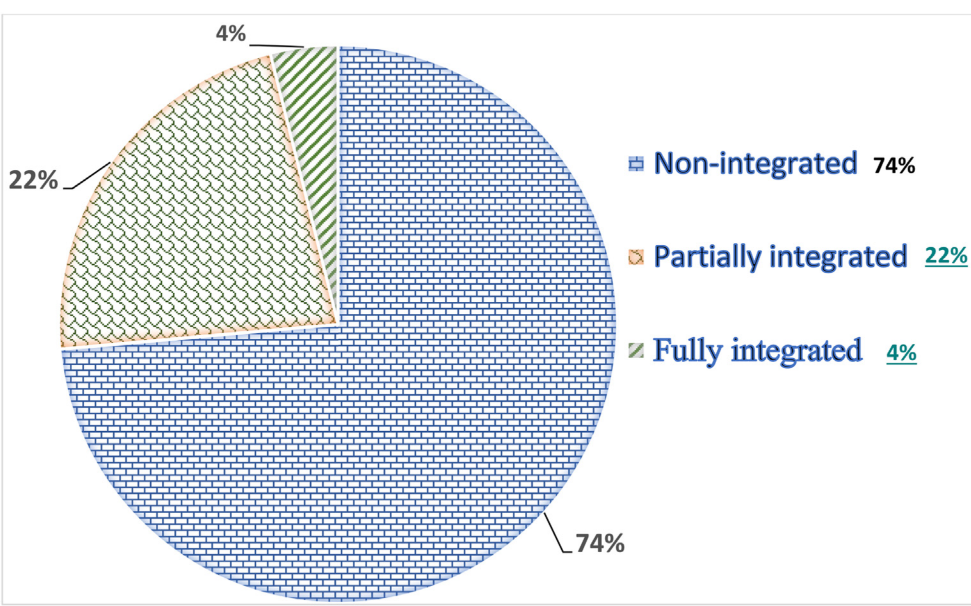

Figure 1. Levels of vertical integration among poultry farms.

Table 5. Description of variables used in econometric analysis.

Variables	Non-integrated (75)	Partially integrated (23)	Fully integrated (4)	Overall (102)
Discrete variables	(%)	(%)	(%)	(%)
Sex				
1 = male	62.70	91.30	75.00	69.60
0 = female	37.30	8.70	25.00	30.40
Education				
1 = No formal education	10.70	8.70	50.00	11.80
2 = Basic/Junior High School	42.70	17.40	0.00	35.30
3 = Secondary/ Senior High School	34.70	56.50	50.00	40.20
4 = Tertiary	12.00	17.40	0.00	12.70
Nature of occupation				
1 = Full time	73.30	95.70	75.00	78.40
0 = Part-time	26.70	4.30	25.00	19.60
Membership of association				
1 = Yes	80.00	100.00	100.00	85.30
0 = No	20.00	0.00	0.00	14.70
Land acquisition				
1 = Family/ inheritance	68.90	30.40	75.00	60.40
2 = Individual ownership	16.20	52.20	25.00	24.80
3 = Lease arrangement	14.90	17.40	0.00	14.90
Type of farm business ownership				
1 = Sole proprietorship	78.70	82.60	100.00	80.40
2 = Family farm	21.30	13.00	0.00	18.60
3 = Partnership arrangement	0.00	4.30	0.00	1.00
Extension/veterinary contact				
1 = Yes	83.8	43.5	50.00	76.20
0 = No	16.2	56.5	50.00	23.80
Access to credit				
1 = Yes	36.0	87.0	100.00	50.00
0 = No	64.0	13.0	0.00	50.00
Access to non-farm income				
1 = Yes	32.0	13.0	25.00	27.50
0 = No	68.0	87.0	75.00	72.50
Continuous variables	***Compare means (ANOVA)***			
Age of poultry farmer	49.25 (11.53)	53.83 (7.02)	50.50 (11.03)	50.33^{ns}
Household size	5.19 (2.25)	6.83 (1.64)	6.0 (2.58)	5.90***
Farming Experience	6.60 (5.36)	10.09 (6.02)	11.0 (4.23)	7.52**
Number of employees	2.19 (0.95)	5.35 (2.29)	10.5 (2.74)	6.01***
Total cost of poultry production (Gh'/bird)	68.61 (16.46)	65.32 (6.76)	63.08 (8.24)	67.65***
Total flock size	3,568 (2782)	12,631.74 (54.35.48)	14,675 (7063.22)	6,047**
Total revenue (Gh'/ bird)	138.53 (24.9)	178.10 (56.70)	209.63 (66.60)	199.73***

***Indicates significance at the 1% level. **Indicates significance at the 5% level *Indicates significance at the 10% level and ns indicates non-significance. Numbers in the bracket denote standard deviation. 2020 official exchange rate: US$1 = Gh' 5.4.

starting with 0, 1, 2, 3….) carried out by the *i*th farmer. The response variable (Y_i) is hypothesized to contain excess zeros (inflated) and the reasons for such zeros to occur are different from the reasons for a poultry farm to participate in vertical integration. **β1… β17** are the vector of parameters to be estimated, **β0** is the constant term, and the μi error term. Table 3 presents the descriptions and *a priori* expectations of the independent variables used in the models. The explanatory variables adopted in this study were based on the findings from previous studies [19, 23, 34, 49, 50, 72] across different agri-businesses in developing countries.

4. Result and discussions

4.1. Extent of vertical integration in poultry business

The extent of vertical integration is measured after taking the ratio of the poultry farm's auxiliary activities (besides the core production stage) to the total number of activities along the value chain (Table 4). The ratio is expressed in percentages (Figure 1) to depict the extent to which the poultry farms are vertically integrated. Out of the six (6) major auxiliary poultry value chain activities, 27 of the farms representing 31.0% own and operate their feed mills for mixing feeds. Similarly, about 26.4% owned delivery vans for both wholesale and retail delivery of eggs and chicken carcass within and outside the study's region. Besides, 20.7% of the respondents possess retail outlets in urban consumption centres to dispose of their eggs and birds directly to consumers. The data further shows a significant number (18.4%) of the poultry firms managing their maize farms; the major feed ingredient representing 60% of compound feeds [8] used for both layers and broilers in the study zone. However, there were only one (1.1%) and two (2.3%) farms that have hatchery and processing houses, respectively. The absence of hatcheries to breed local day-old chicks is not uncommon since most poultry farms in Ghana prefer foreign day-old chicks from Europe compared with domestically hatched day-old chicks. According to Luciana [51], day-old chicks from Europe are hardy, disease-resistant, and could recover quickly after sickness compared with the domestically hatched chicks that are generally of low quality. In support, the Ghana Poultry Project (GPP) reported that more than 511,960 broiler and 7,130,999-layer day-old chicks are imported into Ghana on annual basis [8].

Figure 1 shows the levels of vertical integration based on the classification by [35]. Nearly three-quarters (74%) of the surveyed poultry farms fall below 20% of vertical integration and are classified as non-integrated farms. Partially integrated farms (21% and 65% of VI) represent 22% while fully vertically integrated farms are less than 5% in the study area. This finding agrees well with the observations made by Chapman [21] who reported significant non-integrated farms, but few full and partially vertically integrated poultry farms in Nigeria. The low degree of integration for the poultry farms may have a negative implication on the cost of production since farmers are likely to depend on intermediaries to source inputs (feeds, day-old chicks) and to dispose off the final products (egg and broiler meats). According to Begum [34], high transaction and searching costs contribute to increasing the overall costs of producing poultry in developing economies.

4.2. Variable description according to extent of vertical integration

Male farmers operate the majority (69.6%) of the poultry farms, which is slightly lower than the 89.5% reported by Adei [2] in the same study municipality (Table 5). The low proportion of females in the poultry business may be attributed to the socio-cultural and economic constraints faced by women in establishing business ventures in developing economies [52, 53, 54]. The capital demand to set up and maintain poultry farms in sub-Sahara Africa is high, which in turn limits women's participation in the livestock business. The high literacy rate of 52.9% of poultry farmers with more than senior high school certificates could have positive implications for the growth of the poultry business. This is because educated farmers can read and write which improves their ability to keep proper farm records, access information/credit, and adopt technologies to increase production. The literacy data is consistent with the 43.4% of poultry farmers with senior high school and tertiary certificates reported by Nimoh [61] in the same study area. Likewise, 78.4% of the poultry farmers are full-time workers, which

Table 6. Coefficients of factors in the zero-inflated negative Binomial regression model.

Variable	Logistic component			Marginal effects (dy/dx	Negative Binomial component		
	Coef(β)	SE(β)	Z-test		Coef(β)	SE(β)	Z-test
Personal characteristics							
Age of farmer	0.0034	0.0070	0.49	0.061	0.0065	0.1318	0.05
Sex	0.1849	0.2025	0.91	0.556	0.9170	3.2600	0.28
Household size	- 0.019	0.0326	-0.59	-0.620	-1.488	0.8153	-1.83*
Education level							
Completed Basic/Junior High School	0.4059	0.1709	2.38**	0.89**	-0.628	0.3570	-1.75*
Completed Senior High School	0.222	0.1214	1.83*	0.099*	-0.5970	0.2771	-2.15**
Completed Tertiary Education	0.3184	0.1778	1.79*	0.710*	-1.3891	3.0535	-0.45
Non-farm income	0.1025	0.1668	0.61	2.142	2.6840	4.1567	0.64
Nature of Occupation	0.2657	0.1857	3.10***	0.544***	-0.5375	0.2462	-2.18**
Farm experience	0.0306	0.011	2.70***	0.416***	0.5394	0.2552	2.11**
Farm characteristics							
Land ownership							
Individual ownership	0.255	0.1235	2.06**	0.097**	-2.895	3.7870	-0.76
Lease agreement	-0.0364	0.196	-0.19	0.411	-1.154	3.1640	-0.36
Flock size	0.0074	0.0015	4.93***	0.002***	0.0011	0.0006	1.93*
Production cost	-0.0290	0.0095	-3.06***	-0.436***	0.2247	0.1077	2.08**
Revenue per bird	0.0028	0.0012	2.4**	0.035**	-0.0834	0.0514	-1.62*
Type of farm business ownership							
Family farm	0.2701	0.1485	1.82*	0.992*	0.6891	0.4020	1.71*
Partnership	0.2698	0.1236	2.4**	0.397**	-0.1970	0.1173	-1.68*
Employee size	0.089	0.038	2.32**	0.599**	-3.520	2.0690	-1.70*
Institutional characteristics							
Access to credit	0.3540	0.1525	2.32**	0.930**	-0.921	-0.550	1.67*
Extension service	0.2612	0.1288	2.03**	0.541**	7.388	4.5330	1.62
Association membership	0.2980	0.1570	1.89*	0.843*	8.047	4.0030	2.01**
Constant	4.761	0.9180	5.18***		44.078	24.437	1.80*
Model diagnostics							
Number of observations							100
Non-zero observations							44
LR chi-square (21)							69.16***
Inflation model							Logit
Log likelihood							-165.84

***Indicates significance at the 1% level. **Indicates significance at the 5% level *Indicates significance at the 10% level and [ns] indicates non-significance.

emphasised that poultry farming is a major source of livelihood and thus can serve as a conduit for poverty reduction in the study area. This finding relates well with Chapman [21] who reported that over 50% of poultry farmers, particularly in West African countries such as Nigeria are full-time workers.

The significant membership of association of 85.3% presupposes that, through its leadership, the members can have access to reliable information and productive resource to improve poultry production/productivity. This data is consistent with Winkelmann and Zimmermann [73] and Wulff [74] who reported that 70% and 56% of poultry farmers in the study region are members of farmer group organizations. Family/lineage inheritance remains the dominant (60.4%) means of land acquisition in the area. This buttresses the report by McPherson [55] that agricultural lands in Ghana are mainly acquired through family lineage. However, a majority (80.4%) of the farms are owned through sole proprietorship against a few which are under family or partnership arrangements. This finding corroborates with Chapman [21] who reported that 79.1% of poultry farms in Nigeria are operated through sole proprietorship. On extension/veterinary access, more than three-quarters have access to extension/veterinary services. Such high access is expected to have positive impact on poultry production since extension/veterinary technical staff are responsible for the dissemination of technologies and the provision of technical advice for improved production. Fifty percent (50%) of the respondents have access to credit and 72.5% do not have access to non-farm income sources. Having access to credit could afford the poultry farmers the opportunity to expand or maintain their farms and improve productivity. The average age of 50.33 years is an indication of an industry populated by the aged. This calls for a consented effort by the government and other stakeholders to introduce packages including initial startup capital to lure the youth into poultry production. This data is relatively similar to the 46 years reported for poultry farmers in the study region by Yevu [75] but sharply contradicts Nimoh [61] who observed a relatively younger (31 and 40 years) poultry farmer population in the Greater Accra region of Ghana.

The respondents have a relatively higher farming experience of 7.5 years of poultry farm management. Across the extent of vertical integration, farmers who operate fully vertically integrated farms (11.0) dominate before partially integrated farmers (10.09) and finally no integrated farms (6.60). Similarly, the data shows a significant number of employees (10.5), flock size (14,675), and revenue (Gh'209.63) for farmers who operate fully vertically integrated farms compared to their counterparts with partially and no integrated farms. These statistics relate well with the findings of Bamiro and Shittu [21] who reported higher returns and flock size for farmers with vertically integrated poultry farms in Nigeria. Further, the [2]cost incurred is also lower for

[2] The cost incurred is per layer bird per annum.

Table 7. Coefficient of factors in the two-part fractional (2-PF) model.

Variables	Binary component				Fractional component			
	Coef.	Std.Err	z	dy/dx	Coef.	Std.err	Z	dy/ex
Personal characteristics								
Age	-0.028	0.084	-0.34	-0.062	0.001	0.011	0.13	0.014
Sex	0.986	1.613	0.61	0.01	-0.412	0.378	-1.09	-0.011
Household size	0.928	0.513	1.81	0.226**	-0.073	0.055	-1.33	-0.094
Years in education	0.237	0.121	1.96	0.107**	0.033	0.013	2.58	0.089***
Non-farm income	2.495	3.519	0.71	0.016	-0.054	0.298	-0.18	-0.002
Nature of Occupation	10.08	5.71	1.77	0.39**	0.682	0.292	2.34	0.131**
Farming experience	0.265	0.221	1.2	0.072	0.012	0.02	0.61	0.021
Farm characteristics								
Land ownership	-0.705	0.26	2.71	-0.18***	0.273	0.237	1.15	0.028
Flock size	0.001	0.00	2.53	0.24***	0.001	0.00	4.27	0.27***
Production cost	-0.095	0.05	-1.90	-0.183*	-0.04	0.016	-2.7	-0.56***
Revenue per bird	0.038	0.022	1.71	0.446*	0.003	0.002	1.3	0.141
Type of business ownership (Partnership)	6.725	3.651	1.84	0.257**	0.524	0.226	2.32	0.089**
Employee size	2.043	1.095	1.87	0.254**	0.166	0.074	2.24	0.151**
Institutional characteristics								
Access to credit (Yes)	8.059**	3.146	2.56	0.176***	0.628	0.308	2.04	0.103**
Extension contacts (Yes)	5.295	3.477	1.52	0.201*	-0.473	-0.301	-1.57	-0.058
Poultry association (Member)	4.59	2.155	2.13	0.16***	0.523	0.355	1.47	0.095
_Constant	-33.35**	14.815	-2.25		1.109	1.265	0.88	

***Indicates significance at the 1% level. **Indicates significance at the 5% level *Indicates significance at the 10% level and ^{ns} indicates non-significance.

vertically integrated poultry farms (Gh'63.08) compared with partially integrated (Gh'65.32) and no integration farms (Gh'68.61), significant at 1% significance level. The results agree well with the findings of Basant [13] and Chapman [21] who conclude that vertical integration leads to cost reduction, which, in turn, increases investors' investments.

4.3. Parameter estimates from ZIP and ZINB regression models

The coefficients of both zero-inflated Poisson (ZIP) (Appendix 2) and zero-inflated negative binomial (ZINB) (Table 6) regressions are summarised and discussed. The results of the ZIP model show that 16 out of the 20 covariates significantly influence the degree of vertical integration of poultry farms. On the other hand, 14 of the 20 explanatory variables in the ZINB are considered predictors of vertical integration of poultry farming. A large proportion of explanatory variables in the ZIP model are significant compared with the ZINB because the standard errors in the ZIP model are underestimated. This finding is congruent with the study of Greene [38] who reported an overestimated standard error in ZINB concerning ZIP models. We computed various tests to compare and select the best model that describes that data. First, the Voung tests for both models are significant at a 1% significance level, which implies that the data perfectly fit ZIP and ZINB due to the excess zeros instead of the standard Poisson and negative binomial models, respectively. However, the sample mean (0.95) of the response variable (number of auxiliary activities) is less than the sample variance of 1.82, which suggests the case of over-dispersion in the data. Similarly, the AIC (443.38) and BIC (506.11) values for the ZINB model are positive and lower than the AIC (456.69) and BIC (519.22) values reported in the ZIP regression.

The forgoing tests demonstrate that the ZINB is the most appropriate model to examine the determinants of vertical integration of poultry production in event of data with over-dispersion and inflated zeros. Therefore, the significant predictors of vertical integration in poultry production were evaluated (Table 6). Given that the dependent variable, that is the extent of vertical integration, was also measured in ratios (fractions), the result of the ZINB model is compared with estimates from two-part fractional regression as a robust check (Table 7). In this case, only variables that significantly influence farmers' decisions to participate in vertical integration are discussed. The coefficients of the estimated parameters and their marginal effects are reported and explained as follows.

4.4. Results of the ZINB count data model

4.4.1. Personal characteristics

The educational background of poultry farm owners has a positive and significant relationship with the degree of vertical integration in poultry production. The count data of the ZINB model shows that the probability for a farmer with a Basic/Junior High School certificate to engage in vertical integration is 89% greater than a farmer without formal education, *all things being equal*. Similarly, there was a higher probability for farmers with Senior High School (9.9%) and Tertiary education (7.1%) to vertically integrate their poultry farms compared with non-educated counterparts, *all things being equal.* The results agree with Bamiro [21] who found out that the educational background of poultry farmers is important for the vertical integration of poultry farms in Nigeria. In a related study in Rwanda, Issa [49] also concluded that education is a predetermined factor to integrate agro-businesses into developing economies. From the ZINB model, it appears that the nature of occupation has a positive relationship with the likelihood and intensity of participating in the vertical integration of poultry enterprises. This finding could be attributed to the capacity of poultry businesses to provide economic sustenance to farm households who solely depend on the enterprise for livelihood. Farmers whose main source of livelihood is poultry farming may want to explore opportunities to improve production and productivity for higher income and profitability.

4.4.2. Farm characteristics

The type of land ownership tends to significantly influence the degree of vertical integration of poultry farms in the study area. The ZINB model illustrates that the probability of a farmer with full property rights of farmland to engage in vertical integration is 9.7% higher compared with farmers with family/inherited farmlands, *all things being*. The positive effect of full property rights of farmland on vertical integration supports the assertions made by Awudulai [57] in Ghana. Awudulai observed that farmers with full land ownership are more likely to diversify their farm portfolios to reduce the overall cost of production for profit maximization. Likewise, the ZINB model shows that as the flock size of farms increase by a unit, and revenue increases by a dollar ($), the probability of farmers to vertically integrate their farms' increases by 0.2% and 3.5%, respectively, *all things being equal*. This finding is consistent with the result of Issa [49] who documented a significant positive relationship between farm size and the capacity to vertically integrate agribusinesses in Rwanda. Likewise, Elzo [58] asserts that agribusinesses with higher revenue tend to record higher profitability and as such, such businesses will have enough funds for investments in other activities that increase overall firm performance. However, result of the ZINB model shows that as overall production costs increase, the likelihood of vertical integration reduces, *all things being equal*. This finding according to Kusi [6] partly explains the low vertical integration among poultry farms in Ghana. This is so because the high cost of production leads to low profitability of the poultry business, which eventually generates little or no extra funds to invest in other activities along the poultry value chain.

4.4.3. Institutional characteristics

Access to institutional factors such as credit facilities, extension contact, and membership of poultry farm association are well recognized to create the enabling environment for investment and expansion of existing businesses Essel [31]. The data from the ZINB shows that the probability of farmers with credit access is 93% likely to participate in vertical integration of poultry farms compared to farmers without credit access, *all things being equal*. This finding corroborates with de Janvry [24] who noted that access to credit/loan improves the liquidity capacity of the farm; helps smoothen capital fluctuations, and thus facilitates investments in other activities that improve overall business performance. In terms of extension contact and membership of poultry association, the results of the ZINB show that the probability of vertically integrating poultry farms is 93.0% and 84.0% higher for farmers with extension contact and membership of poultry association, *all things being equal*. This result is consistent with the observations made by Marinda [60] who reported that the production and marketing landscape of agricultural products is evolving fast, and this requires the collection and processing of information to gain a competitive advantage and expand on-farm investments. Thus, farmers with improved extension service contact and membership in associations tend to be abreast with improved farming technologies and can access credit facilities for more farm investments to achieve higher profitability.

4.4.4. The logit inflation model

The inflation component of the ZINB predicts the occurred nce of the excess zeros of the model (Table 6). The data shows that farmers' personal factors such as education, primary occupation, and household size decrease the likelihood of absolute zeros while farming experience increases the incidences of absolute zeros. For instance, the odds of being in absolute zero categories for farmers with Junior and Senior High School certificates are expected to decrease by exp (-0.628) = 0.53 times and exp (-0.5970) = 0.55 times, respectively all things being equal. Similarly, the odds of being in the absolute zero groups for full-time poultry farmers are expected to decrease by exp (−0.538) = 0.53 times. In other words, farmers with some form of education who are full-time poultry farmers are less likely to contribute to the excess zeros in the vertical integration of poultry farms. However, an increase in farming experience is likely to increase the odds of being in the absolute zero categories by exp (0.5394) = 1.71.

In terms of poultry farm-related factors, whiles the odds of a certain zero is lower for farms with higher flock size, employee size, and revenue, the odds are higher for farms with a high cost of production. The results also show a higher odds ratio for farmers with full outright ownership of land compared to family/inheritance ownership, all things being equal. The result implies that increasing flock size, employee size, and revenue with full outright land ownership contribute less to being part of the absolute zeros in assessing vertical integration in poultry production. However, a higher cost of production predisposes farmers to belong to the excess zero categories.

The study shows two institutional factors including credit access and association membership significantly influence the absolute zeros of vertical integration. The data shows a lower odds ratio for farmers with credit access to be part of the absolute zeros categories in examining vertical integration of poultry production. On the contrary, access to association membership tends to increase the odds of poultry farmers belonging to the absolute zero groups.

4.4.5. Robustness check with two-part fraction (2-PF) model

As discussed earlier, the 2-Part Fraction model is used as a robust check to the ZIP and ZINB model. The results of the 2-PF model (Table 7) in terms of important precursors of vertical integration are not significantly different from the ZINB model.

The 2-PF model shows a significant positive relationship between education and farmers' decision to participate in vertical integration. Similarly, the model suggests that the probability of a full-time poultry farmer to participate and intensify vertical integration is 3.1% higher compared with part-time poultry farmers, *all things being equal*. Further, the 2-PF model depicts that individual ownership of farmland had a positive relationship with the likelihood of farmers' decision to participate in vertical integration but establishes no relationship with the intensity of vertical integration. The flock size and revenue coefficients of the 2-PF model supports the findings of the ZINB model which establishes a significant positive relationship between the covariates and the probability of farmers' decision and intensity of vertical integration. It is obvious from the 2-PF model that cost of production, extension contact and membership of poultry associations are significant determinants of farmers' decision to vertically integrate poultry farms. However, the result shows no relationship between extension contact and membership of farmers association and the intensity of participation in vertical integrations which is contrary to the findings of the ZINB model.

5. Conclusion

Over the past decades, the poultry industry in sub-Sahara Africa has declined due to the high cost of production. Strategies that enhance the vertical integration of poultry farms would greatly reduce transaction costs, risks, and uncertainties as well as demand variations. These, in turn, will ultimately improve the competitiveness of the sector for higher farmer returns. However, little is known about the implications of vertical integration in the poultry sector, particularly in Ghana. This study, therefore, examines vertical integration in poultry production using econometric models that provide findings with relevant implications for the development of the poultry industry. The study contributes to existing agribusiness management literature by exploring critical factors that influence the vertical integration of poultry farms, particularly in Ghana.

Given that previous studies on the measurement of vertical integration in poultry production are simplistic and inconclusive, this study uses the vertical integration index to accurately and sufficiently capture the extent of vertical integration in the industry. The study evidence that institutional factors such as membership in poultry associations, extension education, and access to credit are important precursors of vertical integration among poultry farms. This finding has implications to strengthen existing poultry associations through periodic capacity building programs for both leadership and members. This is even more important because the study shows a significant relationship between farmers' characteristics such as formal education and the decision to participate in the vertical integration of poultry farms. To complement this effort, special concessionary credit facilities could be made available to members of these associations for diversification of investments along the poultry value chain. Second, the significant effect of farm factors such as costs of production on vertical integration of poultry business demands subsidy or elimination of import duties on critical poultry inputs such as day-old chicks and medications into the country. In summary, it is concluded that important farm (cost of production) and non-farm (extension education, membership of association, formal education and credit access) characteristics are important determinants of vertical integration of poultry production. Lastly, the study shows that the ZINB model best describes the determinant of vertical integration for data with excess zeros and over-dispersion. Therefore, it is highly recommended to use objective criteria in choosing appropriate econometric models to analyse count data problems that are zero-inflated and over-dispersed. To make results of zero-inflated models more reliable, future studies should consider to compare them with other appropriate models such as fractional regression models, Tobit or logit depending on the response variables as a robust check.

Declarations

Author contribution statement

Faizal Adams: Conceived and designed the experiments; Analyzed and interpreted the data.

Amos Mensah; Robert Aidoo: Contributed reagents, materials, analysis tools or data.

Seth Etuah: Performed the experiments; Wrote the paper.

Bright Owusu Asante: Analyzed and interpreted the data.

James Osei Mensah: Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

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APPENDICE

Appendix 1

Table 6. Model comparisons and selections

Test	ZIP	ZINB
AIC	456.69	443.58
BIC	519.22	506.11
Vuong test	5.26***	3.09***
Mean (variance) of response variable		0.95 (1.82)

Appendix 2

Table 7. Coefficients of factors in the zero-inflated Poisson regression model

Variable	Logistic component				Poisson component		
	Coef(β)	SE(β)	Z-test	Marginal effects (dy/dx)	Coef(β)	SE(β)	Z-test
Personal characteristics							
Age of farme	0.01	0.005	1.06	0.11	-0.0067	0.1319	-0.05
Sex	0.25	0.114	2.22	0.02**	-0.9190	3.263	-0.28
Household size	-0.02	0.022	-0.97	-0.62	-1.5011	0.8167	-1.84*
Education level							
Completed Basic/Junior High School	0.42	0.114	3.66	0.88***	-0.630	0.369	-1.76*
Completed Senior High School	0.24	0.073	3.27	0.24***	-0.6080	0.2781	-2.19**
Completed Tertiary Education	0.31	0.113	2.78	0.11**	-1.4627	3.0746	-0.48
Non-farm income	0.08	0.116	0.66	1.67	-2.8042	4.2678	-0.66
Nature of occupation	0.28	0.134	2.09	0.82**	-0.6780	0.244	-2.47**
Farm experience	0.01	0.007	1.70	0.44*	0.5394	0.2552	2.11**
Farm characteristics							
Land ownership							
Individual ownership	0.12	0.062	1.91	0.200*	-3.945	4.656	-0.85
Lease agreement	0.03	0.138	0.23	0.907	-1.2073	3.1855	-0.38
Flock size	0.01	0.001	7.21	0.002***	0.0011	0.0006	1.93*
Production cost	-0.03	0.007	-4.97	-0.529***	0.2358	0.1087	2.11**
Revenue per bird	0.002	0.001	2.23	0.045**	-0.0864	0.0515	-1.68*

(continued on next page)

Table 7 (*continued*)

Variable	Logistic component				Poisson component		
	Coef(β)	SE(β)	Z-test	Marginal effects (dy/dx)	Coef(β)	SE(β)	Z-test
Type of farm business ownership							
Family farm	-0.31	0.097	3.21	-0.237***	-0.758	0.403	-1.88*
Partnership	-0.49	0.217	-2.23	-0.351***	-0.1970	0.1173	-2.53***
Employee size	0.10	0.025	4.10	0.621***	-3.520	2.069	-1.70*
Institutional characteristics							
Access to credit	0.42	0.099	4.23	0.961***	-0.944	-0.560	1.68*
Extension service	0.24	0.082	2.96	0.551***	7.478	4.643	1.61
Association membership	0.25	0.085	2.89	0.065***	8.1047	4.0373	2.01**
Constant	5.11	0.624	1.84*		44.664	24.994	1.79*
	Model diagnostics						
Number of observations							100
	Non-zero observations						44
	LR chi-square (21)						386.21***
Inflation model							Logit
Log-likelihood							-175.54

***Indicates significance at the 1% level. **Indicates significance at the 5% level *Indicates significance at the 10% level and ^{ns} indicates non-significance.

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