Determinants of Vertical Integration in Poultry Production in Ghana: Application of Count Data Models

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ABSTRACT

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 extent of vertical integration in the Ghanaian poultry industry by employing zero-inflated Poisson (ZIP) and Zero-inflated 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 extent 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.

Key words: Poultry production, transaction cost, food security, poverty reduction,
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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) (Food and Agriculture Organisation, 2010). In Ghana, poultry production makes a significant contribution to the economic growth of the country (Adei and Asante, 2012; Atuahene et al., 2010). The sector accounts for about 34% of domestic meat production and employs nearly 2.5 million people, of which the majority are women who subsist on poultry and other related products for livelihoods (Guèye, 2000; Ministry of Food and Agriculture [MoFA], 2020). Despite its influential contribution to the growth of the economy, the Ghanaian poultry industry, over the past decades, has declined due to intense competition from imported poultry products and high cost of production (Kusi et al., 2015; Anang et al., 2013; Atuahene et al., 2010). For instance, official data shows that domestic broiler meat supply has declined from 60% to 20% culminating in an increase in imports from 13,900MT to over 155,000MT in 2018 (Figure 1) (FAOSTAT, 2019).

To help create a more competitive and efficient poultry industry, the United States Development Agency (USDA) implemented the Ghana Poultry Project (GPP) from 2015 to 2020 (USDA, 2017). This was further strengthened by the introduction of the “Rearing for Food and Jobs” program by the Government of Ghana to produce 40,000MT of broiler meat by the end of 2020 (MoFA, 2019). In these initiatives, much emphasis were placed on strategies such as the provision of subsidized inputs, producer’s capacity building, and strengthening of buyer-supply linkage to minimize the cost of production and improve the overall competitiveness of the Ghanaian poultry industry (Anang, 2013; Global Agricultural Information Network (GAIN) report, 2017).
However, an important management strategy that has a significant influence on the overall performance and competitiveness of the poultry industry but has received little attention in these initiatives is **vertical integration**. 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 of Ghana (Atuahene, 2010). This study, therefore, 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 (Baum, 1951; Coarse, 1937; Buzzel, 1983; Maddigan, 1981; Grega, 2003; Martinez, 2012). Isaksen et al. (2002) suggests that vertical integration of firms helps to reduce production costs while improving efficiencies. In a multi-study of agricultural products, Martinez (2012) observes that not only does vertical integration enable

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**Figure 1: Production and Importation of Poultry in Ghana, 2000-2016**

**Data source: FAOSTAT Database, Various Years**

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firms to eliminate risk and uncertainties, but to overcome market failures and expand market power for competitive advantage. 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 (Carlton and Perloff, 2005). Despite this, there are only few studies (e.g. Bamiro et al., 2006; Bamiro and Shittu, 2009; Bamiro et al., 2014) across sub-Saharan Africa that consider vertical integration of poultry farms as a conduit to increase competitiveness and efficiency of the sector. Moreover, the findings of these limited studies have generally been mixed and inconclusive (Bamiro et al., 2006; Bamiro and Shittu, 2009; Bamiro et al., 2014). This is because the over-reliance on the use of value-added ratio as a proxy to measure the extent of vertical integration of poultry farms is fairly limited (Barrera-Ray, 1995). According to Hamdaoui and Boyuad (2019), the two economic variables of sales and purchases, which are key indicators of value-added ratio in the determination of vertical integration, may be influenced by other factors (such as production techniques and staff competencies) besides vertical integration. In this study, therefore, we compute a vertical integration index based on available data to measure the extent of vertical integration in poultry production. We also examine the key determinants of extent of vertical integration by paying special attention to important farmer, farm level, and institutional factors. The rest of the study is organized as follows. First, theoretical concept of vertical integration and its measurement are reviewed in Section II. The research method is presented in Section III before 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 (1928), and Stigler (1951). Yet to
date, there is no universally accepted definition of the concept (see, for instance, Coase, 1937; Buzzell 1983; Rehber, 1998; Luciana, 2008; Basant and Mishra, 2017). 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 (Hamdaoui and Bouayad, 2019). As a result, the product developed is not transmitted via the market and, hence, does not reflect market prices (Hamdaoui and Bouayad, 2019). In summary, Barrera-Ray (1995) 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 (Grega, 2003; Barrera-Ray, 1995; Bamiro and Shittu, 2009). 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 (Hamdaoui and Bouayad, 2019). 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 computation of indices based on available data (Kaiser and Obermaier, 2020).
In terms of financial measures, the Value Added to Sales (VAS), proposed by Adelman (1955), 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 as $VAS = (sales - purchases)/sales$ (Buzzel, 1983). 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 (Hamdaoui & Bouayad, 2019), and not on physical activities/transactions that contribute to the degree of vertical integration (Barrera-Ray, 1995). Similarly, the measure is criticised as not being symmetric concerning production stages, as it favours upstream activities (Barrera-Ray, 1995; Isaksen et al. 2002). 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 (Essel et al., 2019). However, the VAS is the dominant approach used in the few existing studies that consider vertical integration of poultry production across sub-Saharan Africa (See, for instance, Bamiro et al., 2006; Bamiro and Shittu, 2009; Bamiro et al., 2012).

In this study, we adopt a more data-driven approach (vertical integration indices) that permits the use of reliable and readily available data of poultry farms to measure the extent of vertical integration. The indices proposed by Chapman and Ashton (1914), and Gort (1962) 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. In this modified approach, the poultry farm’s main activity (i.e., production of eggs and meat) is separated from its auxiliary activities and values assigned to each activity in the
poultry value chain. Empirically, six (6) major auxiliary activities are performed along the value chain. These include ownership of crop farm (mainly maize), feed mill, hatchery, delivery van, processing plant and retail outlet (Begum, 2005). 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:

\[
V_i = \sum \left( \frac{n_i}{N} \right) \times 100\%
\]

where, \(V_i\) is the extent of vertical integration expressed in percentage, \(n\) is the number of activities engaged in by \(i\)th poultry farm 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 (2019) to measure the extent of vertical integration in the Moroccan textile industry. The following criteria as defined by Misund (2016) are used to categorise the poultry farms based on the extent of vertical integration, which was used in the further econometric analysis (see Table 1).

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

**Source:** Adopted from Misund (2016)

### 3. RESEARCH METHODS

#### 3.1. Study area

The study was conducted in the Dormaa municipality located in the western part of the Bono region of Ghana (Figure 1). The municipality has a total land area of 1210.28km\(^2\) with a population of 112,111, representing 4.9\% of the national population. Dormaa has an agrarian economy that employs 68.4\% of its total population. About 73\% of the population is located in rural
communities. Crop and livestock framings are the major agricultural activities in the area. The Municipality is noted for the production of poultry, which constitutes more than 70% of the total livestock production in the area. Besides, the old Brong Ahafo region (now comprising Bono East, Bono, and Ahafo) is ranked third in terms of poultry production in Ghana with Dormaa municipality contributing more than 80% to the regions’ poultry population (Anang et al., 2013; Kusi et al., 2015). 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 (Adei and Asante, 2012).

![Figure 1 Map of Dormaa Municipality](Ghana Statistical Service, [GSS] 2010)

**3.2 Study design and data collection procedure**

The mixed research technique that comprises both quantitative and qualitative designs was used to carry out the study. Combining the two techniques helps 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 comprises 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 4 selected poultry producing communities
in the study area. Key qualitative data collected included farmers’ perception of vertical
integration, bottlenecks to practicing vertical integration as well as general production and
marketing information. On the other hand, a 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 employs 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 towards meeting the objectives of the study. Seven (7) poultry farmers were
randomly selected and used in the pre-testing.

The study conducted a full census to include all the 137 registered commercial poultry farms in
the Dormaa municipality. The list of all the farms was obtained from the leadership of the poultry
farmers’ associations in the municipality. The veracity of the list was authenticated at the
Municipal Department of Agriculture. Information on other poultry farms not registered were also
solicited from the Department and were contacted for data collection. In total, managers and
owners of 102 poultry farms were available for data collection within the survey period. The
communities included in the survey are Wamfie (15), Dormaa Ahenkro (35), Kyeremasu (12), Asuochia (10), Nkrankwanta (30), and Nsesreso (10).

3.3. Analytical approach

Descriptive tools including frequency tables, pie chart 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 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 extent of integration (Atuahene et al., 2010). The ZIP and ZINB models were compared and the model that best fitted the data was selected for further discussion.

3.3.1 Zero-inflated Poisson and Negative Binomial models

In socio-economic studies, outcomes of interest are sometimes count data with excessive zeros (Fang, 2013). 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’ (Lewsey and Thomson, 2004; Yusuf et al. 2018). Under such circumstances, the analysis becomes less useful and less informative if the interest is to determine the number of occurrences (Yusuf et al., 2018).

Zero-inflated model can distinguish between the two processes causing the excess zeros (Diallo et al., 2019; Yusuf et al. 2018). A common feature of zero-inflated model is its ability to

1 Numbers in brackets denotes size of farmers selected in each community
simultaneously produce two outcomes in count data models by: i) examining the effects of covariates on the extra/inflated zeros and, ii) generating Poisson or negative binomial aspect of the model (Diallo et al., 2019; Fang, 2013; Lewsey and Thomson, 2004).

Zero-inflated Poisson and -negative binomial models are specialized types of Poisson regression models that are widely employed in count data analyses with inflated zeros (Fang, 2013; Lambert 1992; Diop et al., 2016; Diallo et al., 2017). Lambert (1992) 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, modeling a zero-inflated count data that has over-dispersion problems with ZIP also produces coefficients that are consistent but inefficient (Fameye et al., 2003; Fang, 2013). Greene (2003) 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 scaler-dependent variable is larger than its mean (Winkelmann and Zimmermann, 1995; Winkelmann and Zimmermann, 1998).

In the ZIP model, the scaler dependent variable \( (Y_1, Y_2, \ldots, Y_n) \) is independent and the assumption behind the model is that given a probability \( P \), there are two possible outcomes; 0 and the probability of \( (1 - \pi_i) \) which leads to the generation of a Poisson random variable \( (\lambda) \) in \( Y_i \) (Cameron and Trivedi, 2013). The distribution of \( Y_i \) is given as follows:

\[
Y_i = \begin{cases} 
0, & \text{with probability } p_i + (1 + \pi_i)e^{-\lambda_i} \\
\text{k, with probability } (1 - \pi_i)e^{-\lambda_i}\frac{\lambda_i^k}{k!}, & \text{k} = 1, 2, 3 \ldots n
\end{cases}
\]  

(1)

The variance and mean of the zero inflated Poisson distribution are specified in (2) and (3), respectively;

\[
V(Y_i) = (1 - \pi_i)(\lambda_i + \lambda^2_i) - ((1 - \pi_i)\lambda_i)^2
\]  

(2)
\[
E(Y_i) = (1 - \pi_i)\lambda_i
\]  
(3)

Similar to ZIP, the ZINB also has two possible outcomes. Assume \( \pi \) as the probability for the occurrence of case 1 which is zero and \( (1 - \pi) \) as the probability for case 2 which is a success. If \( (1 - \pi) \) occurs, the counts (including zeros) generated are line negative binomial model. In this case, Greene (1994) defined the probability of the ZINB random variable, \( Y_i \) as;

\[
Y_i = 0 \text{ with probability } \pi_i
\]  
(4)

\[
Y_i \sim \text{negative binomial } (\lambda_i, k) \text{ with probability } (1 - \pi)
\]

This implies that,

\[
\Pr(Y_i = 0) = \pi_i + (1 - \pi_i)(1 + k\lambda_i)^{-1/k}
\]  
(5)

\[
\Pr(Y_i = y_i) = (1 - \pi_i)\frac{\Gamma(y_i+k^{-1})}{\Gamma(k^{-1})\Gamma(y_i+1)} \frac{(k\lambda_i)^y_i}{(1+k\lambda_i)^{y_i+k^{-1}}}, \quad y_i = 1, 2, \ldots
\]  
(6)

From (5), the mean and variance of \( y_i \) becomes:

\[
V(Y_i) = (1 - \pi_i)\lambda_i 1 + \lambda_i(\pi_i + k)
\]  
(7)

\[
E(Y_i) = (1 - \pi_i)\lambda_i
\]

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

\[
\lambda_i = \exp(X_i'\beta), \quad \text{where } \beta \text{ is a vector of unknown parameters to be estimated from the covariate vector } X_i', \text{ 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 1). First, the Akaike Information Criterion (AIC) (Akaike, 1973) and Bayesian Information Criterion (BIC) (Schwarz, 1978) tests 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 (Cavanaugh and Neath, 2019). 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.

Table 2 Model comparisons and selections

| Test       | Model                                                      | Decision rule                                                                 |
|------------|------------------------------------------------------------|--------------------------------------------------------------------------------|
| AIC        | \( AIC = -2 \times \ln(\text{likelihood}) + 2 \times K \) | Choose model with smallest AIC value                                           |
| BIC        | \( AIC = -2 \times \ln(\text{likelihood}) + \ln(N) \times K \) | Choose model with smallest BIC value                                           |
| Vuong test | -                                                          | Significant test statistic implies the data fits ZIP and ZINB against standard Poisson and Negative Binomial model, respectively. |

Source: Cavanaugh and Neath (2019)

3.3.3. Empirical model specifications

Following the theoretical review of both the ZIP and ZINB, the empirical model guiding this study is specified as:

\[
Y_i = \beta_0 + \beta_1 (\text{SEX}) + \beta_2 (\text{EDU}) + \beta_3 (\text{POCC}) + \beta_4 (\text{FEXP}) + \beta_5 (\text{AGE}) + \beta_6 (\text{HHS}) + \beta_7 (\text{EXTCON}) + \beta_8 (\text{LANDOWN}) + \beta_9 (\text{MFBO}) + \beta_{10} (\text{TFSize}) + \beta_{11} (\text{TCOST}) + \beta_{12} (\text{BTYPES}) + \beta_{13} (\text{FOWN}) + \beta_{14} (\text{ACCRDT}) + \beta_{15} (\text{TEMP}) + \beta_{16} (\text{NONINC}) + \beta_{17} (\text{TR}) + \mu_i
\]

where \( Y_i \) denotes the extent of vertical integration measure by the number of upstream and downstream activities expressed in percentages 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. \(\beta_1 \ldots \beta_{17}\) are the vector of parameters to be estimated, \(\beta_0\) is the constant term, and \(\mu_i\) the error term. In Table 3 are the descriptions and \textit{a priori} expectations of the respondents, farm, and institutional variables included in the model. The explanatory variables adopted in this study were based on the findings from previous studies (Begum. 2005; Issa and Chrysostome, 2015; Harianto et al., 2019) across different agri-businesses in developing countries.

**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 household size 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) | +/- |
### Table 1

| Variable | Description |
|----------|-------------|
| **FOWN** | Type of farm business ownership, measured as categorical variable (1 = sole proprietorship, 2 = family farm, 3 = partnership arrangement) |
| **TBIRDS** | Types of birds managed, measured as categorical variable (1 = 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) |

*base category

### 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 2) 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 64.3% own and operate their feed mills for mixing feeds. Similarly, about 54.8% owned delivery vans for both wholesale and retail delivery of eggs and chicken carcass within and outside the study’s region. Besides, 42.9% of the respondents possess retail outlets in urban consuming centers to dispose of their eggs and birds directly to consumers. The data further shows a significant number (38.1%) of the poultry firms managing their maize farms; the major feed ingredient representing 60% of compound feeds (USDA, 2017) used for both layers and broilers in the study zone. However, there were only one (2.4%) and two (4.8%) 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 Boschloo (2020), 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
GPP reported that more than 511,960 broiler and 7,130,999 layer day-old chicks are imported into
Ghana on annual basis (USDA, 2017).

| Production stages                  | Frequencies | Percentage |
|-----------------------------------|-------------|------------|
| Own maize farm                    | 16          | 38.1       |
| Feed mill                         | 27          | 64.3       |
| Processing house                  | 2           | 4.8        |
| Hatchery                          | 1           | 2.4        |
| Delivery van for marketing        | 23          | 54.8       |
| Retail outlet                     | 18          | 42.9       |
| **Total**                         | **87**      | **207.1**  |

**Source:** Field data (2020)

Figure 2 shows the levels of vertical integration based on the classification by Misund (2016).

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 perfectly with the observations made by Bamiro and Shittu (2009) 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 of the final products (egg and broiler meats). According to Begum
(2005), 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 and Asante (2012) 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 (McPherson, 1992; Robinson & Sexton, 1994; Presser & Baldwin, 1980). The capital demand to set up and maintain poultry farms in sub-Saharan Africa is high, which turns to limit women 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 Amoabeng (2011) in the same study area. Likewise, 78.4% of the poultry farmers are full-time workers, which 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 Bamiro et al (2009) who reported that over 50% of poultry farmers particularly in West African countries such as Nigeria are full-time workers.

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                       | 62.7                | 91.3                      | 75.0                 | 69.6          |
| 0 = female                     | 37.3                | 8.7                       | 25.0                 | 30.4          |
| Education                      |                     |                           |                      |               |
| 1= No formal education         | 10.7                | 8.7                       | 50.0                 | 11.8          |
| 2=Basic/Junior High School     | 42.7                | 17.4                      | 0.0                  | 35.3          |
| 3=Secondary/Senior High School | 34.7                | 56.5                      | 50.0                 | 40.2          |
| 4=Tertiary                     | 12.0                | 17.4                      | 0.0                  | 12.7          |
| Nature of occupation           |                     |                           |                      |               |
| 1 = Full time                  | 73.3                | 95.7                      | 75.0                 | 78.4          |
| 0 = Part-time                  | 26.7                | 4.3                       | 25.0                 | 19.6          |
| Membership of association      |                     |                           |                      |               |
| 1 = Yes                        | 80                  | 100                       | 100                  | 85.3          |
| 0 = No                         | 20                  | 0.0                       | 0.0                  | 14.7          |
| Land acquisition               |                     |                           |                      |               |
| 1 = Family/inheritance         | 68.9                | 30.4                      | 75.0                 | 60.4          |
| 2 = Individual ownership       | 16.2                | 52.2                      | 25.0                 | 24.8          |
| 3 = Lease arrangement          | 14.9                | 17.4                      | 0.0                  | 14.9          |
| Type of farm business ownership|                     |                           |                      |               |
| 1= Sole proprietorship         | 78.7                | 82.6                      | 100.0                | 80.4          |
| 2= Family farm                 | 21.3                | 13.0                      | 0.0                  | 18.6          |
| 3 = Partnership arrangement   | 0.0                 | 4.3                       | 0.0                  | 1.0           |
| Extension/veterinary contact   |                     |                           |                      |               |
| 1= Yes                         | 83.8                | 43.5                      | 50.0                 | 76.2          |
| 0= No                          | 16.2                | 56.5                      | 50.0                 | 23.8          |
| Access to credit               |                     |                           |                      |               |
| 1= Yes                         | 36.0                | 87.0                      | 100                  | 50.0          |
The high FBOs membership of 85.3% presupposes that, through the leadership, the members can have access to reliable information and productive resource to improve poultry production/productivity. This data is consistent with the report by Nimoh et al. (2013) that the majority (82%) of the poultry farmers in Ghana belongs to farmer group organizations. Family/lineage inheritance remains the dominant (60.4%) means of land acquisition in the area. This buttresses the report by Adams and Ohene-Yankyera (2014) 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 arrangement. This finding corroborates with Bamiro and Shittu (2009) who reported that 79.1% of poultry farms in Nigeria are operated through sole proprietorship. On extension/veterinary access, more than three-quarter have access to extension/veterinary services. Such high access has a 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. About half (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

| Access to non-farm income | 0= No | 1= Yes | 0= No | 1= Yes |
|---------------------------|-------|--------|-------|--------|
| 64.0                      | 68.0  | 32.0   | 87.0  |
| 13.0                      | 9.0   | 13.0   | 13.0  |
| 0.0                       | 25.0  | 25.0   | 27.5  |

| Continuous variables                  | Compare means (ANOVA) |
|---------------------------------------|-----------------------|
| Age of poultry farmer                 | 49.25 (11.53) 53.83 (7.02) 50.50 (11.03) 50.33*** |
| Household size                        | 5.19 (2.25) 6.83 (1.64) 6.0 (2.58) 5.9*** |
| 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 non-significance. Numbers in bracket denotes standard deviation. 2020 official exchange rate: US$1 = Gh¢ 5.4
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 that will lure the youth into poultry production. This data contradicts Folitse et al. (2018) who observed a relatively younger (31 and 40 years) poultry farmer population in Greater Accra region of Ghana.

The respondents have higher experience as depicted by the 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 et al. (2009) who reported higher returns and flock size for farmers with vertically integrated poultry farms in Nigeria. Further, the cost incurred is also lower for vertically integrated poultry farms (Gh¢63.08) compared with partially integrated (Gh¢65.32) and no integration farms (Gh¢68.61). The results agree well with the findings of Buzzel (1983) and Bamiro et al. (2009) 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 and zero-inflated negative binomial regressions are summarised in Table 6 and Table 7, respectively. The results of the ZIP model show 16 out of the 20 covariates significantly influence the extent of vertical integration among poultry farms. On the other hand, 14 of the 20 explanatory variables in the ZINB are considered as 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 Yusuf et al. (2018) who reported an overestimated standard error in ZINB in relation to ZIP models. In Table 8, various tests were computed to compare and select the best model that describes that data. First, the Youg tests for both models are significant at 1% significance level, which implies that the data perfectly fits 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 (extent of vertical integration) 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 8). The coefficients of the estimated parameters are reported in odds ratios – exp (coefficient) – similar to the coefficient interpretation of the standard Poisson regression model (See UCLA, 2020).

Table 6 Coefficients of factors in the zero-inflated Poisson regression model

| Variable                     | Coef(β) | SE(β) | Z-test | Coef(β) | SE(β) | Z-test |
|------------------------------|---------|-------|--------|---------|-------|--------|
| **Personal characteristics** |         |       |        |         |       |        |
| Age of farmer                | 0.0051  | 0.0048| 1.06   | -0.0067 | 0.1319| -0.05  |
| Sex                          | 0.2541  | 0.1140| 2.22** | -0.9190 | 3.263 | -0.28  |
| Household size               | -0.0209 | 0.0217| -0.97  | -1.5011 | 0.8167| -1.84* |
| Education level              |         |       |        |         |       |        |
| Completed Basic/Junior High School | 0.4186 | 0.1143| 3.66***| -0.630  | 0.369 | -1.76* |
| Completed Senior High School | 0.2381  | 0.0728| 3.27***| -0.6080 | 0.2781| -2.19**|
| Completed Tertiary Education | 0.3101  | 0.1125| 2.78** | -1.4627 | 3.0746| -0.48  |
| Non-farm income              | 0.0770  | 0.1160| 0.66   | -2.8042 | 4.2678| -0.66  |
| Variable                        | Coef(β) | SE(β) | Z-test | Coef(β) | SE(β) | Z-test |
|--------------------------------|---------|-------|--------|---------|-------|--------|
| **Nature of occupation**       | 0.2793  | 0.1339| 2.09** | -0.6780 | 0.244 | -2.47**|
| **Farm experience**            | 0.0127  | 0.0071| 1.70*  | 0.5394  | 0.2552| 2.11** |
| **Farm characteristics**       |         |       |        |         |       |        |
| Land ownership                 |         |       |        |         |       |        |
| *Individual ownership*         | 0.1190  | 0.0622| 1.91*  | -3.945  | 4.656 | -0.85  |
| *Lease agreement*              | 0.0311  | 0.1377| 0.23   | -1.2073 | 3.1855| -0.38  |
| *Flock size*                   | 0.0076  | 0.0010| 7.21***| 0.0011  | 0.0006| 1.93*  |
| *Production cost*              | -0.0327 | 0.0065| -4.97***| 0.2358  | 0.1087| 2.11** |
| *Revenue per bird*             | 0.0023  | 0.0010| 2.23** | -0.0864 | 0.0515| -1.68* |
| **Type of farm business ownership** |         |       |        |         |       |        |
| *Family farm*                  | -0.3113 | 0.0971| 3.21***| -0.758  | 0.403 | -1.88* |
| *Partnership*                  | -0.485  | 0.2172| 2.23** | -0.1970 | 0.1173| -2.53***|
| Employee size                  | 0.1039  | 0.0254| 4.10***| -3.520  | 2.069 | -1.70* |
| **Institutional characteristics** |         |       |        |         |       |        |
| Access to credit               | 0.4201  | 0.0994| 4.23***| -0.944  | -0.560| 1.68*  |
| Extension service              | 0.2426  | 0.0819| 2.96***| 7.478   | 4.643 | 1.61   |
| Association membership         | 0.2466  | 0.0852| 2.89***| 8.1047  | 4.0373| 2.01** |
| Constant                       | 5.105   | 0.6238| 1.84*  | 44.664  | 24.994| 1.79*  |

**Model diagnostics**

- Number of observations: 100
- Non-zero observations: 44
- LR chi-square (21): 386.21***
- 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

Table 7 Coefficients of factors in the zero-inflated negative Binomial regression model

| Variable                        | Coef(β) | SE(β) | Z-test | Coef(β) | SE(β) | Z-test |
|--------------------------------|---------|-------|--------|---------|-------|--------|
| **Count model**                |         |       |        |         |       |        |
| Age of farmer                  | 0.0034  | 0.0070| 0.49   | 0.0065  | 0.1318| 0.05   |
| Sex                            | 0.1849  | 0.2025| 0.91   | 0.9170  | 3.2600| 0.28   |
| Household size                 | -0.019  | 0.0326| -0.59  | -1.488  | 0.8153| -1.83* |
| Education level                |         |       |        |         |       |        |
| Completed Basic/Junior School  | 0.4059  | 0.1709| 2.38** | -0.628  | 0.3570| -1.75* |
| Completed Senior High School   | 0.222   | 0.1214| 1.83*  | -0.5970 | 0.2771| -2.15**|
| Completed Tertiary School      | 0.3184  | 0.1778| 1.79*  | -1.3891 | 3.0535| -0.45  |
| Non-farm income                | 0.1025  | 0.1668| 0.61   | 2.6840  | 4.1567| 0.64   |
| Primary Occupation             | 0.2657  | 0.1857| 3.10***| -0.5375 | 0.2462| -2.18**|
| Farm experience                | 0.0306  | 0.011  | 2.70***| 0.5394  | 0.2552| 2.11** |
| **Logit for inflation model**  |         |       |        |         |       |        |
| Personal characteristics       |         |       |        |         |       |        |
| Age of farmer                  | 0.0034  | 0.0070| 0.49   | 0.0065  | 0.1318| 0.05   |
| Sex                            | 0.1849  | 0.2025| 0.91   | 0.9170  | 3.2600| 0.28   |
| Household size                 | -0.019  | 0.0326| -0.59  | -1.488  | 0.8153| -1.83* |
| Education level                |         |       |        |         |       |        |
| Completed Basic/Junior School  | 0.4059  | 0.1709| 2.38** | -0.628  | 0.3570| -1.75* |
| Completed Senior High School   | 0.222   | 0.1214| 1.83*  | -0.5970 | 0.2771| -2.15**|
| Completed Tertiary School      | 0.3184  | 0.1778| 1.79*  | -1.3891 | 3.0535| -0.45  |
| Non-farm income                | 0.1025  | 0.1668| 0.61   | 2.6840  | 4.1567| 0.64   |
| Primary Occupation             | 0.2657  | 0.1857| 3.10***| -0.5375 | 0.2462| -2.18**|
| Farm experience                | 0.0306  | 0.011  | 2.70***| 0.5394  | 0.2552| 2.11** |
| Farm characteristics           |         |       |        |         |       |        |
| Land ownership                 |         |       |        |         |       |        |
| Individual ownership           | 0.255   | 0.1235| 2.06** | -2.895  | 3.7870| -0.76  |
| Lease agreement                | -0.0364 | 0.196 | -0.19 | -1.154  | 3.1640| -0.36  |
| Flock size                     | 0.0074  | 0.0015| 4.93***| 0.0011  | 0.0006| 1.93*  |
**Table 8 model comparisons and selections**

| Test          | ZIP       | ZINB   |
|---------------|-----------|--------|
| AIC           | 456.692   | 443.58 |
| BIC           | 519.216   | 506.11 |
| Vuong test    | 5.26***   | 3.09***|
| Mean (variance) of response variable | 0.95 (1.82) |

### 4.4 Count data component of the ZINB model

#### 4.4.1 Personal characteristics

The educational background of the poultry farmer was positively and significantly related to the extent of vertical integration of poultry production. For instance, the extent of vertical integration for a farmer with Basic/Junior High School certificate is likely to increase \( \exp(0.4059) = 1.5 \) times compared with a farmer without formal education, all things being equal. Similarly, there was a higher odds ratio for farmers with Senior High School (1.24 times) and Tertiary education (1.37 times) to vertically integrate their poultry farms compared with non-educated counterparts, all things being equal. The results agree with Bamiro et al. (2009) who found out that the educational...
background of poultry farmers is important for vertical integration of poultry farms in Nigeria. In a related study for Rwanda, Issa and Chrysostome (2015) (2014) also concluded that education is a predetermined factor to integrate agro-businesses in developing economies. Similarly, the primary occupation of the poultry farmer positively influences the extent of vertical integration of poultry farms at a 1% significance level. The results imply that full-time poultry farmers are more likely to vertically integrate their poultry farms exp (0.2657) = 1.30 times compared with part-time poultry farmers, all things being equal. Likewise, poultry farmers with higher farming experience are exp (0.0306) = 1.031 times more likely to participate in the vertical integration of poultry farms. The latter finding is in line with Elzo et al. (2010) who argued that experienced farmers tend to accumulate managerial skills over the years to better manage the complexities associated with different production stages under the same management units of a business as in the case of vertical integration. The finding relates well with Bamiro et al. (2009) who reported a significant positive relationship between poultry farmer’s experience and the degree of vertical integration.

4.4.2 Farm characteristics

The type of land ownership tends to significantly influence the extent of vertical integration of poultry farms in the study area. For instance, the extent of vertical integration is expected to increase exp (0.255) = 1.29 times for farmers with full property rights of farmland than farmers with family/inherited farmlands. This finding supports the assertions made by Awudulai et al. (2008) who observed that owner-operated with full rights of farmland is more likely to increase investments in other activities of farm to reduce the overall cost of farm production, thereby increasing profitability in Ghana. Likewise, increases in flock size and revenue would increase the degree of vertical integration by factors of exp (0.0074) = 1.007, and exp (0.0028) = 1.003, respectively, all things being equal. The result on flock size is similar to the findings of Issa and
Chrysostome (2015) who documented a significant positive relationship between farm size and the capacity to vertically integrate agribusinesses in Rwanda. Likewise, Elzo (2010) 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, the data shows that increases in overall production costs are expected to decrease the extent of vertical integration by a factor of \( \exp(-0.0290) = 0.97 \), all things being equal. This finding according to Kusi et al. (2015) 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 et al., 2018). The data shows that the extent of vertical integration for farmers with access to credit facilities is expected to increase by \( \exp(0.354) = 1.42 \) times compared to farmers without credit access, all things being equal. This finding corroborates with de-Janvry et al. (2005) 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 depict that the extent of vertical integration for farmers with extension contact and membership of poultry association is expected to increase by \( \exp(0.2612) = 1.26 \) times and \( \exp(0.2980) = 1.37 \) times, respectively, all things being equal. These findings did not deviate from the observations made by Marinda et al. (2006) 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 competitive advantage and expand on-farm investments. Thus, farmers with improved extension service contact and membership of 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 occurrence of the excess zeros of the model (Table 7). The data shows that farmer personal factors such as education, primary occupation, and household size decreases 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, 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.

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 influence transaction costs, risks, and uncertainties as well as demand variations, which ultimately improves 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 serious 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 vertical integration index to accurately and sufficiently capture the extent of vertical integration in the industry. The study evidences that institutional factors such as membership of 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 farmer’s 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. 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.

6.0 DECLARATIONS

Availability of data and material
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interest
The authors declare that they have no competing interest

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All authors sanctioned the manuscript publication

Authors’ Contribution
FA wrote the proposal, collected the data, did the analysis, and wrote the paper. AM also participated in the data collection and performed the analysis. SE, RA and JOM edited and reviewed the manuscript. All the authors read and approved the manuscript for publication.
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Figures

Figure 1
Production and Importation of Poultry in Ghana, 2000-2016 Data source: FAOSTAT Database, Various Years

Figure 2
Map of Dormaa Municipality (Ghana Statistical Service, [GSS] 2010)
Figure 3

Levels of vertical integration among poultry farms