EVALUATION OF PRODUCTION EFFICIENCY OF POULTRY EGG FARMS IN KADUNA STATE, NIGERIA: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

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ABSTRACT:

This study estimates the technical, allocative and economic efficiency obtained from the Data Envelopment Analysis (DEA) approach using data from a sample of 225 poultry egg farmers in Kaduna State, Nigeria. The results from the DEA approach show that there is substantial technical, allocative and economic inefficiency in poultry egg production in the State. The results of the study reveal that under constant return to scale (CRS) and variable returns to scale (VRS) specifications, the mean technical, allocative and economic efficiencies were 79, 61, 49 and 84, 78, 65 percent respectively. The result indicated that efficiency scores vary substantially across the sampled egg farms and it could be increased by 21, 39, 49 and 16, 22, 35 percent respectively to attain the production efficiency of the best practicing egg farmer in the study area. This research finding is valuable for policy makers since it would help to guide policies towards increased egg production efficiency thereby resulting in reduction in high production cost and hence improve farm revenue. The Formation of cooperative feed mills will enable farmers formulate feeds on-farm to cut down feed cost which forms about 70 percent of the total cost of poultry egg production in the state.

KEYWORDS: Economic efficiency, DEA, poultry farms

INTRODUCTION

The term poultry refers to local and exotic fowls which are raised and fattened for their products. This include eggs, meat and in some cases feathers. Birds that are raised as poultry include fowls, turkey, ducks and geese, among others. Poultry production consists of two parts: poultry egg production and poultry meat production. In the case of meat type poultry, they are fast growing with very efficient feed to meat conversion ratio. Feed utilisation by poultry has dual purpose of body maintenance and growth. The birds feed on properly formulated diet to aid meat or egg production. The industry under egg and meat production has continued to be major livestock industry in Nigeria. Substantial number of small, medium, and large scale poultry farms is located in this industry.

Poultry in Nigeria can be broadly divided into two systems: traditional rural backyard and commercial farming system. Commercial poultry farming system started in the early 1960s,
Federal government’s poultry development policy enhanced commercial poultry production which resulted in a spectacular increase in the number of poultry farms. For ease of analysis of the development of poultry egg production in Nigeria, the periods are divided into three. These are 1978 - 1985, which is regarded as the pre-structural adjustment programme (SAP) era; 1986-1993, SAP era and 1994-2001 era of guided deregulation. Between 2001 and 2015 programmes and policies were formulated by the government such as ban on the importation of poultry and poultry products into the country to encourage local production. These periods saw an increased poultry egg production.

Nigeria became a large Poultry egg producer recording an average annual growth rate of 4% between 2000 and 2012 when output of egg reached 640,000 tonnes. However, the rate of expansion has slowed to around 2.5% since 2008, reflecting a large increase in input costs and their impact on profitability. Food and Agriculture Organisation (FAO), (2012).

The Nigerian poultry sub-sector has a great potential for wide range of reasons. Poultry farming has considerable potentiality for providing income opportunities, reducing malnutrition, generating employment opportunity and alleviating poverty especially for small farmers in Nigeria. Small farmers can start poultry farm at their homestead area at low cost compared to other livestock farming. In addition, poultry farming also provides opportunities for other industries like feed mills, hatcheries etc.

The productivity growth in poultry sector needs to be fostered through either technological development or an increase in production efficiency in order to stand the demand pressure and self sufficiency of egg and meat production. To this end, measuring farms efficiency is important as this could be the first logical step in a process that leads to substantial resources utilization. A lot of research on poultry production in Nigeria had concentrated on the government role, profitability, future projections, processing and marketing (Adepoju, 1999; Adepoju and Alamu, 1999; Ogundipe and Sanni, 2002; Hassan, 2002; Hassan, 2005 and Hassan, 2009). Studies have also been carried out on efficiency in crop and livestock farms and other livestock production such as poultry egg farms (Hassan, 2014; Binuomote et al., 2008; Yusuf & Malomo, 2007; Ojo, 2003), dairy farms (Bravo-Ureta & Rieger, 1993), and fish farms (Inoni, 2007).

The study aims at finding out better use of existing production resources in poultry egg production process and to support the policy maker and the government to further take some suitable steps or strategies for removing the farmer’s inefficiency in poultry egg production. Thus, the objective of this research was to investigate the poultry farm’s technical, allocative and economic efficiency.

**MATERIALS AND METHODS**

**Model Specification**

Efficiency is the most widely used concept in economics. Efficiency expressed as a combination of technical and allocative efficiencies. Technical efficiency is the ability of the farmer to produce maximum output from a given level of inputs while allocative efficiency measures the ability of the farmer to use inputs in optimal proportions, given input prices. Two efficiency measurement methods are widely used in efficiency studies, one is the parametric Stochastic Frontier Analysis (SFA) and the other method is non-parametric method Data Envelopment Analysis (DEA). The Comprehensive reviews of the two approaches are provided by Lovell
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(1993), Ali and Seiford (1993), Coelli (1995), Bauer (1990), Fried et al. (1993), Bravo-Ureta and Pinheiro (1993). In general, a large number of studies on efficiency measurements argue that a researcher can safely choose any of the methods since there are no significant differences between the estimated results (Coelli, Sandura & Colin, 2002).

The framework for the non-parametric method (Data Envelopment Analysis (DEA) approach) was initiated by Farrell (1957) and reformulated as a Mathematical Programming problem by Charnes, Cooper & Rhodes (1978). DEA is a systems approach widely used in management science and economics, in which the relationships between all inputs and outputs are taken into account simultaneously (Yusuf and Malomo, 2007). Given a number of production units, which are Decision Making Units (DMUs), an efficiency frontier is constructed from the sample of producing units. DMUs that are not on the frontier are said to be inefficient. DEA enables the researcher to find out the relative efficiency of a farm and to examine its position in relation to the optimal situation. The strength of DEA is that it does not require any assumptions about the functional form. The major weakness of DEA is that it is deterministic.

In this paper, we used the DEA method to investigate the technical, allocative and economic efficiency of the sample poultry egg farmers. There are a number of multiple-input single-output production units (the poultry egg farms) to be evaluated, which are taken as DMUs. Each DMU consumes varying amounts of inputs to produce different level of egg output. In this study input-oriented measures were chosen to reflect local reality, where a decrease in scarce resources (input) use is relevant.

Let us suppose that there are \( k = 1, \ldots, K \) DMUs, which in the context of our empirical application are poultry farmers. Each DMU produces \( m = 1, \ldots, M \) outputs using inputs that are both under and beyond a farmer control. Let us further assume that there are data available on \( K \) inputs and \( M \) outputs for each of \( N \) exploitations. The \( K \times N \) input matrix \( X \) and the \( M \times N \) output matrix \( Y \) represent the data for all the firms. An intuitive way to introduce the DEA is via the ratio form. For each farm we would like to obtain a measure of the ratio of all outputs over all inputs. According to Charnes et al. (1978), the optimal weights are obtained by solving following mathematical programming problem (1):

\[
\begin{align*}
\text{Max}_{u,v} \left( u'y_j/v'x_i \right) \\
\text{Subject to } u'y_j/v'x_i \leq 1 \\
j = 1, 2 \ldots , N \\
u, v \geq 0 \\
\end{align*}
\]

Where, \( u \) is an \( M \times 1 \) vector of output weights and \( v \) is a \( K \times 1 \) vector of input weights. The efficiency measure for the \( i \)-th DMU is maximized, subject to the constraints that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, Charnes et al. (1978) proposed the use of a CRS (constant return to scale) equivalent Duality Linear Program which is defined as the following:

\[
\begin{align*}
\text{Min } \theta \lambda \theta \\
\text{Subject to } -y_i + Y\lambda \geq 0 \quad \theta x_i - X\lambda \geq 0 \\
\lambda \geq 0 \\
\end{align*}
\]
Where $\theta$ is a scalar and $\lambda$ is a vector of constants, $x_i$ and $y_i$, are column vectors with the input and output data for the i-th farm. $X$ is a K by N matrix and $Y$ is an M by N matrix with respectively all input and output data for all N farms in the sample. The value $\theta$ is a score always lying between zero and one, with a value of one indicating that the farm lies on the frontier and is efficient. An implicit assumption of the model described above is that returns to scale are constant and thus farms are operating at an optimal scale (Fraser and Cordina, 1999). A BCC (Banker Charnes and Cooper, 1984) DEA model computes however for a Variable Returns to Scale (VRS) by adding the convexity constraint: $N1' \lambda = 1$, to the CCR model (2) above. Without this convexity constraint, the DEA model will describe a CRS situation.

However, based on the technical and allocative efficiency the economic efficiency can be determined as $EE=AE*TE$ (also called cost efficiency). Allocative efficiency itself is calculated in two steps. First a cost-minimizing vector of input quantities given the input prices is determined using the model from program 3:

Min$xi*,\lambda$  $w'xi*$
Subject to  $-y_i + Y\lambda \geq 0$
$x_i* - X\lambda \geq 0$  $N1'\lambda = 1$
$\lambda \geq 0$………………………………………………(3)

where, $w_i$ is a vector of input prices for the i-th farm and $x_i*$ (which is calculated by using linear programming) is the cost-minimizing vector of input quantities for the i-th farm, given the input prices $w_i$ and the output levels $y_i$. The other symbols are defined the same as in eq 1. The economic efficiency (EE) of the i-th farm is calculated as the ratio of the minimum cost to the observed cost (eq. 4)

$EE= w'i x_i*/ w'i x_i ............. (4)$

Data Collection and Field Survey

The analysis was based on the primary data collected through a comprehensive field survey. A pre-survey of the 23 Local Government Areas (LGAs) of Kaduna state was undertaken to determine the number of commercial poultry egg enterprises in the state. It was observed that most of commercial poultry egg enterprises were located in the LGA headquarters. The number of commercial poultry egg enterprises identified in the LGAs was 322(sample frame) poultry egg enterprises were identified in the state during the pre-study survey. Poultry egg farms with a minimum of 200 layers were purposively selected and were administered with the research questionnaire. About 70% of the poultry egg farms with a minimum of 200 layers were randomly selected from the study area, giving a sample size of 225.The period of investigation of this study covered one year beginning from January 2013 to December 2013. The data were organised by Excel and finally it was analysed by a DEA-Solver (LIMDEP).

The state was selected as study area for poultry egg production because it is the third most populous state in the Nigeria (NPC, 2006). The population is spread across the 23 LGAs. Within the state there are a number of establishments ranging from companies, research institutes, higher institutions and colleges. The choice of Kaduna state as the study area for this research is influenced by certain considerations such as:
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i. Kaduna state is centrally located in the North and is representative of the general climatic conditions of vegetation and socio-economic activities; and

ii. Poultry farmers in the state have the advantage of proximity to research institutions like National Animal Production and Research Institute (NAPRI), National Agricultural Extension Research and Liaison Services (NAERLS), Institute for Agricultural Research (IAR).

iii. The advantage of the above to the poultry egg producers in the state is that they have access to research output in time before other farmers who are not close by.

RESULTS AND DISCUSSION

Efficiency Measurement in Poultry Egg Production in the Study Area
The main costs of poultry farms in Nigeria are variable costs, which consisted of day old chick, feed, labor, vaccine and medicine, transportation, litter, equipment, housing, land use cost, etc. For the measurement of economic efficiency the inputs used were: (i) human labour (man-days) and wage rate; (ii) Day Old Chicks (numbers and price), and (iii) Feed (bags) and price of per bag of feed, etc. We used these three variables because under all variable costs, these variables are major and cover 75 to 80 percent of the total cost (Hassan, 2014; Hassan, 2005; Begum et al, 2005; Ukil and Poul, 1992; Bhuiyan, 2003; and Uddin, 1999). Besides, other variable data was only found in value term, but for efficiency analysis we used physical term. Output data were also recorded by the cumulative quantity of egg produced per bird per production cycle. The frequency distribution of the efficiency estimates obtained from the DEA frontier and their summary statistics are presented in Table 1. Given the large variability in the computed measures, efficiency scores are clustered into six groups such as 0.00–0.50, 0.51–0.60, 0.61–0.70, 0.71–0.80, 0.81–0.90, and 0.91–1.00.

Table 1: Frequency distribution and summary statistics on technical efficiency, allocative efficiency, economic efficiency and scale efficiency measures under CRS DEA and VRS DEA Models in Kaduna state, Nigeria.

<table>
<thead>
<tr>
<th>Efficiency (%)</th>
<th>CRS</th>
<th>VRS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TE</td>
<td>AE</td>
</tr>
<tr>
<td>1 – 50</td>
<td>18(8.0)</td>
<td>67(29.8)</td>
</tr>
<tr>
<td>51 – 60</td>
<td>13(5.8)</td>
<td>26(11.6)</td>
</tr>
<tr>
<td>61 – 70</td>
<td>25(11.1)</td>
<td>58(25.8)</td>
</tr>
<tr>
<td>71 – 80</td>
<td>50(22.2)</td>
<td>41(18.2)</td>
</tr>
<tr>
<td>81 – 90</td>
<td>60(26.7)</td>
<td>29(12.9)</td>
</tr>
<tr>
<td>91 – 100</td>
<td>59(26.2)</td>
<td>4(1.8)</td>
</tr>
<tr>
<td>Total</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Mean</td>
<td>0.79</td>
<td>0.61</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.36</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Values in parentheses are percentages
The estimated mean values of technical, allocative and economic efficiency were 79, 61, and 49 per cent for CRS DEA frontier and were 84, 78, and 65 per cent for VRS DEA frontier (Table 1). Thus the results of DEA analysis reveal substantial inefficiencies in poultry egg production in the study area. There is a scope for reducing cost of production and hence obtaining egg output gain through efficiency improvement. The low AE and EE scores indicate that if the farmers operate at the optimal efficiency level, they can reduce, on average, the production cost by 35 percent while producing the same level of poultry egg output under VRS assumption.

The estimated mean TE measure for the poultry egg production farms under CRS and VRS approaches were 79 and 84 percent respectively. This result implies that the egg output of the farms potentially could be increased by 21 percent if the operation was technically efficient if CRS is assumed or by 16 percent if VRS is assumed. This result agrees with the findings of Amir (2013) in his study on efficiency of broiler production in Iran where he obtained similar results.

The distribution of efficiency scores for the CRS DEA model (Table 1) shows that about 24, 67 and 84 percent representing 56, 151 and 174 poultry egg producers were operating at less than 70 percent TE, AE and EE, respectively. About 49, 31 and 14 percent representing 110, 70 and 32 poultry egg producers were operating between 71 to 90 percent TE, AE and EE, respectively. Only 4, 2 and 2 percent representing 8, 4 and 4 poultry egg producers were found to be operating at 100 percent TE, AE and EE, respectively. This result revealed that there exists a great inefficiency in the operation of the poultry egg farms in the study area under CRS DEA assumption.

Also the distribution of efficiency scores for the VRS DEA model revealed that 17, 25 and 58 percent representing 38, 130 and 130 poultry egg producers were operating at less than 70 percent TE, AE and EE, respectively. About 46, 60 and 39 percent representing 104, 134 and 88 poultry egg producers were operating between 71 to 90 percent TE, AE and EE, respectively. Only 7, 3 and 3 percent representing 15, 4 and 4 poultry egg producers were found to be operating at 100 percent TE, AE and EE, respectively. It was found out that these producers have a low feed usage which could be as a result of good quality of the feed and also that they produced their feeds on-farm which is responsible for the low feed cost. The efficient farms exhibit good technical knowledge on best management practices of poultry egg production. This also implies that the poultry egg producers in the study area were operating at an inefficient level under VRS assumption.

Heidari, et al. (2011) studied technical, pure technical and scale efficiencies of broiler farms in Yazd province, Iran. The average values for 44 farmers involved in their study were found to be 0.92, 0.99 and 0.93, respectively. Their results showed that based on CCR results only 9 farmers were relatively efficient. But from the results of BCC model 14 farmers were efficient. The average values of PTE, TE and SE for all 44 farmers were found to be 0.9189, 0.9856 and 0.9324, respectively. The result of Heidari et al. (2011) conforms to the findings from this study.

In terms of the returns to scale, table 2 revealed that 172 poultry egg farms representing 76 percent of the poultry egg farms in the study area exhibited Increasing Returns to Scale (IRS) and this implies that they have huge potential to increase their farm efficiency through expanding their scale of production as they are currently operating at a suboptimal scale. Therefore, proportional increase in inputs for poultry egg production will lead to a more than proportional increase in output of the poultry egg farms. 35 poultry egg farms representing 16 percent of the poultry egg farms exhibited Decreasing Returns to Scale (DRS) which implies that they were
operating above the optimal scale of production and hence, proportional increase in inputs for poultry egg production will lead to a less than proportional increase in output of the poultry egg farms. Therefore, reducing the scale of production will be the best option for the farms to enhance their efficiency. This is in conformity with Asghar et al. (2013) who noted that DMUs operating in decreasing returns to scale status can improve their overall efficiency by decreasing their production size. Eighteen (18) poultry egg farms representing 8 percent of the poultry egg farms exhibited Constant Returns to Scale (CRS) which implies that they were operating at an optimal scale of production and hence, proportional increase in inputs for poultry egg production would lead to a proportional increase in output level of the poultry egg farms.

Table 2: Distribution of commercial poultry egg producers according to Return to scale in Kaduna state, Nigeria.

<table>
<thead>
<tr>
<th>Zone</th>
<th>IRS Frequency</th>
<th>IRS %</th>
<th>DRS Frequency</th>
<th>DRS %</th>
<th>CRS Frequency</th>
<th>CRS %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samarun Kataf</td>
<td>59</td>
<td>26.2</td>
<td>13</td>
<td>5.8</td>
<td>7</td>
<td>3.1</td>
</tr>
<tr>
<td>Maigana</td>
<td>39</td>
<td>17.3</td>
<td>9</td>
<td>4.0</td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td>Birnin Gwari</td>
<td>31</td>
<td>13.8</td>
<td>7</td>
<td>3.1</td>
<td>5</td>
<td>2.2</td>
</tr>
<tr>
<td>Lere</td>
<td>43</td>
<td>19.1</td>
<td>6</td>
<td>2.7</td>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>Pooled</td>
<td>172</td>
<td>76.4</td>
<td>35</td>
<td>15.6</td>
<td>18</td>
<td>8.0</td>
</tr>
</tbody>
</table>

The egg producers that exhibited DRS in the study area operated above the optimal scale of production. They operated in stage III of production. A proportionate increase in inputs use for poultry egg production would lead to a less than proportionate increase in output of the egg producers. Therefore, cutting the scale of production will be the best option for the egg producers to be able to enhance their efficiency.

For the farms that exhibited Constant Return to Scale (CRS), only a small proportion 18 (8 percent) of the egg producers across the state were operating at an optimal scale of production. A proportionate increase in inputs use for poultry egg production would lead to a proportionate increase in output level of the poultry egg producers. These groups of egg producers operated in stage II of production.

**CONCLUSION**

In this study, technical, allocative and economic efficiency of poultry egg farms in Kaduna state were estimated by using the Data Envelopment Analysis (DEA) approach and the variation in Assessment of efficiency implies considerable amount of technical, allocative and economic inefficiency among the sample farms. The sampled farmers, on average, could increase their
poultry production if they could operate at full technical, allocative and economic efficiency levels, given the existing technology. The study provides information to policy makers and extension services on how to better aim efforts to improve poultry farm efficiency. This could contribute to compensation of high production cost, hence improve farm revenue, welfare and generally help agricultural as well as economic development.

**RECOMMENDATIONS**

1. The technical efficiency of the egg producers in the four agricultural zones need to be improved through efficient use of production inputs. Extension agents and other development agencies in the livestock sector should train the farmers on how to use their production resources efficiently. This could be done by adopting the production practices of the best farms in each of their zones.

2. Despite the relatively high production efficiency of the poultry egg farmers, there is still opportunity for enhancing their present level of efficiency which would require efficient resource utilization by the poultry egg farmers. This could be achieved by improving their technical knowledge on best management practices of poultry production through effective extension and training of the poultry egg producers on the best management practices. Hence, extension service delivery to poultry egg farmers needs to be strengthened as inadequate extension service has been identified as one of the constraints encountered in commercial poultry egg production in the study area.

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