Efficiency analysis of goat producers in Ghana: An instrumental variable approach

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Abstract

Agriculture and economic growth nexus is a phenomenon that needs critical attention. In Ghana, about 70% of the population derives their livelihood from crop and livestock production. Therefore, exploring the factors that influence livestock production efficiency is important. This study investigates the technical efficiency (TE) of goat farmers in Ghana using survey data collected from the Upper West region. An instrumental variable (IV) and data envelope analysis (DEA) are employed to analysis the goat farmers' TE. The study results revealed that the majority of the goat farmers are producing below the frontier with average technical efficiency of 0.724, 0.313 and 0.431 for variable returns to scale (VRS), constant returns to scale (CRS) and scale efficiency SE respectively. The role of variables such as access to credit, access to extension officers, years of farming experience, being an association member and off-farm income are significant in achieving higher TE. Also, insufficient capital, inadequate credit facilities and extension officers are the three major problems confronting farmers in the study areas. Our findings provide policy implications to curtail credit constraints and enhance the artisanal fishermen TE.

Keywords: Technical efficiency. DEA. Goat Production. Ghana

1. Introduction

Agriculture and economic growth nexus is a phenomenon that needs critical attention. In Ghana, about 70% of the population derives their livelihood from crop and livestock production (Antwi-Agyei *et al.*, 2012; Ghana Statistical Service, 2018)**.** Agriculture's role in Ghana's economic growth cannot be concealed. For instance, the agriculture sector contribution to the nation's growth since 2006, has been between 22 and 32 percent with an annual growth rate ranging between −1.7 and 7.4 (Ghana Statistical Service, 2018). This tremendous impact is as a result of the increased productivity of crops, forestry and logging, livestock, and fishing. This study focuses on livestock production. The reason for analyzing livestock production is not only because of its contribution to the economy but also because of its role play on improving food security, i.e., providing the people of Ghana the sufficient protein need in their diet. The livestock sub-sector also provides employment to its core player (farmers), hence, enhancing farmers' welfare through income generation.

In Ghana, because of the vast grazing land and the availability of forage resources makes the northern part of the nation, which includes the Upper West region (the focus region), suitable for livestock production. In spite of the comparative advantages that exist in the northern part of the nation and the growing significance of livestock production to rural households and the economy as a whole, the livestock industry faces several challenges. Lack of improved breeding stock, diseases and inadequate feed and fodder have been identified as problems impeding livestock farmers (Adzitey, 2013). According to the Ministry of Food and Agriculture (MoFA, 2014), inadequate credit facilities, appropriate grassland policy, research and effective extension programs also detrimentally affect livestock production. The Ministry of Food and Agriculture (2014) reported that the reduction in the stock of sheep and goats in the nation is as a result of these challenges. The high transaction cost also makes it tedious for the goat/sheep farmers to actively participate in the market (Homann et al., 2007; Udo et al., 2011). Again, concerning the inadequate stock of goats and sheep production products, the uncontrollable risk associated with their production such as drastic changes in the weather may not be the only cause but also the farmers' and farm characteristics to improve technical efficiency (TE) (Asante, Villano e Battese, 2017; Lebbie, 2004). Therefore, examining the determinants of goat farmers' technical efficiency is essential.

Although technical efficiency of dairy or livestock has been examined widely by a couple of researchers (Asante, Villano e Battese, 2017; Devendra, 2001; Gul *et al.*, 2018; Gül *et al.*, 2016; Silva, Almeida e Marta-Costa, 2018), few are known in Ghana. The analysis of crop farmers' technical efficiency has also been the focus for majority of the studies in Ghana. Therefore, this study is to fill this gap using data collected from goat farmers in the Upper West regions of Ghana. The objective of the study is twofold. First, this study tries to determine the factors influencing goat farmers' production efficiency, second, to identify the challenges faced by the farmers. Studying the determinants of efficiency will assist policymakers in identifying major challenges faced by the goat producers and also help in the designing of policies to enhance efficiency for improving income as well as food security for the nation and the world at large. The contributions of this study are twofold. First, this is the first study to estimates the technical efficiency of goat producers in Ghana. Second, this study also dealt with the problem of endogeneity associated with efficiency analysis, which many studies have ignored.

The rest of the paper is organized as follows. Section 2 discusses the literature review. Section 3 deals with the methodology which includes the data collection process and the empirical econometric models proposed in this work. Section 4 discusses the results, and the final section presents the main conclusions drawn from the results and policy implications.

2. Literature review

This study aims to identify the factors that affect the technical efficiency of goat producers in Ghana. In terms of efficiency among livestock producers, many works have been carried out in many countries including Ghana, among them include; (Gul *et al.*, 2018; Gül *et al.*, 2016) in Turkey, (Alex, Kunniyoor Cheemani e Thomas, 2013) in India, (Silva, Almeida e Marta-Costa, 2018) in Portugal, (Asante, Villano e Battese, 2017) in Ghana. All these studies showed that householder/household characteristics influence technical efficiency (e.g., age, gender, education, household size, and many others), farm characteristics (e.g., farm size and herd size) and other social and institutional characteristics (e.g., cooperative member, farming experience, market information, income, off-farm income, access to credit, access to extension officers etc.). Using data envelope analysis (DEA), the study of (Gül *et al.*, 2016), technical efficiency of goat farmers in Turkey, revealed that majority of the goat farmers were inefficient in the production. The mean production efficiency score recorded 0.44 and 0.66 for constant and variable returns to scale assumptions, respectively. In India, (Alex, Kunniyoor Cheemani e Thomas, 2013) examined the returns and determinants of technical efficiency in small-scale Malabari goat production units in Kerala. From the data obtained from 100 goat farmers in northern Kerala, the study found out that Individual farm technical efficiency ranged from 0.34 to 0.97 with a mean of 0.88. The location and the herd size of the farm were identified as the main determinants of technical efficiency among the goat farmers. Again, to estimate the technical efficiency of dairy farmers (milk production) in Portugal and with an emphasis on full and part time farmer, (Silva, Almeida e Marta-Costa, 2018) reported that both farmer technical efficiency were low. Thus, 0.679 for part time farmers and 0.689 full time farmers. In Ghana, (Asante, Villano e Battese, 2017) used a survey data collected from 510 farmers from three districts (Atebubu-Amantin (A-A), Nkoranza South (N-S) and Ejura-Sekyedumase (E-S)) of the forest savannah transition agro-ecological zone to examine the effect of integrated crop livestock management practices (ICLMPs) on the productivity and technical efficiency of production of small-ruminant outputs of farmers. The study argued that technical efficiency of the crop-livestock farmers in the three districts was determined age, gender and education, by their participation in projects, obtaining off-farm income, market information and access to extension advice. The results indicate that across the three district, small-ruminant production technologies were significant different. The average TEs were 0.856, 0.799 and 0.810 for district A-A, N-S and ES, respectively.

3. Methodology

3.1. Study area and Data Collection Procedure

The data include primary measurements collected through a household survey which was conducted between August 2019 and September 2019 in a district (Lawra) in the Upper West region of Ghana. The Upper West region is located in the northern part of the nation. Lawra district which is dominated by farmers (83.5%), has a total land size of 527.37 square kilometres. Due to the mono-modal rainfall pattern in the region, farmers are engaged in one season of farming (Ghana Statistical Service., 2014). The 2010 National Population and

Housing Census (PHC) estimated 54,889 people in the district, out of which 26,347 are male (48.0%) and 28,542 are female (52.0%). About 88.2% of the district's population lives in rural localities. The northwestern corner of the region is found the district capital (Lawra) between longitudes 2°50 - 2°53 west and latitudes 10°35'' – 10°40'' north. Lawra district is characterized by grassland with medium-sized trees. This vegetation of the district is suitable for livestock production (cattle, sheep, goats, pigs and poultry), which contributes significantly to household incomes in the districts (Ghana Statistical Service., 2014).

A structured questionnaire was used to elicit relevant goat farmers' information to identify key household-level and other significant factors that influence access to credit (being it from formal sources (e.g., banks and microfinance organizations) or informal sources (e.g., money lenders, friends and family relatives) and technical efficiency. Enumerators who speak the local language assisted us in offering a face-to-face interview due to the complex nature of the questions. Also, the questionnaires gathered both qualitative and quantitative information. The quantitative research utilizes certain measurement techniques while qualitative research employs observation techniques (Bryman, A. & Bell, 2015).

A two-stage sampling technique was employed to solicit for representative farmers for the study. In the first stage, three (3) communities were randomly selected from the district. They include; Mettoh, Kasalgri, and Tabier. The final stage also involved simple random sampling in locating respondents (goat farmers). In all, a total of 130 respondents were selected based on the size of the three communities. However, out of the 130 questionnaires administered, 124 of those returned were found analyzable and thus utilized for the study.

3.2. Empirical model specification

The aim of the study is to analyze the technical efficiency of goat farmers in Ghana. The study utilizes a two-stage analysis. In the first stage, data envelopment analysis (DEA) was used to measure the technical efficiencies of smallholder goat farmers as an explicit function of unrestricted variables. At this stage the dependent variable is the value of output measured by revenue generated from the goat production (e.g., meats, fibers etc.) in Ghana cedis (GH¢). Besides, the inputs for production are the cost of veterinary, pen construction, labor, farm size, herd size (see Table 1). In contrast to one of the most popular models, i.e., Stochastic Frontier Analysis (SFA), DEA allows the analysis of the introduction of multiple inputs and outputs. Furthermore, if a two-stage DEA is used, it does not only enable the identification levels of inefficiency for each farm unit but also refutes the assumption of the distribution of the inefficiency term, which is seen in SFA. In the second stage, we explore the relationship between technical efficiency and other relevant social, economic and environmental variables, such as farmer's age, the background of farmers in agriculture, credit facilities and many others by using the Tobit model.

The two basic models in DEA are constant returns to scale (CRS) and variable returns to scale (VRS). Under the assumptions of CRS (where results of analyses are always the same) and VRS (where analyzed results vary because of the variations in inputs), we calculated the goat farmers' efficiency scores, as well as the scale efficiency (SE) score in this study. This enables us to differentiate the efficiency scores of CRS and VRS since their calculated efficiency scores will always be different. Again, in DEA, the assumption that a producer's decision making unit (DMU) can produce output (Y) with (X) inputs should hold for the producer with similar DMU. Thus, the new DMU should be able to provide an equal amount of output (Y) with the same inputs (X). There is efficiency should this happens. The goat farmers in Ghana aimed at maximizing output in production using variable inputs. Thus, using the Tobit model, socio-economic and institutional factors influencing the efficiency of goat farmers were regressed based on an output-oriented DEA VRS assumption in the final stage of the analysis, as specified below (Coelli *et al.*, 2005).

$$
\begin{aligned}
& min_{\theta,\lambda}\theta \\
& subject\ to \\
& -y_i + Y\lambda \geq 0 \\
& \theta x_i - X\lambda \geq 0 \\
& N1'\lambda = 1 \\
& \lambda \geq 0
\end{aligned}
\qquad (1)
$$

where the scalar representing efficiency score of ith decision-making unit is θ. λ refers to a $(N \times 1)$vector of a constant. Here, the condition $\lambda \leq 1$ is satisfied, with the value of 1 indicating a point on the frontier, i.e., technically efficient farmer (Farrell, 1957).

The Cobb-Douglas (CD) production function is used in this study. Although the CD production function has some limitations, during a given production, it can provide enough representation of the technology (Binam *et al.*, 2004). Concerning the problems associated with modeling multiple inputs (e.g., heteroscedasticity, multi-collinearity, and autocorrelation), CD function deals with them all. That is, it does not introduce any distortion, even though there are imperfections in the market. The relationship between the output and input is defined by using a Cobb-Douglas production function which is expressed as:

$$lnA_i = \beta_{0i} + \beta_i lnX_i + \mu_i \quad (2)$$

where A_i is the output (revenue from goat production) of the goat producer and the subscript i indicates the ith goat farmer in the sample $(i = 1,2..N = 124)$. X_i are the inputs used in production such as farm size, herd size, veterinary cost, pen construction cost and the number of labors (see Table 1 for detail description). β_i are the parameters of the model to be estimated and μ_i represents the random disturbance term.

In the second stage, after calculating technical efficiency scores using the DEA, a two-tailed Tobit model was employed to identify sources of inefficiencies. This is because efficiency scores range between 0 and 1, i.e., a continuous variable. Previous studies (Dagistan *et al.*, 2009; Gül *et al.*, 2016; Koc, Gul e Parlakay, 2011; M. *et al.*, 2019; Mitra, Khan e Nielsen, 2019; Unakıtan e Kumbar, 2018) have used the Tobit model to find inefficiencies.

Another problem that needs attention was the issue of potential endogeneity of the of-farm work variable in the Tobit model. The reason for this problem is because the distribution of off-farm work is not random since engaging in off-farm work is based on the farmer's decision. Therefore, considering the nature of the dependent variable (censored and continuous) and the endogeneity bias issue related to off-farm employment, the authors employed the instrumental variable (IV)-Tobit model posited by (Newey, 1987) to estimate the determinants of efficiency. There is a need for an instrument when dealing with IV analysis. Following (Pfeiffer, López-Feldman e Taylor, 2009) and (Ma, Zhou e Renwick, 2019), this study we used social network (whether the farmer has friends or relatives working in the city who can help them find an off-farm work). This instrument was chosen because it is expected to affect household member decision to find off-farm employment (treatment) but does not directly affect efficiency status (outcome). A farmer with a connection with someone who can introduce an off-farm job is likely to secure an off-farm job. Several factors (endogenous and exogenous variables) were regressed upon the DEA VRS scores in this model. The equation for the IV-Tobit model regression is specified as follows:

$$Y_i^* = \alpha_i O_i + \beta_i X_i + \varepsilon_i \qquad Y_i = \max(0, Y_i^*) \quad (3)$$

where Y_i^* is a latent variable, while Y_i measures the observed value of the technical efficiency scores of farmer i; O_i is the off-farm work of farmer i; X_i represents the other determinants of inefficiency and they include; access to credit, access to extension service, experience, education, age, association member, and gender (see Table 1 for detail description). α_i and β_i are the parameters of the model to be estimated and ε_i represents the random disturbance term.

Again, to add to novelty, this study identified confronting problems that goat farmers are facing in the study areas using the problem confronting index (PCI). To determine problems and constraints according to their severity, the PCI could serve as a good measuring instrument. Following (Roy, Farouque e Rahman, 2014), this study used a four-point rating scale to measure the problem confrontation score. The weights assigned for each response were: 3 for high confrontation, 2 for medium confrontation, 1 for low confrontation and 0 for not at all. The farmers were asked to give their response to 8 selected problems they face in production. The problem confrontation score was computed for each respondent. The possible range of total score for the 8 problems could be 0 (zero) to 24, while '0' indicating no problem confrontation and '24' indicating high problem confrontation in agriculture participation. The PCI was computed to identify the highest confronting problem using the formula expressed below;

$$PCI = Ph \times 3 + Pm \times 2 + Pl \times 1 + Pn \times 0 \quad (5)$$

where Ph = total number of respondents that expressed "high" problems; Pm = total number respondents that expressed "medium" problem; Pl = total number of respondents that expressed "low" problems; Pn = total number of respondents that expressed "not at all" problems. Thus, the PCI of individual problems could range from 0 to 372, where 0 indicates 'no' problem confrontation and 372 indicating 'high' problem confrontation.

4. Results and Discussion

4.1. Descriptive analysis

Table 1 presents the descriptions, means and standard deviation of the key variables of interest of the study. The data depicts that the mean of the outcome variable, value of output, is GH¢1102.91 and it was achieved by an average farm size of 1.43acres, 9.22 labors, 19.13 herd size, veterinary cost of GH¢48.67 and cost of pen construction of GH¢63.14. Among the farmers, 51% had access to credit (being it formal or informal source), 23% had access to extension services and 52% were members of an association. While 73% of the farmers were males, majority of them had off-farm work. The average age and years of formal education of the farmers were 42.14 and 6 years, respectively. This implies that most of the farmers are in their youthful stage and therefore, can work hard.

Table 1: Socioeconomic, Demographic and other characteristics of the respondents used for technical efficiency analysis

Variables	Descriptions	Mean	SD
Revenue (Output)	Total amount of revenue from goat production (in GH¢)	1102.91	663.71
Farm size	Farm size (in acres)	1.43	1.17
Labor	Number of labors	9.22	4.33
Herd size	Farmer's total number of goats	19.13	1.54
Veterinary cost	Cost of veterinary visit (in GH¢)	48.67	17.26
Pen construction cost	Cost of pen construction (in GH¢)	63.14	19.18
Access to credit	1 if the respondent received credit (formal/informal source) and 0 otherwise	0.51	0.46
Access to extension services	1 if the respondent has access to extension services and 0 otherwise	0.23	0.31
Experience	Respondent years of farming experience	14.27	8.07
Education	Respondent years of formal education	5.70	4.51
Age	Respondent age	42.14	11.27
Association member	1 if the respondent is an association member and 0 otherwise	0.52	0.49
Off-farm job	1 if the respondent has off-farm work and 0 otherwise	0.62	0.48
Gender	1 if the respondent is a male and 0 otherwise	0.73	0.50

Source: survey results. Note: USD1=GH¢5.2

4.2. Cobb-Douglas production function

Under this section, the authors used the DEA to analyze the relationship between inputs and output. Using the Cobb-Douglas (CD) production function, the econometrics results showed R-square of 0.68. The table indicated that farm size, labor, and veterinary cost had a positive influence on the output. In other words, the output is likely to increase by 1.3%, 5.6% and 1.6% should there arise in the cost of veterinary visitation to check the health status of the goats by GH¢1, increase in the number of labors and farm size. These results are consistent with the findings of (Mengui, Oh e Lee, 2019; Wagan *et al.*, 2019) who argued that as labor increases, farm productivity (output) also rises. Besides, the findings of (Danquah, Ankrah Twumasi e Asiamah, 2019) study, who reported that farm size positively influences farmers' output level is consistent with this result.

Table 2: Result of the coefficients of the Cobb-Douglas production function

Variables	Coefficient	SD	P-Value
Farm size	0.0134	0.9056	0.0344**
Labor	0.0563	0.1834	0.0550*
Herd size	0.1261	0.7765	0.1531
Veterinary cost	0.0169	0.4571	0.0043***
Pen construction cost	-0.0034	0.0002	0.8791
Constant	-3.4413	1.1786	0.0000***
R-square	0.6851		
Observations	120		

*Source: Survey results. Asterisks *, **, and *** represent statistical significance at 10%, 5% and 1% alpha levels respectively. SD is robust standard errors.*

4.3. Frequency distribution of technical efficiency scores

Here, technical efficiency frequency distribution scores of VRS, CRS, and SE are presented. Table 3 shows that the mean technical efficiency level of the goat farmers is about 72.4% for VRS, 31.3% for CRS and 43.1% for SE. This is an indication that for an efficient goat farmer to maintain the same level of output, there should be a reduction in their production cost by 27.6%, 68.7% and 56.9% under VRS, CRS and, SE respectively. Again, while among the 124 goat farmers, only 13 (10.5%) were efficient under VRS, 3 (2.4%) and 4(3.2%) were efficient under CRS and SE respectively.

Table 3: Frequency distribution of technical efficiency scores

Efficiency Score	VRS	CRS	SE
0.00-0.09	0	4	0
0.10-0.19	0	47	13
0.20-0.29	7	23	21
0.30-0.39	11	19	29
0.40-0.49	23	9	20
0.50-0.59	21	6	19
0.60-0.69	14	1	5
0.70-0.79	19	5	7
0.80-0.89	11	5	5
0.90-0.99	5	2	1
1	13	3	4
Total DMUs	124	124	124
Min.	0.266	0.089	0.115
Max.	1	1	1
Mean	0.724	0.313	0.431
SD	0.215	0.273	0.344

Source: survey results

4.4. Determinants of technical efficiency

To further estimate the determinants of efficiency, this study employed the Tobit model. Under this section of the study, farmers and farm characteristics were regressed upon the technical efficiency levels. The results revealed that access to credit, extension service, being a member of an association and years of farming experience positively influence efficiency while off-farm work had an inverse relationship with efficiency. The positive and significant coefficient of the access to credit implies that relative to farmers without access to credit, those with who had credit are likely to be more efficient. This finding agrees with the results of (Chandio e Jiang, 2018; Twumasi, Jiang e Acheampong, 2018; Twumasi, Jiang e

Danquah, 2019) who argued that access to credit helps the farmer to increase their productivity as well as making farmers more efficient. Also, farmers who frequently consult extension officers are more efficient than their counterparts.

Moreover, years of farming experience positive and significant coefficient shows that the more experience gained by farmers in the field, the more efficient they become. This finding is consistent with the study of (Mengui, Oh e Lee, 2019). The significant influence of joining an association on efficiency indicates that farmers with this opportunity can acquire skills and ideas to enhance their production from other skilled and experienced members during meetings. The result revealed that off-farm income has a significant and negative relationship with efficiency, suggesting that farmers with an additional job are less likely to be efficient. The reason could be that these farmers may have limited time to manage their farm properly; hence, efficiency reduces. The finding contradicts the study of (Lin *et al.*, 2019; Twumasi, Jiang e Acheampong, 2018) but is consistent with the work of (Ma, Grafton e Renwick, 2018) who argued that off-farm income reduces farm income.

Table 4: Tobit model results of the determinants of technical efficiency

Variables		VRS	
	Coefficient	Std. Dev.	P-Value
Access to credit	0.0067	0.0018	0.0028***
Access to extension services	0.0630	0.0142	0.0721*
Experience	0.1401	0.1106	0.0047**
Education	-0.0289	0.0230	0.1677
Age	-0.0198	0.0444	0.3401
Association member	0.0150	0.0154	0.0739*
Off-farm job	-0.0763	0.0341	0.0677*
Gender	0.1006	0.1703	0.2735
Constant	0.6324	0.1877	0.0000***
Log-likelihood	-173.4583		

Source: survey results. *Asterisks *, ** and *** represent significant levels at 10%, 5% and 1% respectively. Standard errors in parentheses*

4.5. Problem confrontation Index results of goat farmers

Concerning the problem confronted by the farmers, the PCI was employed to measure the extent of severity. According to the rank order in Table 5, the respondents identified insufficient capital, inadequate credit facility and inadequate extension services as the 3 major problems in the study areas. The farmers also revealed that this job influences their household income greatly.

Table 5: Problem Confrontation Index (PCI) computation

Problem	Extent of problem confrontation					Rank Order
	High (3)	Medium (2)	Low (1)	Not at all (0)	PCI	
1. Insufficient capital	101	23	0	0	349	1
2. Inadequate extension services	77	25	22	0	303	3
3. Marketing Problem	37	29	15	43	184	7
4. Climate change problem	29	30	41	24	188	6
5. Poor income generating	11	16	55	42	120	8
6. Inadequate credit facility	87	26	11	0	324	2
7. Energy demanding	56	34	27	7	243	5
8. Poor veterinary service	46	52	17	9	259	4

Source: Survey results

5. Conclusions and Policy Implications

With the help of household survey data from the Upper West region, Lawra district, this study explored the efficiency level of goat farmers. Based on the above analysis, the research mainly draws the following conclusions:

The econometric model revealed that efficiency among the goat farmers was mostly influenced by access to credit, access to extension officers, years of farming experience, being an association member and off-farm income. The study also revealed that majority of the farmers were producing below the production frontier, i.e., inefficient. Precisely, among the farmers, only 13 (10.5%) were efficient under VRS, 3 (2.4%), and 4(3.2%) were efficient under CRS and SE respectively. From the PCI model, the study identified insufficient capital, poor credit facilities and extension officers as the three major challenges faced by the goat producers in the study area.

From the above results, this study offered several implications. First, the results reveal that designing policies to bring all the farmers under one union is essential. This is because cooperative members were efficient because of the support (shared ideas and skills) gained from other members, which in turn will improve farmers' efficiency. Besides, given the significant positive impact of access to credit, the national policymakers should aim at enhancing credit accessibility avenues for rural dwellers.

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