Analysis of profit efficiency among smallholder sheep farmers of N8 development corridor Free State, South Africa

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Abstract

The livestock sector is the largest agricultural-sub sector in South Africa contributing approximately 30% to the agricultural output. The aim of this research is to measure the profit efficiency of smallholder sheep farmers and to identify the factors affecting profit efficiency of the farmer, in order to propose better strategies for sustainable livestock production among smallholder farmers in the Free State. A stochastic profit frontier approach was used to evaluate the profitability and efficiency of 217 smallholders in the N8 development corridor Free State, South Africa. The results found that the farmers are not efficiency and have great capacity to improve profitability in sheep production. The result showed that Profit efficiencies of the farmers varied between 15.5% and 80.4% with a mean of 65.1% implying that an estimated 34.9% of the profit is lost due to a combination of economic and allocative inefficiencies in sheep production. The study found that profit efficiency is positively influenced by level of education and household size (members below 18 years old) while gender and sheep loss increase profit inefficiency. Profit efficiency of the farmers can be significantly increased through effective education and training of farmers.

Keywords: profitability, stochastic profit function, profit efficiency; inefficiency, sheep production, South Africa

1. Introduction

Livestock production makes an important contribution to most economies around the world, especially developing economies that depend largely on livestock production for their livelihoods (Tamirat, 2013). Livestock production is important because it is a source of wealth creation and improves the livelihoods of rural poor households (Ndoro et al. 2014). Smallholder livestock production is a major economic occupation and creates employment for approximately 70% people in rural areas around the world (Poole 2017). The livestock production contributes approximately 45% of South Africa's agricultural output and provide employment for approximately 500 000

people (South Africa Department of Agriculture, Forestry and Fisheries (DAFF) 2012). Livestock production contributes between 25% and 30% annually to South Africa's national agricultural gross domestic product (GDP) (Ngarava et al. 2019).

Sheep production plays a very important role in the South African livestock industry, because it is a source of cash income and therefore contributes to smallholder farmers' livelihood (Brundyn et al. 2005). Sheep production provides food security, enhances crop production (by providing manure), generates income for smallholder farmers, provides fuel for transport and produces value-added goods that can have a multiplier effect and help create a need for further services (FAO 2012). Smallholder livestock farmers play a major role in enhancing livestock production in South Africa. South Africa has an estimated 28.8 million sheep, of which 7.4 million are owned by smallholder farmers and 21.4 million owned by commercial farmers (Molotsi et al. 2017). This shows that commercial farmers who produce and supply the local and international markets dominate the sheep industry in South Africa. Even though the market is dominated by commercial farmers, South Africa remains a net importer of sheep and sheep products (Nyam et al. 2019). Factors such as, consumer preferences, changing lifestyle, globalisation, high population and income growth have increased the demand for sheep and sheep products in the local market (Rios et al. 2009). Climate change especially drought and increasing production cost has slowed down sheep production in South Africa (Molotsi et al. 2017). This gap between demand for and supply of sheep and sheep products has provided a great opportunity for integrating smallholder sheep farmers into the value chain (Ndoro et al. 2015). However, the inability of smallholder sheep farmers to exploit the full potential is due to inadequate infrastructure, lack of management skills, inadequate feed resources, as well as inadequate techniques for genetic improvement of their livestock (Rege et al. 2011). These constraints are inhibiting the performance of smallholder farmers, their profitability and competitiveness in the local and international markets.

Previous studies have examined livestock production and market participation of smallholder livestock farmers in South Africa (Rios et al. 2009; Mafukata 2015; Ndoro et al. 2014; Ndoro et al. 2015; Ngarava et al. 2019; Molotsi et al. 2017; Bahta and Bauer 2012), market factors inhibiting the competitiveness or profitability of smallholder farmers (Mpandeli and Maponya, 2014; Dlamini, 2014), technical efficiency and technological gap in sheep production (Nyam et al. 2019). The limitations of these studies lie in that they did not account for factors influencing the

profitability and profit efficiency of smallholder farmers, and only assumed technical efficiency in terms of input use and production technology. Furthermore, Nyam et al. (2019) only focused on the technical efficiency and technological gap that exist between smallholder sheep farmers and failed to estimate the economic and allocative efficiencies of the smallholder farmers. Economic and allocative efficiencies are important to determine the profit efficiency and competitiveness of farmers. The above limitations makes the study important because efficiency is estimated and examined for its actual and potential influence on profitability, competitiveness and the factors affecting them. Similar studies in Africa (e.g. Tijani et al. 2006; Mawa et al. 2014; Bahta and Baker, 2015; Ojo et al. 2020) have analysed the profit efficiency of smallholder farmers. However, there is limited information available in South Africa on the profit efficiency of smallholder sheep farmers, thereby, making this study very relevant.

The aim of this paper was to measure the profit efficiency (PE) of smallholder sheep farmers and identify the factors affecting it in order to propose strategies for an integrated livestock sector. The stochastic profit frontier approach is used to measure the PE and determine the factors influencing sustainable livestock production. The profit frontier is useful for providing information to policy makers on the effect of socio-economic indicators on profit inefficiency (Bahta and Baker 2015). Given the gap between the demand for and supply of livestock in the local market, identifying the determinants of profit efficiency will inform policy makers of the best policy options for developing an inclusive market system and enhancing profitability of sheep production. To better, understand the factors influencing profit efficiency and inefficiency, and enhance sheep production and profitability, this study estimates profit efficiency for Thaba Nchu and Boshabelo as a single profit function (pooled).

The paper is organised as follows: study area is discussed in section two, while the methodological approach, which includes the empirical estimation followed in the study and the descriptive analysis, is explained in the third section. Results are presented and discussed in section four. Finally, some conclusions and policy implications of such findings are discussed in the final section.

2. Study area and data

2.1. Study area

This study was conducted in the N8 development corridor, Free State province of South Africa (Figure 1). The Free State province is located in the central part of South Africa and is one of nine administrative provinces of South Africa. The Free State province is situated between latitude 26.6° S and 30.7° S and between longitude 24.3° E and 29.8° E. The province has a total land surface area of approximately 129 825 km², accounting for an estimated 10.6% of the country's land area (Davis et al. 2006). It is the second-largest province in South Africa alongside Western Cape and shares borders with Gauteng, Mpumalanga, North West, KwaZulu-Natal and the Kingdom of Lesotho. Crop production and mixed livestock production are the main agricultural activities of the Free State province. Livestock production is a key economic activity in the province and the study area. The Free State is home to large farms that keep cattle for beef and dairy production, sheep and goats and, to a lesser extent, poultry and pigs. The Free State contributes 20% of sheep, 20% of beef and 40% of goats produced in South Africa (Maphalla and Salman 2012).

Figure 1: Map of the research area within the Mangaung metropolitan.

Source: AfriGIS (Pty) Ltd. (2019).

2.2. Sources of data and sampling procedure

Data for this study were collected using structured questionnaires. A total of 217 farmers were interviewed, 157 farmers from Thaba Nchu and 60 farmers from Botshabelo. These two districts are dominated by small-scale livestock production and it represent a major source of livelihood for the farmers in the areas. The interviews captured sheep production activities for the 2016/2017 production season. A proportionate stratified random sampling approach was used in Thaba Nchu. A complete list of all villages in Thaba Nchu was requested and obtained from the Department of Agriculture. Villages with the most sheep farmers were identified in the different areas and categorised into sub-groups. Seven farmers were chosen from each village in the different sub-groups, making a total of 21 farmers per sub-group. As a result, 168 farmers were interviewed in Thaba Nchu. Due to incomplete information from some respondents, only 157 responses were eligible (complete) for this study. A complete list of the villages with sheep farmers could not be obtained from the Department of Agriculture in Botshabelo. Therefore, a simple random sampling technique was used to select sheep farmers from two areas known for sheep farming (Bradford farm and Naledi Commage. Sixty sheep farmers were selected at random and interviewed, and all their responses were eligible for the study.

The questionnaires were designed to capture relevant input-output data of smallholder sheep farmers. Questions included farmers' sheep production (sheep value in South African Rand (ZAR), flock size (animals), size of grazing land (ha), amount of labour (hired and family labour in man-days), amount spent on animal health services (ZAR) and amount spent on feed (ZAR), operating and transportation costs, management practices or grazing systems (access to communal land or access to tenured land), and choice of breed. Other relevant information, such as socio-economic and institutional variables, were also captured. The socio-economic variables captured included age, gender, household size and education, while the institutional variables included extension services, veterinary services, access to credit, distance to the nearest market and land tenure systems. It was noticed that farmers within the study areas do not always keep proper records of farming incomes and expenses. However, some of the information, especially price information and the information on the number of animals sold were obtained from the extension officers who keep some records on the farmers' production activities.

3.1. Socio-economic and Institutional Characteristics of Respondents

The survey results the average sheep output was R 2 972 and R 3 023 for Thaba Nchu and Bostabelo respectively. The respondents indicated that the average purchase price for sheep was R 1 320 and R 1 250 for Thaba Nchu and Botshabelo respectively. Conradie and Piesse (2015) found sheep farmers in Laingsburg, South Africa, to have a sheep output of R 664 on average per year. Furthermore, sheep farmers in Thaba Nchu spent R861.39 on average per month on veterinary drugs, while farmers in Botshabelo spent R670.83. Veterinary drugs enhance the health of the sheep, which will increase the productivity of the sheep. Spending more money on veterinary drugs could increase sheep output. A study by Otieno et al. (2012) found that smallholder cattle farmers in Kenya spent the equivalent of R5 633.93 per year. Nyam et al. (2019) found that an increase in veterinary cost would reduce the technical efficiency of sheep farmers in Thaba Nchu and Botshabelo.

Farmers in Botshabelo spent, on average, R 466 on operating expenses on their farms per month, while farmers in Thaba Nchu spent R417.79 per month on operating expenses. Distance to a market was measured in kilometres from the farmer's house to the nearest market centre. Sheep farmers in Botshabelo travelled shorter distances (on average 4.8 km) to the nearest market centre than farmers in Thaba Nchu (5.69 km). Shomo et al. (2015) found that small-scale sheep farmers in Syria where approximately 46.33 km, on average, from the nearest market. The grazing land (measured in hectares (ha)) per farmer in Botshabelo (425.33 ha) is on average larger than that in Thaba Nchu (353.26 ha). Even though the survey data indicates that the sheep farmers in Botshabelo are operating on a more grazing land than in Thaba Nchu, there is a high variability ($SD = 553.819$) between the sizes of grazing land used by farmers in Thaba Nchu and Botshabelo ($SD = 76.429$). This means that some farmers in Thaba Nchu graze on larger pieces of land (Max. = 2486 ha) than others (Min. = 15 ha). Conradie and Piesse (2015) found that sheep farmers in Laingsburg grazed on 12.58 hectares of land, on average, with a standard deviation of 4.88. Shomo et al. (2015) found sheep farmers in Syria grazed on 6.05 ha. Farmers along the N8 development therefore have relatively larger grazing land because they are grazing on communal land without title deeds.

Sheep farmers in Botshabelo were older, on average, than farmers in Thaba Nchu. The average age of the farmers was 57 years in Botshabelo, and 54 years in Thaba Nchu. The results also

demonstrates that sheep farmers in Thaba Nchu had more experience (average 13 years) in sheep production than those in the Botshabelo (average 10 years). Farmers in Botshabelo have, on average, three more sheep (27) than farmers in Thaba Nchu, who have 24 sheep on average.

Table 1: Socio-economics and institutional characteristics of sheep production

Variables			
	Thaba Nchu	Botshabelo	Pooled
	(N=157)	(N=60)	(N=217)
Profit efficiency function			
Value of sheep output (Rand per year)	2 972 (1 656)	3 023 (2 669)	2 997.5 (5 535)
Average sheep price (Rand)	1 320 (4 125)	1 250 (3 150)	1 866 (5 059)
Veterinary cost (Rand per month)	861.39 (1 170.79)	670.83 (735.16)	766.11 (952.9)
Operating cost (Rand per month)	684 (1216)	466 (234)	575 (725)
Feed cost (Rand per mouth)	685.37 (774.85)	543.22 (625.32)	614 (700.09)
Profit inefficiency function			
Distance to market (kilometres)	5.69 (8.963)	4.8 (6.635)	5.24 (7.80)
Communal land size (hectares Ha)	353.26 (2 486)	425.33 (850)	389.30 (1 668)
Age	54 (25)	57 (30)	55.5 (27.5)
Gender (% female farmers)	36.9%	26.7%	34.1%
Family Labour (man-days)	8 (13)	18 (21)	13 (16.5)
Educational level (years of formal education)	7 (3)	6 (3)	7 (3)
Sheep loss (number of sheep lost due theft or disease per year)	11 (18)	13 (21)	12 (19)
Farm experience (years)	13 (12)	11 (8)	12 (10)
Herd Size (number of sheep)	24 (25)	27 (27)	26 (26)

Note: 1 USD = R 15.00 (ex.com 2020). Values in bracket represent standard deviation

3.2. Methodological Approach

3.2.1. Empirical Model

The stochastic profit frontier used in this study requires two stages. The proposed stages involves the explanation of each observation's unit profit performance in terms of technical and allocative efficiency in the first stage and the second stage explains differences in efficiency in terms of farm-specific variation. The frontier production function is a very popular method for measuring the technical efficiency of farms (Nganga et al. 2010). Measuring the profit efficiency of farmers is

important because it examine factors that have a direct influence on sheep production and profit efficiency.

The value of sheep output measured in this study is in Rand value and shows the levels of profit efficiency of sheep production for the 2016/2017 production year. It shows that even though the smallholder farmers produce at small scale, they equally make profits though not enough to sustain their livelihoods in some instances (Nyam et al. 2019). Profit efficiency is defined in this study as revenue gained from sheep production, taking farm-specific prices and associated costs into account. Given that smallholder sheep farmers in the study area operate to maximize profit in other to uplift their livelihoods, it is important to consider all factor inputs required to produce the desired sheep output. This according to Batha and Baker (2015) is subject to perfectly competitive input and output markets and the level of technology. Considering the fixed and variable costs, the actual profit function be derived as follows:

The stochastic profit function of smallholder sheep farmers can be estimated in terms of gross margin (GM) per farm. GM equals total revenue (TR) from sheep production minus total variable cost (TVC) incurred in sheep production, that is (GM= TR – TVC). The profit function follows Batha and Baker (2015) and is specified as:

$$GM_{C\pi} = \sum (TR - TVC) = \sum (PQ - WX_i)$$

$$\frac{\pi}{p}(P, Z) = \frac{\sum (PQ - WX_i)}{P} = Q - \frac{WX_i}{P} = f(X_i, Z) - \sum P_i X_i$$

$$GM_{(\pi)} = \sum (TR - TVC) = \sum (PQ - WX_i) \dots\dots\dots (1)$$

Where TR is the total revenue from sheep production, TVC are the related variable cost incurred in the sheep production process (operating cost, feed cost, veterinary cost, sheep purchase cost, etc.), per farm i; Q is sheep output; X represents the (optimal) quantity of input used; W represent the cost of inputs (WX_i = number of inputs*price of inputs), Z represents fixed inputs, while f(X_i, Z) represents the production function.

The choice of functional form is very important when specifying the model, as it can influence the results of the estimated efficiency (Ogundari et al. 2010). Functional forms, like linear models, semi-log models, trans-log and the Cobb-Douglas have been used in other studies (e.g., Aung

2011; Ogundari 2008). However, the Cobb-Douglas profit function was chosen for this study because the functional form provides a better fit for the data.

The Cobb-Douglas profit function used in the study is expressed as:

$$\pi_i = f(p_i, Z) \exp(v_i - u_i) \quad i = 1, 2, 3, \dots, n \quad (2)$$

Where π_i is the gross margin, P_i is the price of inputs while Z represent fixed inputs. $V_i - U_i$ denotes the total deviation, which is independent of each other. V_i is a symmetric two sided normally distributed random error that accounts for the random effects beyond the farmers' control (e.g. temperature, diseases and parasites, natural hazards, omitted variables, measurement error and other statistical noise) (Coelli et al. 2005). The systematic random-error component (V_i) is assumed to be independently and identically distributed with zero mean and variance (Battese and Broca, 1997). U_i denotes the asymmetric non-negative random-error component that measures technical inefficiency. The non-negative variable U_i is assumed to be independently and identically distributed truncations (at zero from below) of the $N(m_i, \sigma_u^2)$ distribution, where $m_i = Z_{ik} \Phi_k$ is a vector of parameters to be estimated and Z_{ik} is a vector of variables that may influence inefficiency of the sheep farmers (Coelli et al. 2005; Greene 2003; Otieno et al., 2012).

According to Battese and Coelli (1995), estimating the profit frontier function captures profit of individual farms and farm specific inefficiencies. The Cobb-Douglas profit function is specified as:

$$\ln \pi = \ln \beta_0 + \beta_1 \ln C_{1i} + \beta_2 \ln C_{2i} + \beta_3 \ln C_{3i} + \beta_4 \ln C_{4i} + \beta_5 \ln C_{5i} + (v_i - u_i) \quad (3)$$

Where π represents the profit, C_1 represents operating costs, C_2 represents veterinary cost, C_3 represents feed cost, C_4 represents fixed cost, C_5 represents sheep purchase cost, and β 's are the unknown parameters to be estimated. As earlier indicated, the non-negative random variable (u_i) is independently distributed with a truncation at zero of the normal distribution, $N(m_i, \sigma_u^2)$ with mean μ , where $m_i = Z_{ik} \Phi_k$ as defined below.

229 The technical inefficiency effects (u_i) defined in equation (3) is specified as:

$$230 \quad u_i = \phi_0 + \sum_{k=1}^{10} \phi_k Z_{ik} + v_i \dots\dots\dots (4)$$

231 where v_i represent the inefficiency error term and Z_{ik} are the inefficiency variables (gender of
232 household head (dummy), education of household head, age of household head, household size,
233 extension services received, annual household income, capital availability, and herd size measured
234 in sheep numbers owned) observed for farm i . Furthermore, ϕ_0 is a vector of unknown coefficients
235 to be estimated simultaneously with production function specified in equation 3.

236 Sigma-squared (σ^2) and gamma (γ) are variance parameters that will also be estimated. The
237 gamma value is used to determine the presence of inefficiency in the production data. For example,
238 a gamma value of 0.7 shows that 70% of the variation in sheep production would be because of
239 technical inefficiency (Coelli et al. 2005). The gamma value can be used to gauge for the presence
240 of technical inefficiencies in the data.

$$241 \quad \gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2) \dots\dots\dots (5)$$

242 The sigma squared (σ^2) value is used to determine if the distributional assumption of the
243 inefficiency effect is correctly specified. It follows that (Aigner et al. 1977):

$$244 \quad \sigma_u^2 = (\sigma_v^2 + \sigma_u^2) \dots\dots\dots (6)$$

245 The variance parameters of the model were also specified as:

$$246 \quad \gamma = \frac{\sigma_u^2}{\sigma^2} \text{ Such that } 0 < \gamma < 1 \dots\dots\dots (7)$$

247 The Cobb-Douglas profit function specified in Equation (3) shows the profit efficiency (PE_i) of
248 the i^{th} sheep farm in the production frontier which can be defined as the ratio of observed output
249 to the expected maximum level from the use of inputs available, given that there is no technical
250 inefficiency in production (Battese and Coelli 1988). From the above definition, PE_i can be
251 expressed mathematically as (Boshraadi et al. 2008):

$$PE_i = \frac{Q_i}{Q_i^*} = f \frac{(x_{ik}; \beta_k) e^{(U_i - V_i)}}{f(x_{ik}; \beta_k) e^{(V)}} e^{-U} \dots \dots \dots (8)$$

Battese and Coelli (1988) derive the best predictor of PE from Equation (4) and specify it as follows:

$$PE_i = E[\exp(-U_i)] \quad 0 \leq PE_i \leq 1 \dots \dots \dots (9)$$

The profit frontier and inefficiency functions specified in equations (3) and (4) were estimated jointly using FRONTIER 4.1 (Coelli 1996). It combines the two-stage procedure: the maximum likelihood method estimates the parameters of the profit function, and those of the inefficiency model (Bahta and Baker, 2015). The simple OLS and ML were fitted to determine whether the profit efficiency in sheep production in N8 development corridor is affected by farm-specific characteristics. The simple OLS function do not account for efficiency effects (i.e. $U_i=0$), while the stochastic frontier production function accounts for the total variation of output due to technical inefficiency. In the ML model, $\gamma \neq 0$ (Ngwenya et al. 1997). All hypotheses tests were carried out using the generalised likelihood-ratio test. The test statistics (λ) is defined as (Coelli 1995):

$$\lambda = -2[L(H_0) - L(H_a)]$$

Where $L(H_0)$ and $L(H_a)$ are the values of the log likelihood functions for unrestricted (H_0) and the restricted (H_a) models (Coelli 1995). The test statistics have an approximately asymptotic chi-square or mixed chi-square (X^2) distribution with degrees of freedom equal to the number of parameters specified to be zero in the null hypothesis. The Kodde and Palm chi-square distribution tables were used to obtain the critical values. The estimated test statistics were compared to the Kodde and Palm (1986) critical values at a 5% significance level. The null hypotheses are rejected if the X^2 statistic estimated exceeds the X^2 critical value.

4. Discussion of Results

4.1. Profit Efficiency Function Estimates

The profitability parameter estimates for sheep production for the stochastic profit function is presented in Table 2. The results of the stochastic profit functions were pooled together to have single profit function for both Thaba Nchu and Botshabelo.

Profit inefficiency is measured by the value of gamma (γ) and was estimated using the generalized Log Likelihood Ratio test. Table 2 shows that the estimated value of gamma is greater than zero, suggesting that variations in profit efficiency is as a result of both production inefficiency and external factors uncontrolled by the farmer, random shocks and measurement errors. Generally, the variation in sheep production for the study areas is primarily as a result of profit inefficiency on the part of the sheep farmers, as explained by the gamma value for the pooled sample. The implication is that the average production function, which has no profit inefficiency effects, is not an adequate representation of the data (Battese et al. 1996). The gamma value for pooled profit function is 0.698 and is significant at 1%. The implication is that PE is a significant contributor to the total deviation of output. This means therefore that inefficiency contributes to 68.9% of the variation in the dependent variable. The generalized Log Likelihood Ratio test was performed at 5% level of significance and 9 degrees of freedom. The value of the test was significantly higher critical values on the Kodde and Palm Chi-square table (Kodde and Palm 1986). The σ^2 value is significant meaning that the technical efficiency equation can explain the differences between each farm's profit and the profit on the frontier function (Bahta and Baker 2015). Table 2 presents the stochastic profit frontier; the parameter estimates and the level of significance. The profit frontier is the first stage of the estimation.

The effects of all production costs is positive except for operating and purchase cost, which are negative. However, operating cost is not statistically significant. Feed cost has a significantly positive effect on profits in the sample. This result is against expectation as it is assumed that profit will increase with falling input prices. The implication of this result is that, as farmers' increase their herd size, the cost of feed will increase to complement the herd size, which will increase sheep production. This result is consistent with Nganga et al. (2010) who found a positive

relationship with feed cost and milk profit in Kenya. However, Bahta and Baker (2015) and Tijani et al. (2006) found a negative relationship between feed cost and beef profit in Botswana.

Table 2. Stochastic Profit Frontier Estimates

Variables	Parameters	coefficients	Prob
Constant	β_0	3.140***	0.000
Ln (Operating cost)	β_1	-0.078	0.146
Ln (Veterinary cost)	β_2	0.039	0.513
Ln (Feed cost)	β_3	0.156***	0.000
Ln (Purchase cost)	β_4	-0.547***	0.000
Ln (Fixed cost)	β_5	0.419***	0.000
Diagnostic statistics			
Sigma square	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.331***	0.000
Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.698***	0.000
Log-likelihood function	LF	-193.82148	
Observation		217	

Note: *, **, *** Significant at 10, 5, 1% level respectively.

The negative sign associated with purchasing cost (include cost of buy sheep) was highly expected. This implies that as the cost of purchasing sheep goes up, sheep production decreases. This cost will the increase cost of producing one unit of sheep and as a result reduce the profits farmers would receive per unit of sheep. However, fixed cost has a positive impact on sheep production. This implies that as fixed cost increase, sheep production will equally increase. This result was highly unexpected given that that this set of farmers are operating on a small scale and do not enjoy the benefits of economies of scale. This results is consistent with Bahta and Baker (2015) who found fixed cost to have a positive influence of small scale beef production in Botswana

4.2. Determinants of Profit Inefficiency among Sheep Farmers

The second stage was to identify factors that determine the producers' level of profit efficiency (PE). The estimates of the determinants of profit inefficiency of sheep in the study area are presented in Table 3. Since the parameters of the inefficiency levels enter the production model as dependent variables, a variable with a negative sign in the inefficiency parameters means the corresponding variable reduces inefficiency or increases efficiency (Otieno et al. 2012). On the other hand, a positive variable in the inefficiency model is seen to negatively affect or influence efficiency (Coelli et al. 2005).

The results in Table 3 show that Extension services (5%), and educational level (5%) would significantly increase PE in sheep production in the study area. The results show that educational level had positive relation to PE in the study area and is significant at 5%. This implies that the more educated a farmer is, the more efficient the farmer becomes. Most farmers in the study area have undergone formal education, though not to high levels. This means that farmers have some level of formal training, which helps them with sheep production. However, Bahta and Hikuepi (2015) and Otieno et al. (2012) found that educational level decreases TE of cattle production. Bahta and Hikuepi (2015) explained, further, that the more educated a farmer becomes, the more the farmer engages in activities other than cattle production, thereby reducing the efficiency of the farmer. Mensah and Brummer (2016) also found educational level to reduce TE in mango production in northern Ghana.

Extension services has a negative coefficient in the results, indicating that an increase in extension services will increase PE in the study area. This result is highly expected, as extension services is expected to equip farmers with better production techniques and market information, among other benefits, which will lead to an increase in PE. Furthermore, if extension officers have been trained properly and have experience, they can provide farmers with accurate information, which will assist the farmers in production and increase the PE of farmers. This result is consistent with Nyam et al. (2019) who found that access to extension services reduces technical inefficiency in sheep production among smallholder farmers.

348

349 Table 3. Determinants of Profit Inefficiency among Sheep Farmers

Variables	Parameters	coefficients	Prob.
Constant	δ_0	-8.745***	0.000
Gender (female)	δ_1	3.811**	0.050
Age	δ_2	0.009	0.824
Household size (below 18)	δ_3	1.628**	0.029
Household size (above 18)	δ_4	-0.045	0.886
Extension services (Yes=1; No=0)	δ_5	-7.772**	0.024
Annual household income	δ_6	0.248	0.611
Herd size	δ_7	0.825	0.563
Years of education	δ_8	-0.691**	0.043
Capital availability	δ_9	0.805	0.264
Sheep loss (theft and diseases)	δ_{10}	0.163***	0.000

350 Note: *, **, *** Significant at 10, 5, 1% level respectively. A parameter with a negative sign in
 351 the inefficiency means signifies that the associated variable has a positive effect on the economic
 352 efficiency and vice versa.

353 Sheep loss has an expected influencing on profit efficiency. Sheep loss is one of the constraints
 354 affecting smallholder farmers' performance and efficiency (Nyam et al. 2019). This result was
 355 expected because sheep loss due to theft (which is very high in the study area) and diseases will
 356 significantly reduce sheep production and subsequently profit all things being equal. Diseases and
 357 parasites contribute significantly to livestock loss and profit among smallholder farmers (Bahta
 358 and Baker 2015). Household size (members younger than 18) has a positive and significant
 359 coefficient at 5% level of significance. The significance of this result means that household with
 360 members younger than 18 years old reduces PE. This result could be explained by the fact that
 361 farmers in the study area depend on family labour for sheep production and individuals younger
 362 than 18 years are considered too young to engage in farming activities. This result is consistent
 363 with the findings of Nganga et al. (2010). However, Ojo et al. (2020) found household size to
 364 positively influence smallholder rice farmers in Nigeria.

The coefficient for gender (female) is positive and significant at 5% level of significance. This implies that female sheep farmers are less efficient compared to male farmers. The fact female head of households are often engaged in household and farming activities could explain this result. They are less likely to fully engage in sheep production thereby reducing their profit efficiency. This result is consistent with Ojo et al. (2020) who found gender to have positive influence on profit inefficiency among smallholder rice farmers in Nigeria. However, Bahta and Baker found a negative relationship between gender and profit inefficiency.

Figure 2 shows the inefficiencies estimates of sheep farmers in the study area. Furthermore, Table 4 also shows the descriptive statistics for the profit efficiency scores.

Figure 2: Distribution of farm specific profit efficiency scores

The average profit efficiency score is 0.651 for the sample with most of the scores lying between 0.71 to 0.8. This indicates that there is a considerable scope to improve sheep profitability using available input at market prices and production technology among sheep farmers in the N8 development corridor. The average efficiency score of 65.1% means that on the average an estimated 34.9% of the farm profit is lost to economic inefficiency. This value of the 34.9% shows that smallholder sheep farmers can improve both their economic and allocative efficiencies.

Table 4: Summary of Profit Efficiency Scores for Sheep Production

Statistics	Efficiency score
Average	0.651
Minimum	0.155
Maximum	0.804
Standard deviation	0.159

5. Conclusion and Policy Recommendation

This study used a stochastic profit frontier model to examine the profitability of sheep farmers and to identify the determinants of profit efficiency in smallholder sheep production in the N8 development corridor. It can be concluded from the results of the study that farmers in the study area are producing well below the production frontier indicated by the average PE scores obtained. This means that farmers have the potential to increase their profitability and efficiency and produce at full capacity. The gamma values estimated show that a considerable variation in sheep production efficiency in the study area is caused by technical inefficiencies and, to a lesser extent by statistical noise or random shocks.

The stochastic profit function was estimated in the first stage, followed by the inefficiency function and the PE scores. Farmers in study area obtained an average PE score of 65.1%, meaning they have a 34.9% potential to increase production at full capacity and enhance profitability. The profit frontier results show the variables that influence sheep production in the study area. The profit frontier revealed that feed cost, sheep purchase cost and fixed cost were the most important inputs for sheep production. These factor inputs were positive and significant. This means that an increase in feed cost, purchase cost and fixed production cost will cause sheep output to increase. It should be noted this results goes against expectation because increasing input prices will increase cost of production and if this increase in production cost is not followed by increase in output prices, profitability of the farmers will reduce. It is hypothesised that farmers want to maximise profit by minimising cost of production.

Furthermore, the inefficiency shows that extension services and educational levels of household head will increase profit efficiency in the study area. Extension services is negative and significant at 5% level. This means an increase in extension services will increase profit efficiency of the farmers. Educational level of household heads is negative and significant at 5% level. This means an increase in the educational level of the household head will increase profit efficiency in the

study area. However, gender (female) and household size (under 18 years) were positive and significant. This means an increase in either gender or household size (under 18 years) will reduce profit efficiency of the farmers.

The analysis of profit efficiency in this study indicate that improvement in extension services, education and training of farmers can contribute significantly to smallholder sheer producers' profit efficiency. Sheep loss due to theft and diseases is still a major constraint inhibiting the ability of sheep farmers to increase production and profit and therefore should an area of government concern. Assisting sheep farmers to build shelters to keep their sheep and subsidizing the cost of veterinary drugs will go a long way in reducing sheep losses. The results presented in this study has shown that smallholder sheep farmers lack the skills to sustainably manage their farm operation in order to be profitable. The government, through the Department of Agriculture, should organise training workshops and seminars on appropriate management skills to support the decision-making of sheep farmers on the efficient use of farm resources and the coordination of their farm operations. Farmers should be provided with livestock extension training on farm management and keeping proper records of their activities. Extension officers should present demonstration workshops on farms to encourage more experienced farmers to share their farm knowledge with less experienced farmers. The government should subsidise the cost of veterinary drugs and services so that farmers can have easier access to these services. This will help them deal with diseases and parasites that affect their sheep. In the long run, farmers should be sensitised on diseases and parasites that affect livestock and techniques of identifying and dealing with these diseases.

Availability of data and materials

The data that support the findings of this study can be obtained from the authors upon request.

Ethics approval and consent to participate

The study received an ethical clearance and each participant signed a consent form

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Conflicts of Interest: The authors declare no conflicts of interest.

Authors’ contributions

YSN structured the general research with the goals and aims. He equally designed the methodology and models used in the research. TOO used statistical, mathematical, and computational techniques to analyse or study data; JAB Drafted the introduction and study area of the study; AAO discussed the results of the study and AAA edited the structure of the paper. All authors read and approved the final manuscript.

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Figures

Figure 1

Map of the research area within the Mangaung metropolitan. Source: AfriGIS (Pty) Ltd. (2019).

Figure 2

Distribution of farm specific profit efficiency scores

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