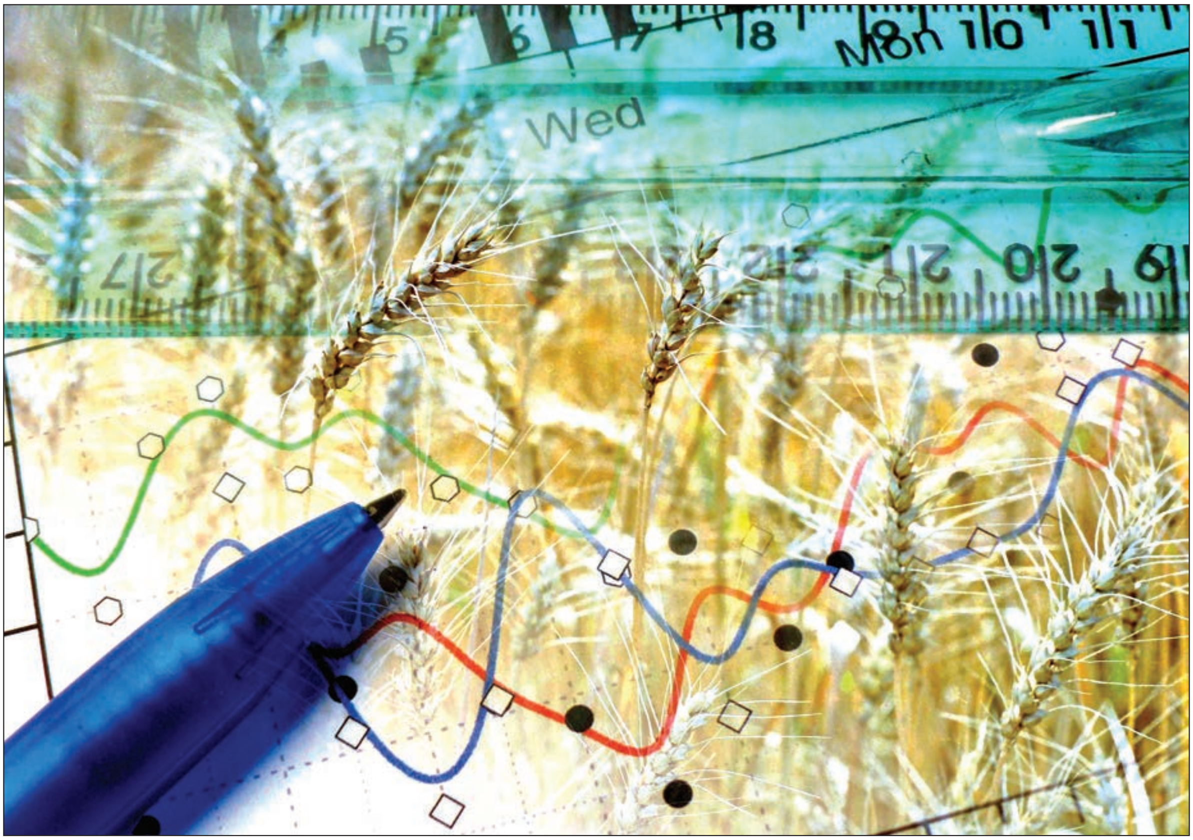

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Research Article
Measuring Technical Inefficiencies in Small-scale Small Stock Production in Dr. Ruth Segomotsi Mompatsi District, North-West Province, South Africa

[1]J.N. Lekunze and [2]U. Luvhengo

[1]School of Business and Governance, North-West University, Mahikeng Campus, Private Bag 2046, 2735 Mmabatho, South Africa
[2]Department of Economics and Information Technology, Taung Agricultural College, Private Bag X532, Taung Main Road, 8584, South Africa

Abstract
Background and Objective: Controversies surrounds the term "Small scale" in South Africa because it is associated with backward, non-productive, non-commercial, subsistence, inefficiencies in production by farmers. Small scale agricultural are vital because they generate employment and income in rural regions of the country. The economic performance is therefore crucial because it is only good economic performance in production that can ensure the businesses continue performing their aforementioned vital role. However, studies on the technical efficiencies of these type of production at a local level in the country is lacking as similar studies have focussed on large scale commercial production. The objective of this study was to measure the level of technical inefficiencies amongest small scale small-stock farmers and hypothesised that socio-economic factors do not contribute to inefficiency of small-stock farmers. **Materials and Methods:** A total of 300 land reform small-stock farmers out of a total population of 1554 in which 330 are land reform farmers were interviewed using structured questionnaires. The stochastic frontier production model was used to analyse levels of technical efficiencies among sample farmers. **Results:** Regression analysis reveals educational level, experience in small-stock production, access to transport, government support through extension services and educational levels were the most significant values. The average technical efficiency of famers was at 75% indicating that the average farmer could save 22.6% of costs and the most technical efficient could realise a 91.75%. The presence or absence of technical efficiency was tested using the log likelihood in the half normal model function (σ^2) and the estimate was 0.422 which significantly differs from zero. The estimated lambda (λ) was 0.9999 indicating differences between actual (observed) and computed output suggesting that 99.99% of the variation in small-stock output in the district is due to socio-economic factors rather than differences in technical inefficiencies of farmers and therefore rejects the null hypothesis. **Conclusion:** The study reveals that farmers are producing below the production frontier and there is room for improvements if access to resources and special training targeting women are implemented. Furthermore, for small-stock farmers in the study area to become efficient, they will have to increase the amount of input used, while at the same time reallocating their existing inputs until a point where the marginal value product is equivalent to the marginal costs of that particular input.

Key words: Technical inefficiency, stochastic frontier model, small-scale small-stock farmers, socio-economic factors, return to scale, empirical approaches

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Corresponding Author: J.N. Lekunze, School of Business and Governance, North-West University, Mahikeng Campus, Private Bag 2046, 2735 Mmabatho, South Africa

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In South Africa, the phrase "Small-scale farmers" is laden with a lot of definitions, meaning and interpretations (Averbeke and Mohamed, 2006). Kirsten and Van Zyl (1998) have argued that controversies surrounds the term "Small scale" because the phrase "Small-scale" in South Africa is associated with backward, non-productive, non-commercial, subsistence and inefficiencies in production. Greenberg (2013) and Lekunze *et al.* (2011) argues that rhetoric in favour of building small-scale agriculture in South Africa has not materialized and neither the land reform programme nor agricultural restructuring processes has facilitated the realization. This is because government tailored agribusiness policies opted for a contract farming model to integrate selected small-scale black farmers into corporate value chains has left the fundamental agrarian and agri-food structure similar to those of colonial period. Luvhengo *et al.* (2015) in a study on resource use efficiency by smallholder broiler farmers in the Capricorn district of Limpopo province South Africa have used the stochastic production function to determine the level of resource use efficiency by smallholder broiler farmers. The study found all the inputs used by broiler farmers were significant at 1% and the overall return to scale was greater than one indicating that resources are being under-utilized. The result also revealed an estimated farm level technical efficiency ranging from 8-97% with a mean of 75% on average indicating that smallholder broiler farmers are technically inefficient.

The objective of this study was to measure the level of technical inefficiencies amongst small-stock land reform farmers in the Dr. Ruth Segomotsi Mompatsi (Dr. RSM district) district of the North-West province. In South Africa, small-scale agricultural are vital because they generate employment and income especially for those in rural regions of the country. The economic performance of these type is therefore crucial for the country because it is only good economic performance of these type of production that can ensure these businesses continue performing their aforementioned vital role. However, studies on the technical efficiencies of these type of production at a local level is lacking as similar studies in the country have focussed on large scale commercial production. This study argues that, considerable study on the measurement of technical inefficiencies (Sekhon *et al.*, 2010) on agricultural productivity in South Africa have focussed on large scale commercial farms to the neglect of small scale farms scattered in rural areas across the country. The study hypothesised that socio-economic factors do not contribute to inefficiency of small-stock farmers and that inadequate government support, poor education, farming experience, access to credit, rising price of labour, increasing inputs costs, inadequate infrastructure, age of farmers and educational level of farmers as well as gender are sources of inefficiencies for these farmers.

MATERIALS AND METHODS

The study took place in the Dr. Ruth Segomotsi Mompati district municipality (Dr. RSM district) of North-West province of South Africa. The district is predominantly rural by nature with low-density, scattered rural settlements and villages. The district municipal area may be described as the rural hinterland of the North-West province of South Africa (Integrated development planning, 3rd generation, 2015-2016). The total area of the district is estimated at 12.46 million hectares with the estimated population of 5.404 million people in 2011 (SSA., 2012). The selection of smallholder farmers was done using disproportionate stratified random sampling procedure and the strata being gender. This was to ensure both males and female farmers are equally represented even though they are not proportional in size. The estimated total number of smallholder farmers in the district was 1554 and 330 are land reform farmers. Approximately, 300 of the small-scale small-stock farmers were selected for this study and interviewed using a structured questionnaire.

The use of stochastic frontier model was used to measure technical efficiencies as stated by Farrell in the 1950s (Farrell, 1957). The model distinguished between technical and allocative efficiency and was known as a deterministic non-parametric frontier. Aigner *et al.* (1977) also proposed the stochastic frontier production function stating that maximum output may not be obtained from a given combination of inputs because of the effects of inefficiency. Several extensions of Farrell deterministic model have been done by economists. Battese (1992) extended the model allowing simultaneous estimation of individual technical and allocative efficiencies of the respondent farmers as well as determinants of technical efficiency. The model is able to estimate the individual technical efficiency of the respondent small-scale small-stock farmer as well as determinants of technical efficiency while, assuming the presence of technical efficiency in production. The FRONTIER software uses a three-step estimation method to obtain the final maximum-likelihood estimates. First, estimates of the parameters are obtained by Ordinary Least Square (OLS). A two-phase grid search for γ is conducted in the second step with estimates set to the OLS values and other parameters set to zero. The third step involves an iterative procedure, using the Davidon-Fletcher-Powell Quasi-Newton method to obtain final maximum-likelihood estimates with the values selected in the grid search as starting values (Kamruzzaman and Islam, 2008).

The general Model can be written as:

$$Y = f(X_a; \beta)e^{\varepsilon}$$

Where:

Y = The quantity of agricultural product

X_a = A vector of input and other explanatory variables quantities

β = A vector of unknown parameter to be estimated

e = Error term

ε = Stochastic disturbance term consisting of two independent elements U and V and where:

$$\varepsilon = U+V$$

Where:

U = Assumed to be independent and identically distributed random errors which have normal distribution with mean zero and unknown variance σ_v^2

V = Non-negative unobservable random variables associated with the technical inefficiency of production

The random error represents random variations in the economic environment facing the production units, reflecting luck, weather, machine breakdown and variable input quality, measurement errors and omitted variables from the functional form Aigner *et al.* (1977).

Then the frontier of the farm is given by:

$$Y = f(X_a, \beta)e^{(u+v)}$$

Measures of efficiency for each farm can be calculated as:

$$TE = \exp.|E(V|\varepsilon)||$$

Where:

v = $f(Z_b, \delta)$

Z_b = A vector of farm specific factors

δ = A vector of parameters

The function is linearised so that it can be possible to use the maximum log-likelihood function. Both parameters of stochastic frontier and the inefficiency effects model can be consistently estimated by maximum likelihood procedure. Frontier 4.1 and microsoft excel were used for analyzing and editing the data. The MS excel was used to log all of the input data before creating a data file for the program to use.

The function is summarized as follows:

$$InY = \beta_0+\beta_1 InX_1+\beta_2 InX_2+\beta_3 InX_3+\beta_4 InX_4+V\text{-}U$$

where, Y is the total quantity of indigenous leafy vegetables produced and it is measured in kilograms.

In is the logarithm to base e, X_1 is the medication (Rands per annum), X_2 is the total labour used, measure in man-days (man hours per annum), X_3 is the inputs (Rands per annum) and X_4 is land under grazing (Ha).

The range of Technical Efficiency (TE) is 0-1. The TE = 1 implies that the farm is producing at its production frontier and is said to be technically efficient (Battese and Coelli, 1995). In this study, technical efficiency is an estimate of resource use efficiency by small-scale small-stock farmers in Dr. RS Mompatsi district.

Stochastic production model can be written as:

$$Y = f(\lambda a; \beta i)\ eE$$

Where:

Y = Quantity of output produced

λ_a = A vector of input and other explanatory variable quantities

β_i = A vector of unknown parameter to be estimated

e = Error term

E = Stochastic disturbance term consisting of two independent elements which are U_i and V_i, where by $E = U_i+V_{i,}$

U_i = One-sided efficiency component with a half normal distribution

V_i = The non-negative unobservable random variables associated with the technical efficiency of output production. The random error E represents random variations in the economic environment facing the production units, reflecting chance such as weather, disease outbreak and variable input quality, measurement errors and omitted variables from the functional form Aigner *et al.* (1977)

Then the frontier of the farm is given by:

$$Y= f(\lambda a\ \beta_i)+E$$

Efficiency measures for each farm can be calculated as:

$$U_i = f(Zb; dI)$$

where, Zb is vector of farm specific factors and dI is vector of parameters.

Both parameters of stochastic frontier and the efficiency effects model can be consistently estimated by maximum likelihood procedure. The function is summarized as follows:

$$\ln Y = \beta_0+\beta_1\text{-n } \lambda_1+\lambda_2\text{-n } \lambda_2+\beta_3\text{-n } \lambda_3+\beta_4\text{-n } \lambda_4+\beta_5\text{-n } \lambda_5+\ldots+(U_i+V_i)$$

Where:

- Y = Number of livestock produced (No. of livestock per year)
- λ_1 = Age (years)
- λ_2 = Hired labour employed for production (Man hours per year)
- λ_3 = Quantity of feeds (kilograms per year)
- λ_4 = Government support (subsidy per Rand)
- λ_5 = Experience in production (total number of years in farming)
- λ_6 = Access to credit (acquire loan or not)
- λ_7 = Gender (male/female)
- λ_8 = Access to transport (use own or hired transport)
- λ_9 = Extension services (number of visits per year)
- β_i = Coefficients of unknown parameters to be estimated
- U_i = One-sided efficiency component with a half normal distribution
- V_i = Random variability in the production that cannot be influenced by the farmer
- U_i = Deviation from maximum potential output attributable to technical efficiency

According to Battese and Coelli (1995), the variances of the parameters V_i and U_i are σ_v^2 and σ_v^2, respectively and the overall variance of the model is given as σ^2 which can be calculated as:

$$\sigma^2 = \sigma_v^2+\sigma_u^2$$

In this study, the measure of total variation of output (small-stock) from the frontier, which can be attributed to technical efficiency is measured by lambda (Ω). Microsoft Excel software was used to log all of the input data before creating a data file for the program to use. The STATA 10 was used to analyze the data and to find the coefficients of unknown parameters by maximum likelihood estimates.

Hypothesis testing and model fitness: In analyzing technical inefficiencies using a stochastic frontier model, the presence or absence of technical efficiency in the study is tested using the parameter of log likelihood in the half normal model function σ^2. If $\sigma^2 = 0$ it implies there were no effects of technical efficiency and all deviation from the frontier function were due to noise (Aigner *et al*., 1977). In this study, the estimated value of $\sigma^2 = 0.422$ this significantly differs from zero (Table 1). The estimated lambda (λ) parameter is high and estimated to be 0.9999 which according to Aigner *et al*. (1977) can be interpreted to mean that the differences between actual (observed) and computed output amongst small-scale small-stock farmers are dominated by technical efficiency as well as resource use efficiency. The results (Table 1) suggest that about 99.99% of the variation in small-stock output among small-scale farmers in the district is as also due to socio-economic factors and the differences in their technical efficiencies. Based on this finding, the first null hypothesis which states that socio-economic factors do not contribute to resource use inefficiency of small-scale small-stock farmers in Dr. Ruth Segomotsi Mompatsi district is not true.

RESULTS AND DISCUSSION

Socio-economic variables of small-scale small-stock farmers in Dr. Ruth Segomotsi Mompatsi district relevant to output were analyzed using percentiles and frequencies and the results are presented in Table 2.

Table 2 indicates that the majority of small-stock farmers are of age 40 years and older constituting 93.4%, while only

Table 1: Technical factors and inefficiency sources in small-stock farming

Variables	Parameters	Coefficient	Standard errors	Significant level
Production factors				
Intercept	β_0	7.696	0.834	***
Medication (X_1)	Ln β_1	0.091	0.389	NS
Total labour used (X_2)	Ln β_2	0.242	0.107	***
Cost of Inputs (X_3)	Ln β_3	-0.155	0.107	**
Total land (X_4)	Ln β_4	0.0122	0.037	*
Inefficiency factors				
Government support	δ_1	0.009	0.115	NS
Educational level	δ_2	0.548	0.138	***
Experience in production	δ_3	0.326	0.114	***
Access to credit	δ_4	-0.515	0.204	**
Gender	δ_5	-0.807	0.215	***
Access to transport	δ_6	-0.854	0.199	***
Hire labor	δ_7	0.681	0.173	NS
Age	δ_8	-0.741	0.237	***
Diagnostic statistics				
Sigma		0.42218	0.0764453	
	δ^2	4.6 e-07	0.0000427	
	δv	0.64976	0.0588263	
	δu	0.9999	0.0588262	
Lambda	ë			
Log likelihood	-17.97273			

***Significant at 1%, **Significant at 5%, *Significant at 10% and NS: Non-significant, Source: Computed by author from survey data (2015)

Table 2: Socio-economic characteristic of small-scale small-stock farmers

Parameters	Frequency (%)	Percentage
Age		
≥30	4	6.5
31-50	40	65.5
51≤	17	27.9
Total	61	100
Gender		
Male	13	21
Female	48	79
Total	61	100
Marital status		
Single	21	34
Married	40	66
Total	61	100
Education background		
Formal education	56	8.2
No formal education	5	91.8
Total	61	100
Level of involvement		
Full time	55	90
Part time	6	10
Total	61	100
Flock size kept		
100-500	22	36
501-1000	39	64
Total	61	100
Access to credit		
No access	58	95
Access	3	5
Total	61	100
Government support		
No support	55	90
Support	6	10
Total	61	100

Source: Computed by author from survey data (2015)

6.6% are below the age of 30 years. Seventy nine percent of the farmers were females, while 21% were males. The study found that 90% of the farmers are full time farmers compared to 10% part time farmers. The study further shows that the majority of the farmers (66%) are married and that farming is a supplementary source of income to support households. The minority of the small-stock farmers (8.2%) in the study area have acquired some form of education ranging from primary, secondary and tertiary.

Table 1 presents results from the regression analysis. The results reveals that educational level, experience in livestock production, access to credit, gender, access to transport and age were statistically significant at varied risk levels. The regression results also reveals that the coefficient of government support through extension services and educational level of small-stock farmers were the most significant and positive variables (1%). The implication that extension support in the form of inputs suppliers, marketing advice and educational levels of these farmers have positively contributed towards increase level of technical efficiency of these farmers. Furthermore, the coefficient of experience in agricultural production was significant at 1% and positive while that of access to credit was negative but significant at 5%. Majority (56%) of the interviewed farmers indicated that they learn by practicing small stock husbandry over time and improve their level of efficiency through experience. The coefficient of gender was found to be negative but significant, while that of access to transport was negative but significant, at 1%. This could be attributed to the fact that majority of the farming households in the area are headed by females whose husbands are providing migrant labour in mines. The farmers also indicated that they do not have access to transport hence, the negative impact as reflected in the regression analysis. The coefficient of hired labour was positive but not significant at 1, 5 and 10%, while age was negative but significant at 1% confirming the earlier findings which shows that the majority of these farmers are of ages 31-50. Although, the age bracket may seem to be the most productive bracket in terms of physical strength and experience, the positive impact is offset by the inadequate availability of resources and education of these farmers. Small-stock farmers in the study area further indicated that the use of veterinary services as hired labour is significant towards their productivity. However, they could not afford it on a full time basis unless it is provided by extension services.

Medication and vaccine: The estimated coefficient for medication and used by small-stock farmers in the study area was found to be positive and significant at 0.1 level of significance. Considering exposure to diseases in the study area it is important lack of technology and funding for proper veterinary services by smallholder farmers and output level depends on land size. The results tally with other studies Luvhengo *et al*. (2015) that also suggested that medication and vaccine has an impact on survival rate of smallholder farmers. Medication and vaccine was important in small-stock production, its shortage not only negatively affect production but also indirect negatively affect output by reducing the marginal productivity of non-medication inputs. Statistically the coefficient indicates that a 1% increase in the land devoted will lead to a 0.0917 increase in the level of small-stock productivity. This shows that the use of medication and vaccine in small-stock production is significant in productivity.

Total labour used: The estimated coefficient of labour was found to be positive and significant as expected. This indicated the importance of labour in the production of this small-stock for small-scale farmers, this was expected considering the traditional farming system that farmers practice and animal husbandry. This confirm what other studies (Oladele and Oladele, 2011) have found on the importance of labour in animal production and husbandry. Thus, the more labour engaged in animal production the higher the yield is achieved, the 0.2424 elasticity of labour indicate that a 1% increase in the labour use will lead to an increase of 0.2424 in output level. Labour significance draw from the fact that farming system used by small-scale farmers is labour-intensive from animal handling.

Cost of inputs: The coefficient of variable cost was negative and significant. This means that a 1% increase in the cost of tractor will lead to a 0.1554 decrease in the output level. The negative sign of the tractor coefficient could be due to small-land devoted to these crops production as compared to total farm size. This suggested that there was an over use of tractor in the study area. The other possible reason might be because the total cost considered was for the whole farm not only the land devoted to small-stock production.

Land under grazing: The estimated coefficient of land was positive and not that significantly different from zero. This indicates the importance of land on improving production level. Manure was the land supplementing input therefore leading to improvement in small-stock production. Izidine *et al.* (2008) supported that the area under smallholder husbandry can improve the stock size, therefore, productivity. From the Table 1 above 1% increase in land for grazing will lead to 0.0122 in the small-stock production.

Return to scale: The return to scale was found by adding all the values of betas (β). The return to scale indicates what would happen to output if all the inputs were increased simultaneously. For constant return to scale, the sum of the coefficients β must be equal to one, for increasing return to scale, they must be greater than one and for decreasing return to scale they must be less than one.

The results as presented in Table 1, the sum of β's was less than one indicating a decreasing return to scale. This meant that resources were over-utilized and resulting in small-stock farmers being technically inefficient. Input cost used per unit was more than the return from output. Farmers invested more inputs into this production and more than they received. With farmers experiencing decreasing return to scale they will have to decrease the amount of input used for them to reach the point where the cost per unit of inputs used was equal to output/returns per unit. Then, there would be sufficient room for further production and productivity improvement in small-stock production.

The coefficient of gender was found to be negative but significant. This is an indication that female farmers, who were dominating the respondents by 79% were more involved in small-scale small-stock production compared to their male counterparts. Furthermore, the coefficient for access to transport was negative but significant at 1% indicating that lack of access to own transport contributes to resource-use inefficiency by small-scale farmers in the study area. The coefficient of hired labour is positive but not significant at 1, 5 and 10% because most small-scale small-stock farmers indicated that they do not utilize hired labour to reduce cost to production. But the coefficient of age was negative and significant at 1%, indicating that the age of small-scale small-stock farmers in the study area contributes negatively to the level production efficiency by farmers.

Distribution of technical efficiency in small-scale production: Analysis on the distribution of technical efficiency in small-scale small-stock agricultural production in the study area was performed. The results of the frequency distribution of technical efficiency of small-scale farmers are presented in Table 3. The estimated technical efficiency varied with minimum and maximum values of 8 and 97%, respectively with an average of 75%. It indicated that the average farmer in the study area could save 22.6% [i.e., 1-(75/97)] of costs and the most technical efficient could realize a 91.75% cost saving [i.e., 1-(8/97)] compared with the technical efficient level of the most efficient farmer.

Returns to scale: In computing the return to scale when applying the stochastic production frontier approach, one has to add all the values of delta (δ). The sum of δ's and if the sum is greater than one, the implication is an increasing return to scale, if it is less than one, it implies decreasing return to scale and finally if it is zero, it implies constant return to scale. In this study, the sum was greater than one indicating an increasing

Table 3: Distribution of technical efficiency in production

Technical efficiency (%)	Range	Frequency (%)
0-20	8	13.11
21-40	0	0
41-60	0	0
61-80	1	1.63
81-100	52	85.24
Total	61	100

Maximum technical efficiency: 97%, Minimum technical efficiency: 8%, Mean technical efficiency: 75%, Source: Computed by author from survey data (2015) return to scale. This meant that small-scaler small-stock farmers in the Dr. Ruth segomotsi Mompatsi district were underutilizing their resources. Therefore, this finding cannot reject the second the fact that small-scale small-stock farmers in the district are not utilizing their resources efficiently. The implication is that the return on input per unit is less than the return from output. Therefore, small-scale small-stock farmers in this district must utilizes their input efficiently to achieve an optimum level of resource use efficiency. They will have to increase the amount of input used while at the same time reallocating the existing inputs until a point where the marginal value product is equivalent to the marginal cost of that particular input. By utilizing resources optimally, farmers under this study area will realize an increase in productivity, profitability and at the same time eliminating the inefficiencies associated with this form of enterprise in the study area.

The study reveals, small-stock farmers are generally older than 40 years indicating lack of interest in farming by the youths. Females dominate the sector reflecting poor participation by males in this sector. This finding is consistent with that of FAO (2011) which shows that the agricultural sector in many developing countries is underperforming because women who represent a significant contribution in agriculture are neglected in accessing productive resources due to lack of access to formal credit. Furthermore, the study found direct relationship between full time farming and increase efficiency levels in small-stock production. Echebiri *et al*. (2006) have argued that full time farmers are more likely to make efficient use of production resources because they pay full attention to their business compared to part time farmers.

The study also shows that very few farmers (81.2%) have acquired formal education at higher levels and as such, limit their ability to allocate resources efficiently and acquire technologies. This finding is consistent with a study by Ogolla and Mugabe (1996) and Lekunze *et al*. (2011) who found in a study that smallholder farmers who are formally educated are expected to be efficient resource users compared to farmers with no form of formal education. The level of experience in small-stock production was measured by the number of years in farming and efficiency was found to increase with increasing years in production. Ugwumba and Lamidi (2011) has confirm that experience in any enterprise production is associated with learning by doing which in the long run reduces the cost per unit of the total production. Lekunze *et al*. (2011) access to credit and transport was found to be limiting factors to production efficiency as most resource poor farmers possess limited assets that may be used as collateral to solicitate much needed credit. Small-stock farmers are located away from input sources and output markets with poor road. This makes transportation costs a very significant input cost in terms of accessing inputs and outputs from farm to the market.

CONCLUSION AND FUTURE RECOMMENDATIONS

The study used stochastic frontier models to measure inefficiencies of small-stock farmers in the district. The study have revealed that females are more involved in small-stock production compared to male and any policies to improve productivity should target more women as oppose to men. The findings further reveals that small-stock farmers in the study area were under-utilizing their resources and the level of technical inefficiency can be improved by 25%. The study concludes that for small-scale small-stock farmers to become efficient in the study area, they will have to increase the amount of input used while at the same time reallocating their existing inputs until a point is reached where the marginal value product is equivalent to the marginal costs of that particular input.

Based on these findings the following recommendations are made:

- Access to resources and special training must target women in the study area since they are in the majority
- Technical inefficiencies can be reduce through increasing subsidized inputs and increase visibility of extension services personnel by government and private sectors
- Extension officers must not only focussed their attention to government sponsored projects but equally give attention to those farmers who are bread winners of individual household
- Government must properly define the term "Small-scale" in a South African context and increase support to farmers in the form of capital equipment's, improve farm to market roads, subsidized inputs, improve information transfer and increase visibility of extension service personnel as well as create special financial institutions to manage and operated farmers finances

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