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Technical efficiency estimation in the livestock industry: Case study of the southern rangelands of Kenya

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Measurement of the efficiency of agricultural production is an important issue in developing countries such as Kenya. A measure of producer's performance is often useful for policy purposes, and the concept of technical efficiency provides a theoretical basis for such a measure. This study investigated factors influencing the technical inefficiency of livestock production in the southern rangelands of Kenya. Using cross-sectional household data and Maximum Likelihood Estimate technique we found that the factors contributing to the inefficiency of livestock production were years of schooling of the household, household size, access to market information and input markets. The mean technical inefficiency was higher for sheep and goats (64.98%) than cattle (1.48%) production, implying that about 65% and 2% of output of the small ruminants and cattle respectively is lost due to the misallocation of variable factors within the household.

Keywords: Stochastic frontier function; technical inefficiency; livestock industry; Kenya

1. Introduction

One of the great challenges that the Kenyan Government has been facing over the last 20 years has been to sustain the increase in the amount and efficiency of red-meat production to fulfil export requirements and to satisfy the rapidly increasing domestic demand (Behnke– Muthami 2011). Recent studies on animal products demand and supply projection indicate that, unless appropriate interventional measures are introduced, the country may soon register a deficit in most of livestock products (Farmer–Mbwika 2012). One such intervention proposed by modern economic theorists would be enhancement of efficiency of the farm, which can be achieved through technical efficiencies in factors of production (Farrell 1957). Measurement of the efficiency of agricultural production is an important issue in developing countries such as Kenya because a measure of producer performance is often useful for policy purposes, and the concept of technical efficiency provides a theoretical basis for such a measure.

Livestock farming has been estimated to be present on more than 75% of the smallholdings in Kenya, particularly to supply milk and cash for the farm family (Salami et al. 2010). In addition to meeting subsistence needs, they are expected to produce food and raw materials for local and overseas markets, create jobs and contribute towards poverty reduction. Therefore, for enhanced real livestock productivity, the efficiency in the use of resources among smallholders' farmers is paramount, although question on the resource productivity has lately been raised due to the dwindling of livestock's contribution to the national GDP in Kenya (decline from 16.6% in 1980s to 10% by 2016), casting a cloud of doubt on efficiency in the use of available resources (Behnke et al. 2011). This disquiet necessitated the need to investigate the causes underlying technical inefficiency in the production of cattle, sheep and goats among smallholder farmers in the southern rangelands of Kenya.

Technical efficiency can be defined as a measure of the ability of a firm to produce maximum output from a given level of inputs, or achieve a certain output threshold using a minimum quantity of inputs, under a given technology (Farrell 1957, Varian 1992). As indicated by Fare and Lovell (1978), measurement of technical efficiency is an important tool for the following reasons: Firstly, it is a success indicator in performance appraisal, by which production units are evaluated. Secondly, as measurement of causes of inefficiency, it makes it possible to explore the sources of efficiency differentials and eliminate causes of inefficiency. Finally, the identification of sources of inefficiency is essential to the institution of public and private policies designed to improve performance. Therefore, investigating factors that influence technical efficiency offers important insights into key variables that might be worthy of consideration in policy-making, in order to ensure optimal resource utilization. Technical inefficiency can be modelled as either input-oriented/input-saving or output-oriented/output-augmenting. We adopted an output-oriented measure that indicated the magnitude of the output of the i-th livestock farmer relative to the output that could be produced by the fully efficient farmer using the same input vector (Kumbhakar–Efthymios 2008).

There are two methods that have been widely used in the past to estimate production technical efficiency. These are non-parametric data envelopment analysis (DEA) (Charnes et al. 1978) and the econometric stochastic frontier approach (SFA) (Aigner et al. 1977, Meeusen–Van den Broeck 1977). Upon empirically testing, Coelli et al. (2005) observed that DEA has some limitations in that its deterministic frontiers do not account for measurement errors and other sources of stochastic variation, and hence do not permit hypothesis tests on technical efficiency estimates. Similarly, the estimation of random term of stochastic, DEA is usually hampered by computational complexities. The SFA was found fit for this analysis as it is capable of overcoming the above limitation. Indeed, SFA is useful in providing information on the relationship between the amount of output and the inputs of production, given the level of technology involved.

There is extensive literature on technical efficiency as it applies to crops, livestock and mixed crop-livestock farming, in other part of the world (e.g. Battese–Corra 1977, Featherstone et al. 1997, Hadley 2006, Shaq et al. 2007, Barnes 2008, Ceyhan–Hazneci 2010, Ogunniyi 2010, Kalangi et al. 2014, Mevlüt et al. 2016). In Kenya, past studies on efficiency have mainly focused on crops (e.g. Nyagaka et al. 2010) and dairy (e.g. Kavoi et al. 2010), and so far only one piece of research in the beef industry involving free-range production has been undertaken (Otieno et al. 2014). The present study contributes to this momentum aiming at investigating technical inefficiency effects for cross sectional data from smallholder pastoral livestock farmers in terms of some farmer-specific and inputs variables in the southern rangelands of Kenya.

The paper is organized as follows. In Section 1 we discuss the data and methods used in this study. The main subjects of this section are the location of the survey and its data collection procedure, the theoretical framework of the stochastic production frontier function and the Maximum Likelihood method of estimation and procedure for estimating inefficiencies. The section is concluded by the determination of the variables used in the stochastic frontier and technical inefficiency effects models. Section 2 presents the empirical results, and Section 3 concludes with some recommendations for policy.

2. Data and Methods

2.1. Location of Survey and Data Collection Procedure

This study was confined to the southern rangelands of Kenya. The choice of this region was based on the region's dominance in livestock production relative to other livestock production regions in Kenya. The study used cross-sectional farm household data that was collected during September-October 2013 and was structured and managed in a way that ensured high data quality. The data used was part of the intensive and costly survey conducted under the Agricultural Sector Development Support Program at the Ministry of Agricultural, Livestock and Fishery, and was coordinated by staff from the Kenya Agriculture and Livestock Organization (KALRO) and the University of Nairobi. Agricultural households were selected using a proportionate to population size sampling method and the survey was confined to the prominent production systems (agro-ecological zones) within each county; therefore, each county's sample size was randomly distributed to different areas based on the population density of each production system. Unfortunately, it was not possible to stratify the samples on the basis of livestock numbers on individual properties, and therefore the register list of Kenya National Bureau of Statistic of 2009 was used as it constituted the most complete population listing that was available at the time (GoK 2010a). To ensure fair distribution of sample size, households identified for sampling were entered in Global Positioning System (GPS) by GIS mappers who had earlier been recruited and trained and the identified households were supplied with coupons which were to be submitted to the data clerk after a face-to-face interview. The mapping of households was done prior to the actual data collection. Enumerators and data entry clerks were recruited and trained on the survey instrument, and a pre-test was conducted before actual data collection.

In order to investigate technical (in)efficiency on smallholder pastoral livestock farmers in terms of some farmer-specific and inputs variables in the southern rangelands of Kenya, the project adapted the usual definition of the household. According to the adapted definition, for the purpose of this study, a household consisted of a group of people who cook together and eat together and drawing food from a common source – share resources together and therefore for this purpose, household members are not necessarily the same as family members (Shaw 1988, Unalan 2005, EAL 2008). Data were obtained through face-to-face interviews using a structured questionnaire on 1254 livestock keeping households that were distributed across the six counties that includes Narok, Kajiado, Tana-River, Kitui, Makueni and Kwale counties. The six counties were purposively selected by considering total population of livestock based on the recent livestock population census of 2009 and the total number of farming households in each county (GoK 2010b). Livestock farming in the six counties surveyed is representative of the production systems available to the majority of Kenyan southern rangelands livestock regions, and cattle grazing is generally carried out in association with goat and sheep production and, to a lesser degree, cropping. Output and input data were extrapolated on the basis of the prevailing market values.

2.2. Theory on stochastic Frontier Production function

The stochastic frontier production function (SFPF) is an extension of the familiar regression model based on the theoretical premise that a production function, or its twin, the cost function, or the convex conjugate of the two, the profit function, represents an ideal, the maximum output attainable given a set of inputs, the minimum cost of producing that output given the prices of the inputs, or the maximum profit attainable given the inputs, outputs, and prices of the inputs. Since the seminal paper of Farrell (1957), technical efficiency has typically been analysed using two principal theoretical frameworks; the non-parametric data envelopment analysis (hereafter DEA) (Charnes et al. 1978) and the econometric stochastic frontier approach (hereafter SFA) (Aigner et al. 1977, Meeusen–Van den Broeck 1977). A potential advantage of SFA over DEA is that random variations in production function can be accommodated, so that the measure is more consistent with the potential production under "normal" working conditions. SFA developed from isolated influences but the literature that directly influenced the development of SFA was the theoretical framework for production efficiency which originated in the 1950s (e.g. Debreu 1951) and which to date remains the framework of choice for many scholars (e.g. Nyagaka et al. 2010, Otieno et al. 2014, Mamardashvili–Bokusheva 2014). SFA utilizes econometric techniques whose models of production recognize technical inefficiency and the fact that random shocks beyond producers' control may affect production. Differently from traditional production approaches that assume deterministic frontiers, SFA allows for deviations from the frontier, whose error can be decomposed for adequate distinction between technical efficiency and random shocks. Using SFA idea, the Stochastic SFPF can be expressed using J inputs $(X_1, X_2 \dots X_J)$ to produce output Y as:

$$Y_i = f(X_{ij}; \beta)\exp(v_i - u_i);\ i = 1,2, \dots, N \quad (1)$$

where v_i is a random error associated with random factors not under the control of the producing unit i. It is the "noise" component and assumed to be a two-sided normally distributed variable and constant variance $(v_i \sim N(0, \sigma_v^2))$. Meanwhile, u_i is the non-negative technical inefficiency component and is half normal distributed $(u \sim F)$ with variance σ_u^2. Moreover, u_i and v_i are assumed to be independent of each other and independently and identically distributed across observations. Together they constitute a compound error term, with a specific distribution to be determined, hence the name of "composed error model" as it is often referred to. $f(X_{ij}; \beta_i)$ is the production frontier, β is a vector of technology parameters to be estimated, and u_i defines the ratio of observed output to maximum feasible output. If $u_i = 1$, then, the i-th farmer obtains the maximum feasible output, while $u_i < 1$ provides a measure of the shortfall of the observed output from maximum feasible output. This model is such that the possible production Y_i is bounded above by the stochastic quantity, $f(X_{ij})\exp(v_i)$, hence the term stochastic frontier.

We now turn to the selection of the functional form of the stochastic production frontier function. The issue of functional form for the production or cost function is generally tangential to the analysis and not given much attention. In a production model, the choice of functional form brings a series of implications with respect to the shape of the implied isoquants. In particular, the Cobb-Douglas production function has universally smooth and convex isoquants. The alternative translog model is not monotonic or globally convex, as is the Cobb-Douglas model, and imposing the appropriate curvature on it is generally a challenging problem. Therefore, we adopted the latter and assumed that $f(X_i; \beta)$ takes the log-linear Cobb-Douglas form expressed as:

$$LnY_i = \beta_0 + \sum_{i=1}^{n} \beta_{nj} LnX_{nj} + v_i - u_i, \quad (2)$$

Now, u_i which defines the inefficiency term, can be represented by non-negative unobservable random variables associated with the technical inefficiency of production, such that for a given technology and level of inputs, the observed output falls short of its potential output. This specification allows us to examine the null hypothesis that there are no technical efficiency effects in the model $H_0: \sigma_u^2 = 0$ versus the alternative hypothesis $H_1: \sigma_u^2 > 0$. Value $\sigma_u^2 = 0$ denotes that the deviation from the frontier is due entirely to noise while $\sigma_u^2 = 1$ represents that all deviation is due to technical efficiency.

Technical inefficiency effect model proposed by Battese and Coelly (1995) is described by:

$$u_i = f(Z_i) = \delta_0 + \delta_i Z_i, \qquad (3)$$

where Z are vectors of the socio-demographic and other independent variables assumed to contribute to technical inefficiency, i.e. a $(1 \times M)$ vector of explanatory variables associated with the technical inefficiency effects of the producer i. δ is an $(M \times 1)$ vector of unknown parameters to be estimated. The nature of technical inefficiencies can be examined by conducting a null hypothesis of $(H_0: \lambda = 0)$ versus $(H_1: \lambda > 0)$ the alternative. When $\lambda = \delta_i = 0$, there is no technical inefficiency deterministic or stochastic, and when all $\delta_i = 0$ parameters (except λ_0) are zero and the variables do not affect technical efficiency levels, then the model reduces to the one proposed by Stevenson (1980). The technical efficiency of an individual producing unit is defined in terms of the ratio of the observed output of the corresponding frontier output, given the available technology.

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(X_i;\beta)\exp(v_i - u_i)}{f(X_i;\beta)\exp(v_i)} = \exp(u_i) \qquad (4)$$

Here, Y_i is the observed output and Y_i^* is the frontier output. The parameters β_j in SFPF and δ_j in inefficiency effect model were estimated by the method of maximum likelihood, using the computer program STATA version 11. The production scale elasticity of j-th inputs was computed by $E_j = \sum \beta_i$ and if the frontier is concave in inputs then $E_j < 0$ and SFPF is in the range 0 to 1.

The next step involved the procedure for estimation of the stochastic frontier production function and technical inefficiency effect model. The parameters β_j and δ_j of the stochastic frontier production functions and technical inefficiency effects model respectively were estimated by the method of maximum likelihood and truncated regression approach using the computer program STATA version 12. In case of cross-sectional data, the technical inefficiency model can only be estimated if the inefficiency effects u_i are stochastic and have particular distributional properties. Aigner et al. (1977) assumed a Half-Normal distribution, $u_i \sim N^+(0, \sigma_u^2)$, while Meeusen and Van den Broeck (1977) opted for an exponential one, $u_i \sim \varepsilon(\sigma_u)$. Other commonly adopted distributions are the Truncated Normal (Stevenson 1980) and the Gamma distributions (Greene 2003). The authors of this study opted for a half-normal distribution and Stochastic Frontier analysis was based on two sequential steps: 1) estimates of the model parameters $\widehat{\Theta}$ which were obtained by maximizing the log-likelihood function $e(\Theta)$, where $\Theta = (\alpha, \beta', \sigma_u^2, \sigma_v^2)$[1], and 2) point estimates of inefficiency which were obtained through the mean (or the mode) of the conditional distribution $f(u_i|\hat{\varepsilon}_i)$, where $\hat{\varepsilon}_i = Y_i - \hat{a} - X_i;\beta$

2.3. Determination of the variables for empirical analysis

Several independent variables were selected to estimate the predicted values of the dependent variables. The choice of the variables used is largely based on work by Ceyhan and Hazneci (2010), Ogunniyi (2010), Kalangi et al. (2014), Otieno et al. (2014) and Mevlüt et al. (2016) where factors contributing to farmer production (in)efficiency in the livestock industry were extensively reviewed. The set of independent variables potentially expected to contribute to the (in)efficiency in production of cattle, sheep and goats in the SR of Kenya are grouped into two, with the stochastic frontier model variables and the inefficiency effects model variables

Table 1 Variables for stochastic frontier and technical inefficiency effects model

Variable name	**Variable descriptions**	**Anticipated sign**
Stochastic frontier model		
Natural pasture (X_1)	Discrete (land in hectares)	+
Labour (hired and family) (X_2)	Discrete (man-days)	+
Use mineral supplements (X_3)	Have been using mineral supplements = 1, 0 otherwise	+
Use dewormers (X_4)	Have been using dewormer = 1, 0 otherwise	+
Purchase fodder (X_5)	Have been purchasing fodder = 1, 0 otherwise	+
Inefficiency effects model		
Household head age (Z_1)	Discrete (age in years)	-
Years of schooling of the household head (Z_2)	Discrete	-
Household size (Z_3)	Discrete (Head count of active member)	-
Number of technology adopted (Z_4)	Discrete	-
Membership agricultural group / association (Z_5)	Belong to farmers' group or association = 1, 0 otherwise	-
Agricultural extension services (Z_6)	Access to extension services = 1, 0 otherwise	-
Agricultural research services (Z_7)	Access to agricultural research services = 1, 0 otherwise	-
Market information (Z_8)	Access to market information systems = 1, 0 otherwise	-

Source: Own construction based on the literature

[1] Note, that different model parametrizations are used in the Stochastic Function literature as, e.g. $\Theta = (\alpha, \beta', \sigma^2, \lambda)'$ where $\sigma^2 = \sigma_u^2/(\sigma_u^2 + \sigma_u^2)$ and $\lambda = \sigma_u/\sigma_v$ where λ measures the association between variables and ranges from 1 (perfect association) to 0 (no association).

and their descriptions and the expected signs being summarized in Table 1. Generally, on a priori bases, the marginal productions of the stochastic frontier production function (equation 2) were expected to be positive, as the rate of change of the mean of production with respect to the j-th explanatory variable. In a one-step stochastic frontier production estimation, the parameter for inefficiency level (u_i) usually enters the model as the dependent variable in the inefficiency effects component of the model (equation 3), and therefore a negative sign for variables in the Z-vector is expected, which implies that the corresponding variable would reduce level of inefficiency.

3. Results and Discussion

3.1. Descriptive statistic of the variables

Before discussing the results of the SFA analysis, it would perhaps be of interest to present some of the descriptive data of the analysis. The summary statistics of selected technical, social and economic variables that influence livestock production is presented in this section. In this study, livestock were grouped into two classes; cattle representing large ruminants and sheep and goat (hereafter shoats) representing small ruminants. The combining of sheep and goat together was important because the two types of livestock are grazed together and share the same inputs and so proved difficult to distinguish from one another. As indicated in Table 2, the mean and standard deviation of herd size per household was more for shoats (38.78±86.55) and lower for the cattle (20.95±55.41) which concurred with the findings by Otieno et al. (2014).

Table 2 Summary statistics of the survey data

Variable descriptions	**Cattle**	**Shoats**
Input/output variable		
Number of livestock	20.95±55.41	38.78±86.55
Natural pasture land in hectares	41.34±82.06	38.76±177.43
Labour (hired and family) (man-days)	85.50±164.11	94.31±165.35
Use mineral supplements in percent	52.03	42.58
Use dewormers in percent	77.73	70.93
Purchase Fodder in percent	8.57	7.98
Socioeconomic indicators in livestock rearing		
Age of the Household Head (in years)	48.20±15.21	48.49±15.16
Years of schooling of the household head	6.54±5.24	6.60±5.26
Household size (active member)	6.59±3.02	6.61±3.06
Number of technology adopted	0.23±0.62	0.21±0.60
Membership of an agricultural group/association in percent	12.50	11.90
Access to the agricultural extension services in percent	11.80	10.50
Access to agricultural research services in percent	4.00	3.60
Access to market information in percent	29.30	28.30
Access to input market in percent	35.00	33.90

Source: Own construction using household survey data

The higher mean in shoats explains why shoats are often regarded as an important alternative to cattle in pastoral areas (Huho et al. 2011). In general, both stochastic frontier inputs and inefficiency factors did not exhibit a significant difference between shoat and cattle production. The results show a high standard deviation from the mean for land and labour input in the two enterprises. This is because a majority of smallholder households have less than five hectares of the land, and therefore keep relatively few animals, which also require low labour input. Labour was captured on a weekly basis, recognizing the fact that cattle and shoat production are labour intensive. The percentage use of mineral supplements was higher in cattle (52.03%) than in shoat production (42.58%). Meanwhile, the rate of use of dewormer was over 70% for both cattle and shoat production. This is a clear indication that farmers are mostly concerned with the control of worm infections which have remained one of the major disease constraints to livestock production in Kenya. This confirms the findings by Perry et al. (2002) who found that worm infestation in livestock continue to be a major challenge, especially in small ruminants in the tropics and subtropics. Purchase of fodder for supplementing livestock was very low among cattle and shoat producers, although relatively high for cattle production alone. In general, shoat feed intake is low compared to large livestock like cattle and camels, and perhaps it subsequently makes no economic sense for farmers to buy feed for shoat production.

In the case of socioeconomic variables, the margins in the difference of the averages and percentages for the two enterprises were relatively low. For instance, the mean age and standard deviation of household head calculated was 48.20±15.21 and 48.49±15.16 for cattle and shoats respectively, translating to a difference in margin of less than one. However, the result indicates that a majority of livestock farmers in the southern rangelands of Kenya are within the productive age bracket (between 30-50 years) suggested by Skirbekk (2003). The mean years of schooling was 6 years with standard deviation of 5 years which implies that literacy levels were very low; indeed the household heads' average level of education was the equivalent of completing primary school. Similar findings were reported by Ogunniyi (2010) for livestock farmers under similar environmental condition in Nigeria. The average number of people per household engaged in shoat and cattle production was relatively high based on the average herd size, translating to a livestock-to-people ratio of 3-6 animals, implying a low average marginal productivity. Although the number of technologies adopted by each farm was insignificant, and membership of agricultural groups and associations was relatively high among cattle farmers (12.5%). Coming together as a group has the potential impact on cattle production. It is probably less likely in shoat production because of the relatively lower returns, meaning there would be no perceived personal benefit to farmers from belonging to a shoat production group and participating in collective action. The result also indicates that cattle enterprise benefit from relatively better access to livestock extension, agricultural research, market information services and input markets compared to shoat production.

3.2. Estimating stochastic frontier model

The results of the estimated parameters of the SFPF (equation 2) are presented in Table 3. The results show that the natural pasture land size, labour and use of dewormer had the expected positive sign and were statistically significant (either at 1%, 5% and 10%) for both shoat and cattle production. The coefficient for natural pasture land was 0.28 and 0.29 for cattle and shoats respectively. This implies that 10% increases in the pasture land in terms of quantity and quality would result in a 28% and 29% increase in the herd of cattle and shoats respectively. The impact of labour was positive and statistically significant at 1% and 10% for cattle and shoat production respectively. The coefficients for labour inputs were 0.14 and 0.09 for cattle and shoat production respectively. These results imply that cattle production is relatively labour sensitive. The positive coefficient of labour implies that as more labour is employed, gross margin increases. The coefficients for the use of dewormer were 0.62 and 0.53 for cattle and shoat production respectively. This variable was captured as a dummy variable and the result indicates that a one unit increase in the number of farmers using dewormer would result in an upward shift of the production frontier function by a margin of 0.62 and 0.53 for cattle and shoats respectively. Use of mineral supplement had the expected positive sign. The relationship between use of mineral supplement and shoat production was significant at 5%. Purchases of fodder for livestock had a negative influence on livestock production. The negative sign confirms that livestock production in this region is semi-commercialized. The constant term for shoat was statistically significant at 1% implying that there are other variables contributing to shoat production that were not included in the analysis.

The value of lambda (λ) indicates the proportion of variation in the model that is due to capacity utilization. The lambda value of 0.73 for shoat production was very high indicating that the unexplained variations in output are the major sources of random errors. The estimates for σ_s^2 of 1.21 and 1.91 for cattle and shoats respectively was significantly different from zero at 1% level of significance. This indicates a good fit and correctness of the specified distributional assumption of Normal-Half Normal of the composite error term. This suggests that conventional production function is not an adequate representation of the data. The log likelihood ratio and Wald chi2 (5), indicate that all the five predictors' regression coefficients are significantly different from zero at 1%. The elements in the row labelled ‘scale elasticity’ are the sum of the individual effects of inputs on livestock output, which reflects the output oriented measure in response to a change in all inputs variables combined usually referred to as return to scale. In the two enterprises, the scale elasticity is less than one and therefore the returns to scale are decreasing. Since the scale elasticity of stochastic frontier production function is in the range 0 to 1, the frontier is concave to the inputs.

The Likelihood-ratio test technical inefficiency error terms are also presented in Table 3. These tests involve the null hypothesis $H_0 \colon \sigma_u^2 = 0$ against the alternative hypothesis $H_1: \sigma_u^2 > 0$. If the null hypothesis is true, the stochastic frontier model reduces to an OLS model with normal errors. For this case, the result shows a likelihood-ratio (LR) of 0.00 with a p-value of 1.00 for the half-normal model for cattle production which implies that σ_u^2 is zero and therefore the stochastic model reduces to OLS with a normal error term. The LR for shoats was 0.17 with a p-value of 0.34, implying that σ_u^2 is also different from zero. This implies that at the probability of 34%, the level on inefficiency in shoats (sheep and goat production) is 17%. Ogunniyi (2010) and Otieno et al. (2014) obtained similar results in their different studies.

Table 3 Maximum likelihood estimation for stochastic frontier production function

	Cattle			Shoats		
Variables	Coefficient	Std. Dev	z-value	Coefficient	Std. Dev	z-value
Pasture Land	0.2854215***	0.038245	7.4	0.28909***	0.0432775	6.68
Labour	0.1380475***	0.0494517	2.79	0.085688*	0.0533552	1.61
Mineral	0.1628442	0.1496802	1.09	0.387198**	0.1680707	2.3
Use Dewormer	0.6188858***	0.1586346	3.90	0.525808***	0.1587034	3.31
Buy Fodder	-0.4597568***	0.2038254	-2.26	-0.2993532	0.2277415	-1.31
Constant	0.5524782	0.7760403	0.71	1.9984***	0.6271836	3.19
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	1.213671***	0.1021317	-	1.91476***	0.7716011	-
$\lambda = \sigma_u^2 / \sigma_v^2$	0.0168126	0.9014291	-	0.7276227	0.912332	-
Log likelihood	-447.12328***	-	-	-552.0394***	-	-
Scale elasticity[a]	0.7454422	-	-	0.988431	-	-
Likelihood-ratio test for technical inefficiency error term σ_u^2	0.000	-	1.000	0.17	-	0.341

*Significant at 10% level ($p < 0.10$);
**Significant at 5% level ($p < 0.05$);
***Significant at 1% level ($p < 0.001$).
Wald chi2(5) for cattle = 115.55 and Shoats = 112.00
[a]Total production elasticity of j-th inputs

Source: own construction

3.3. Estimating the inefficiency effects model

Presented in Table 4 are the estimated parameters for the inefficiency effect model (equation 3). The estimates of the parameters for the schooling of the household head, household size, number of technologies adopted, membership of a group or association, access to research and input markets had a positive impact on the inefficiency experienced in shoat production, while household size, number of technologies adopted, access to livestock market information and input markets were significant in determining the level of inefficiency. The positive effect of years of schooling of the household head and membership to a group were statistically significant at 10% while access to input market was significant at 1%. The positive relationship between age of the household and the level of inefficiency would perhaps be attributed to the relatively old mean age reported in Table 2. This implies that as age increases, productivity reduces, widening the gap away from the optimal frontier.

Table 4 Technical inefficiency of shoat rearing in southern rangelands of Kenya

Variables	**Coefficient**	**Std**	**z-value**
Age of household head	0.0008036	0.0007665	1.0
Years of schooling of household head	0.0039033*	0.0020837	1.87
Household size	-0.0085943**	0.0037286	-2.30
Number of technologies adopted	-0.0264413*	0.0164617	-1.61
Membership of an agricultural association	0.0497639*	0.0285603	1.74
Access to the agricultural extension services	0.0099435	0.0298006	0.33
Access to agricultural research services	0.0221102	0.0543631	0.41
Access to livestock market information	-0.07919***	0.0266762	-2.97
Access to input market	0.08558***	0.0234373	3.65
σ_2	0.19254***	0.0073947	26.04
Log likelihood	77.4564***	-	-

*Significant at 10% level ($p < 0.10$);
**Significant at 5% level ($p < 0.05$);
***Significant at 1% level ($p < 0.001$);
Wald chi2(9) = 33.31

Source: own construction

Education is said to be one of the factors that could improve technical efficiency, since it could improve the managerial capacity of farmers and contribute to farmers' capacity to understand information on livestock production, and a positive sign of the length of education to technical inefficiency could be explained by the high level of illiteracy reported in Table 2. Similarly, in Kenya it has also been shown that as the average number of years of schooling increases, inefficiency increases (Karanja 2002, Kibaara 2005). This could probably be explained by the observations that high education attenuates the desire for farming, and that farmers consequently tend to concentrate more on salaried employment. As the number of school years increases, inefficiency increases and the number of farmers decreases. Closely related to years of schooling of the household head is the number of technologies adopted by household, which had the hypothesized negative sign and was significant at 10%. The more the number of technologies adopted, the higher the reduction of the levels of inefficiency. Household size had the expected negative sign and was also significant at 10%. This variable implies that households with more active members are likely to be more efficient. Based on this variable; an increase in household size by 1 unit would result in a reduction in the inefficiency of the production of shoats by about 0.0086. Research by Sarma and Ahmed (2011) and Mussa et al. (2012) also showed that family size is significant in improving the economic efficiency of agriculture, including the cattle business.

The institutional factors considered in this study were membership of group or association, access to extension, research and market information systems. The coefficient for memberships to groups indicated a positive contribution to the level of inefficiency. Access to market information had the expected negative sign and was significant at 1%. This implies that improvement of the marketing information systems would reduce information asymmetry and hence enhance production of shoats. Access to input made a positive contribution to the level of inefficiency in shoat production and the impact was significant at 1%. This positive result could be attributed to the framing effect, distance and availability of transport to markets, which would need to be further investigated. The estimate of σ^2 (0.19) was significantly different from zero at 1% level of significance. This indicates a good fit and correctness of the specified distributional assumption of half normal of the non-negative error term u. The log likelihood ratio and Wald chi2 (9) shows that all the nine predictors' regression coefficients were significantly different from zero at 1%.

In summary, the most important variables that would significantly reduce the level of inefficiency are household size, number of technologies adopted and access to livestock market information.

3.4. Efficiency size of livestock production

The estimates of technical inefficiency are summarized in Table 5 below. The estimated mean technical inefficiency was 0.015±0.00011 and 0.65±0.202 for cattle and shoats production respectively. The presence of technical inefficiency implies that the allocation of resources in the two productive enterprises is not Pareto efficient therefore there is scope for increasing livestock production in southern rangelands of Kenya by 1.47% and 64.98% for cattle and shoats respectively with the present technology, if the parameters contributing to the inefficiency are improved. The computed efficiency levels for cattle were high (98.5%) while that for shoats was low (14.8%) with the highest being about 55%. Similar high efficiency level for cattle (69%) was reported by Otieno et al. (2014) in Kenya. The differences in the measure of efficiency levels for cattle and shoat production likely have a twofold explanation. The first is associated with the differences in marginal productivity of labour and capital, where the latter was represented by deworming, and second the constant term for shoats is statistically significant at 1% with three times the marginal effect of cattle (Table 3). Cattle production is more efficient in the utilization of the two productive factors. This implies that there are other important factors in shoat production which were not included in the model. Equally, this result confirms the importance of cattle compared to shoats on the small farm, as the estimated ratios of production of shoats in relation to cattle was 1:12 for value and 1:8 for biomass (Stotz 1983).

Table 5 Distribution of Technical (in)efficiency Levels

	Technical inefficiency (TI) levels		Computed efficiency levels (1-TI)	
Classes	**Mean**	**Std deviation**	**Min**	**Max**
Cattle	0.015	0.00011	0.98511	0.98534
Shoats	0.650	0.202	0.148	0.552

Source: Own construction

4. Conclusion

The study aimed at investigating the level of technical (in)efficiency of smallholder farmer-specific characteristics and input variables on livestock production in the southern rangelands of Kenya using a cross-sectional data analysis. A Stochastic Frontier Analysis theoretical framework was employed in providing information about input-output relations and technical (in)efficiencies in shoat (sheep and goat) and cattle enterprises in southern rangelands of Kenya. A production frontier was fitted, and it was found that shoats are further from the frontier than the cattle. The empirical findings suggest that livestock farmers were technically inefficient in the use of productive resources, particularly land, in both enterprise. Production potential can be increased by increasing the use of mineral supplement, and substantially, by frequently deworming the livestock. There is a very high level of technical inefficiency in shoat production which translates to the low level of small ruminant production. The results of this study showed that one of the key avenues for increasing efficiency is to address the institutional and socioeconomic infrastructure which causes drudgery, especially in shoat production. This inefficiency is explained by such variables as the years of schooling by household head, household size, number of technologies and access to input markets and market information. Hence, for efficient production of livestock in the study area, these factors must be addressed and their effects reduced to bare minimum. This can be done through good policy formulation, implementation, proper supervision of livestock production programmes, the effective extension services and proper market information systems.

Government should make policies that will motivate livestock farmer to optimally allocate productive resources to achieve optimum level of production, which should also form the basis for future research in exploring critical issues such as the marginal productivity level. A pro-pastoral Livestock Input Subsidy Programme similar to the Input Subsidy Programme under the Kenya National Accelerated Agricultural Inputs Access Programme of 2007/08, which was found by Mason et al. (2017) to improve productivity in the crops industry, is required. The study recommends capacity building of livestock farmers through regular training on the efficient use of resources and agribusiness techniques. The results also show that poor market information flow impacts negatively on livestock productivity. It also increases costs of market information and sourcing for inputs and produce, thereby increasing information asymmetry and reducing the margins of farmers. New investments and improvements in the existing market information network would require the enhancement of public expenditure on rural infrastructure. This implies that the government must remain the main player in rural information network development in order to promote smallholder agriculture.

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