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Technical efficiency of beef cattle production technologies in Nigeria: A stochastic frontier analysis

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The paper investigated the determinants of beef cattle production and technical efficiency of beef cattle farmers using stochastic frontier production function which incorporates a model of inefficiency effects. A multi-stage random sampling procedure was employed for the selection of 360 respondents comprising 97 nomads, 208 agro-pastoralists and 55 ranchers across the 6 major producing states in Nigeria. The inefficiency effects are assumed to be functions of education of farmers, beef cattle farming experience, access to credit sources and farmers’ membership of cooperative societies. Empirical results indicate that significant increase recorded in output of beef cattle in the country could be traced mainly to the critical inputs. The estimated average technical efficiencies for the three groups were 0.59, 0.69 and 0.83 for the nomadic pastoralists, agro-pastoralists and ranchers, which indicated that there is still much opportunity for increased efficiency given the present state of technology. The need to develop some low cost labour saving technologies to ease labour constraints on farms was emphasized.

Key words: Beef cattle, production technologies, efficiency, stochastic frontier analysis, Nigeria.

INTRODUCTION

The livestock sub-sector (LSS) has always been an important component of Nigeria’s economy. In addition to its contribution to the Gross Domestic Products (GDP) of the country, it contributes substantially also to the supply of animal protein (FDLPCS, 2013). By its population and capacity for animal production, with 25% of livestock herds in the sub-region, Nigeria is by far the leading livestock producer in Central and West Africa (Grain de sel, 2012). Based on the limited empirical and policy-focused enquiries, huge endowment of natural resources, public expenditure and private investment on cattle production in Nigeria, beef cattle was selected as representative of livestock for the study. Cattle are indeed the most predominant and highly valued livestock in Nigeria but there is a documented report on a decline in beef cattle production especially, in developing countries; a wide gap exists between the level of local production and national needs and demand. The average demand for beef in Nigeria from 2006 to 2015 stood at 286 MT whereas the supply was 235 MT for the same period, a
deficit of 51 MT (OECD-FAO, 2015).

It is obvious that Nigeria, with a population of over 160 million people requires several heads of cattle to satisfy its demand for cattle and cattle products. Again with a population growth rate nearing 2.8% per year, the country’s own domestic production is by far from being able to meet demand (Grain de sel, 2012). In the bid to address the demand supply gap, governments at various times have come up with policies and programmes which have been observed to be inconsistent. These erratic policies reflect the dilemma of securing cheap beef for consumers and fair price for producers. Notwithstanding the various policy measures, domestic beef cattle production has not increased sufficiently to meet the increased demand (Nwigwe et al., 2015). Thus, these fluctuations in policy and limited capacity of the Nigerian beef sector to match the domestic demand have led the country to expend huge amount of foreign exchange on the importation of beef into the country. The limited capacity of the Nigerian beef sector to meet the domestic demand has raised a number of pertinent questions both in policy circle and among researchers. For example, what are the factors explaining why domestic beef production lag behind the demand for the product in Nigeria? Central to this explanation is the issue of efficiency of the beef cattle farmers in the use of resources.

Some researchers (Loevinsohn et al., 2012; Beshir et al., 2012; Diiro, 2013) opined that attention to productivity gains arising from a more efficient use of existing technology is justified. They argued that since the presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and without the need for new technology, empirical measures of efficiency are therefore necessary in order to determine the magnitude of the gain that could be obtained by improving the performance of a production system with a given technology. Mor and Sharma (2012) and Challa (2013) also argued that an important policy implication stemming from significant levels of inefficiency is that it might be more cost effective to achieve short-run increases in farm output, and thus income, by concentrating on improving efficiency rather than on the introduction of new technologies.

At present, there is no comprehensive and up to date information as regards the level of resource use efficiencies of the beef cattle farmers, given the existing technologies. The few available ones were either system based or location specific. Most of these studies focused mainly on the profitability of the enterprise without an in depth inquiry into efficiencies of farmers and factors that determine their level of efficiency. Thus the main focus of this study is to determine the levels of technical efficiency of beef cattle farmers and explain those factors that determine their levels of efficiency. Given the fact that a number of beef cattle development programmes such as improvement in the breeding and feeding methods as well as hybrid development have been implemented to boost the beef sector in Nigeria, the study has been designed to cover the identified three major beef cattle production systems in Nigeria viz, nomadic pastoralism, agropastoralism and ranching. Specifically, the objectives of the study were:

i) to analyze input use and socioeconomic characteristics of the farmers;
ii) to determine the technical efficiency of the beef cattle farmers and establish the differentials in technical efficiency between the three group of farmers;
iii) to examine the factors that determine the level of technical efficiency of the farmers.

Nomadic pastoralists (also referred to as nomads) typically have temporary abodes and migrate seasonally with cattle and other livestock in search for pasture and water. They are less commercialized, but derive a relatively large share of their livelihood from cattle and other livestock. In contrast, the agropastoralists are sedentary; within this system, livestock rearing and crop production are practiced interdependently, where livestock is grazed on harvested fields and animal manure is applied as crop fertilizer (Otieno et al., 2012). In comparison to the traditional pastoralist system where herders go in search of pasture and water during dry seasons, sedentary agro-pastoralists face additional challenges from land pressure and limited pastures for their cattle. However, agro-pastoralist system is more commercialized than the nomadic system. Ranches are purely commercialized livestock enterprises and may also grow a few crops for use as on-fodder or for sale. They mainly use controlled grazing on their private land, and purchased supplementary feeds, in contrast to both the nomads and agropastoralists that generally depend on open grazing, with limited use of purchased feeds. Investigating the TE of various beef cattle production systems in Nigeria should provide insights on how to better integrate livestock development into the national and economic agenda, as well as guidance to farmers on resource allocation.

There is an extensive literature on TE analysis on crop, dairy and mixed crop-livestock enterprises. However, published research on TE of beef cattle is very limited; exceptions include Otieno et al. (2012), Priyanti et al. (2012), Permani (2013), Mloti et al. (2013), Isyanto et al. (2013), Setianto et al. (2014), Nwigwe et al. (2015), Gayatri and Vaastr (2015), Cillero et al. (2016) and Gayatri et al. (2016). In Nigeria, where the livestock sector contributes about 31% of agricultural output (NBS, 2013; ABS, 2013), there are few studies on livestock systems, including beef cattle (Girei et al., 2013; Mamza et al., 2014; Nwigwe et al., 2016) but none of the studies except Nwigwe et al. (2015) emphasized on efficiency of the production systems. The studies undertaken on TE in Nigeria mainly focused on crops (Anyiro et al., 2013;
The rest of the paper is organized as follows: conceptual framework was first presented, followed by a description of the data source, variable measurements and empirical estimations. Results are thereafter presented, discussed and the study concluded.

CONCEPTUAL FRAMEWORK

Technical efficiency (TE) is defined as the ability of a firm to produce a maximum output from a given level of inputs, or achieve a certain output threshold using a minimum quantity of inputs, under a given technology. In other words, a measure of technical efficiency indicates the extent to which a farm could produce additional output without changing the levels of inputs used if it were to operate on the production frontier, which is determined by the best-practice farms. The level of technical efficiency of a particular farm is therefore characterized by the relationship between observed production and some ideal or potential production. The measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a farmer's actual production point lies on the frontier, it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to the potential production defining the level of efficiency of the individual farmer.

Farrell’s definition of technical efficiency led to the development of method for estimating the relative technical efficiency of farmers. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data to determine the best practice production frontier. From this the relative measure of technical efficiency for the individual farmer can be derived. There are two methods widely used in the literature to estimate technical efficiency. The first one is an econometric approach which aims to develop stochastic frontier models based on the deterministic parameter frontier of Aigner and Chu. The second is Data Envelopment Analysis (DEA), which uses a non-parametric approach or mathematically programming method that is useful for multiple-input and multiple-output production technologies.

The econometric approach is stochastic and parametric. It has the ability to separate the effects of noise from the effects of inefficiency and confound the effects of misspecification of functional form (of both technology and inefficiency) with inefficiency, but generates good results only for single output and multiple inputs. On the contrary, the mathematical programming approach is not stochastic and not parametric. It cannot separate the effects of noise and inefficiency during the calculation of technical efficiency, and less sensitive to the type of specification error, but could be useful to apply to farms with multiple-inputs and multiple-outputs production. Since beef cattle production in Nigeria is an example of single output and multiple-input production, this study focuses on the use of an econometric approach for measuring technical efficiency based on the production frontier model. A production frontier model can be written as:

\[ y_i = f(x_{ij}; \beta) + \varepsilon_i \quad (1) \]

where \( y_i \) is output of the \( i \) farm, \( x_{ij} \) is a vector of inputs used by farm \( i \), and \( \varepsilon_i \) is a “composed” error term. The error term \( \varepsilon_i \) is equal to \( v_i - u_i \). The term \( v_i \) is a two-sided \((-\infty < v_i < \infty)\) normally distributed random error (\( v \sim N(0,\sigma_v^2) \)) that represents the stochastic effects outside the farmer’s control (e.g. weather, natural disaster, and luck), measurement errors, and other statistical noise. The term \( u_i \) is a one-sided \((u_i \geq 0)\) efficiency component that represents the technical inefficiency of farm. The distribution of term \( u_i \) can be half-normal, exponential, or gamma. The assumption of term \( u_i \) in the study is a half-normal distribution \((u \sim N(0,\sigma_u^2)\) mainly used in the other studies. The two components \( v_i \) and \( u_i \) are also assumed to be independent of each other.

Equation 1 estimated by the maximum likelihood analysis creates consistent estimators for \( \beta \), \( \lambda \) and \( \sigma \), where \( \beta \) is a vector of unknown parameters, \( \lambda = \sigma_u / \sigma_v \), and \( \sigma_u^2 = \sigma_v^2 + \sigma_u^2 \). The technical inefficiency of individual farms can be estimated by using the conditional distribution of \( u_i \) given the fitted values of \( \varepsilon \) and the respective parameters. If we assume that \( v_i \) and \( u_i \) are independent of each other, the conditional mean of \( u_i \) given \( \varepsilon \) is identified by:

\[ E(u_i | \varepsilon) = \sigma_u \left( \frac{f(u_i; \lambda \varepsilon)}{1 - F(u_i; \lambda \varepsilon)} - \frac{\varepsilon_i \lambda \varepsilon_i}{\sigma} \right) \quad (2) \]

where \( \sigma_u^{-2} = \sigma_v^{-2} \sigma_u^{-2} / \sigma^2 \), \( f^* \) is the standard normal density function, and \( F^* \) is the distribution function, both functions being estimated at \( \varepsilon \lambda / \sigma \).

With the assumption of half-normal model, a simple z-test was used for examining the existence of technical inefficiency, the null and alternative hypotheses are \( H_0: \lambda = 0 \) and \( H_1: \lambda > 0 \). The test statistic is:

\[ Z = \frac{\lambda}{s_{\varepsilon \lambda} | \lambda \rangle} \sim N(0,1,2) \quad (3) \]

where \( \lambda \) is the maximum likelihood estimator of \( \lambda \) and \( se(\lambda) \) is the estimator of its standard error. The technical efficiency of the farms were estimated by using the following equation:

\[ TE_i = \exp(-\hat{u}) = \exp(-E(u_i / \varepsilon)) \quad (4) \]

\( TE_i \) is greater than zero and less than 1. The maximum
likelihood estimates of the parameters of function (1) and the farm-level $TE$ in (4) formular are achieved by using STATA version 11 software.

Several approaches are used to analyze the determinants of technical efficiency from stochastic production frontier functions. The first followed two-step procedure in which the frontier production function is first estimated to determine technical efficiency indicators while the indicators thus obtained are regressed against a set of explanatory variables which are usually firms' specific characteristics (Otieno et al., 2012; Olufemi et al., 2015). The major drawback in this approach is the fact that it violates the assumption of the error term. In the stochastic frontier model, the error term (the inefficiency effects) are assumed to be identically independently distributed.

In the second step however, the technical efficiency indicators obtained are assumed to depend on certain number of factors specific to the firm, which implies that the inefficiency effects are not identically distributed. This major drawback led to the development of more consistent approach which modeled inefficiency effects as an explicit function of certain functions specific to the firm, and all the parameters are estimated in one step, using maximum likelihood procedure (Mor and Sharma, 2012; Anyiró et al., 2013; Ohen et al., 2014; Watcharasakonpong and Thiengburanathum, 2016). The maximum likelihood procedure was therefore adopted in the present study due to its consistency.

**METHODOLOGY**

**Data source**

The study used survey data from six states (Oyo, Ebonyi, Delta, Adamawa, Sokoto and Niger) that are representative of the three beef cattle production systems in Nigeria, namely nomadic pastoralism, agropastoralism and ranching. Nigeria is found in the tropics, where the climate is seasonally damp and very humid. The natural vegetative zones that exist in the country are governed by the combined effects of temperature, humidity, rainfall and particularly, the variations that occur in the rainfall. The humid tropical forest zone of the south that has longer rains is capable of supporting crop production while the northern part of the country representing about 80% of the vegetative zones experience lower rainfall and shorter rainy season and they make up the savannah land. The savannah land forms an excellent natural habitat for a large number of grazing livestock such as cattle. Nigeria's agro-ecological zones can be classified into: mangrove forest and coastal vegetation; forest zone; derived guinea savannah; guinea savannah zone, sudan savannah (short grass savannah); sahel savannah (marginal savannah) and montane savannah. The areas sampled in the study represent different agro-ecological zones, but are contiguous, hence logistically more accessible.

A multi-stage sampling technique was used for the study. In each of the six states, 2 Local Government Areas (LGAs) were selected. Within the 2 LGAs, 4 smaller units (villages) were randomly selected from the list of all the villages in the LGAs, taking into account the general distribution of cattle in the study area. Subsequent stages involved a random selection of a sample of 5 locations. The primary sampling units for the survey were therefore 20 locations in each state. In each of the location, a random sample of respondents was drawn from the list of farmers; in total, 360 farmers including 55 ranchers, 97 nomads and 208 agropastoralists were interviewed. A structured questionnaire was used to collect data on resource inputs and output in beef cattle production, cultural practices of the farmers and their socioeconomic characteristics like age, education, household size etc.

With the assistance of well experienced extension officers, who were trained prior to the survey, the questionnaire was piloted, revised and then administered through face-to-face interviews of farmers between October 2013 and March, 2014. Due to incompleteness of some of the questionnaire, a total of 339 respondents were finally used for the analysis (39 ranchers, 92 nomads and 208 agro-pastoralists). A summary of the variables which were used in the analysis is presented in Table 1.

**Variable measurement**

Beef output was considered as the dependent variable in the study. Due to measurement difficulties, previous studies have used proxy variables such as physical weights of cattle; however, such data were not available in the present study. This study therefore followed the revenue approach employed by Otieno et al. (2012).

**Table 1.** Average input use, output and socio-economic characteristics of farmers by technology per hectare.

<table>
<thead>
<tr>
<th>Variable input</th>
<th>Nomadic system</th>
<th>Agropastoral system</th>
<th>Ranching system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (Kg/ha)</td>
<td>16,511</td>
<td>8,203</td>
<td>44,813</td>
</tr>
<tr>
<td>Farm size (Ha)</td>
<td>1.64</td>
<td>3.26</td>
<td>4.86</td>
</tr>
<tr>
<td>Herd size in number</td>
<td>49</td>
<td>42</td>
<td>53</td>
</tr>
<tr>
<td>Forage (Kg)</td>
<td>184.14</td>
<td>194.73</td>
<td>245.18</td>
</tr>
<tr>
<td>Feed/supplements (Kg)</td>
<td>21</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>Medicine/drugs (vials)</td>
<td>142</td>
<td>209</td>
<td>805</td>
</tr>
<tr>
<td>Family labour (Persons days)</td>
<td>204</td>
<td>198</td>
<td>102</td>
</tr>
<tr>
<td>Hired labour (Persons days)</td>
<td>621</td>
<td>273</td>
<td>1724</td>
</tr>
<tr>
<td>Household size (number)</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Age in years</td>
<td>47</td>
<td>47</td>
<td>44</td>
</tr>
<tr>
<td>Years of experience</td>
<td>21</td>
<td>20</td>
<td>17</td>
</tr>
</tbody>
</table>

Source: Field Survey (2014).

With the assistance of well experienced extension officers, who were trained prior to the survey, the questionnaire was piloted, revised and then administered through face-to-face interviews of farmers between October 2013 and March, 2014. Due to incompleteness of some of the questionnaire, a total of 339 respondents were finally used for the analysis (39 ranchers, 92 nomads and 208 agro-pastoralists). A summary of the variables which were used in the analysis is presented in Table 1.
The model is hereby expressed as:

\[ Q_{n(k)} = \frac{\sum_p w_p}{t} \]  

where \( Q_{n(k)} \) is the annual value of beef cattle output in the \( n^{th} \) farm in the \( k^{th} \) production system (measured in Nigerian Naira; N); \( r \) denotes any of the three form of cattle output considered (e.g. current stock, sales or uses for other purposes in the past twelve-month period); \( y \) is the number of beef cattle equivalents\(^{1}\) (conversion factor); \( p \) is the current price of existing stock or average price for beef cattle sold/used during the past twelve months; and \( t \) is the average maturity period for beef cattle in Nigeria, which is four years (FDLPCS, 2013). The output prices used were average market prices; this possibly controls for differences associated with various market types and ensures that TE measures are attributable to farmers’ managerial abilities.

The main inputs used for the study included herd size (proxy for capital in the classical production), feeds, medicine/drugs, labour, land and other inputs. The cattle herd size was computed as the average number of cattle kept in the past twelve months, adjusted with the relevant conversion factors. In order to capture the approximate share of feeds from different sources in each production system, the quantities of forage (or on-farm) feeds were first adjusted with the average annual number of dry and wet months, respectively, in each state following ABS (2014). Medicine/drugs were measured in vials. Due to measurement difficulties, the local herbs used especially by the Fulani in the treatment of their cattle were not considered.

Labour costs comprised both paid and unpaid labour; the latter valued using the average minimum farm wage in a particular agro-ecological zone. The labour costs were adjusted with the share of cattle income in household income. Land was measured as farmland (adjusted with the share of cattle income in household income). However, it was found to be highly correlated with feeds in agro-pastoralism. Further, it was difficult to establish owner-occupancy on land with respect to cattle production for nomads. Consequently, the use of imputed land rent (as input) was not suitable for this study.

Empirical model

Data were analyzed using the stochastic frontier model (Mliote et al., 2013; Cillero et al., 2016). The stochastic production frontier as an econometric method of efficiency measurement in production systems is built around the premise that a production system is bounded by a set of smooth and continuously differentiable concave production transformation functions for which the frontier offers the limit to the range of all production possibilities. It has the advantage of allowing simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficiency. Following Mor and Sharma (2012), the multiplicative stochastic production function is of the form:

\[ Q_i = f(X_{bi}, \beta) e^{v_i}, i = 1, \ldots, n; k = 1, \ldots, k \]  

where \( Q_i \) is the output of the \( i^{th} \) farm; \( X_{bi} \) is a vector of \( k \) inputs used in the \( i^{th} \) farm; \( \beta \) is a vector of parameters to be estimated and \( v_i \) is the farm specific composite residual term comprising of a random error term \( v_i \) and an inefficiency component \( u_i \).

\[ e_i = v_i + u_i, i = 1, \ldots, n \]  

The two components \( v \) and \( u \) are assumed to be independent of each other, where \( v \) is the two-sided, normally distributed error term \( (v_i \sim N(0, \sigma^2_v)) \) and \( u \) is one-sided efficiency component with a half-normal distribution \((u_i \sim N(0, \sigma^2_u))\). It follows that the maximum likelihood estimation of Equation (1) yields estimates for \( \beta \) and \( \lambda \), where \( \beta \) was defined earlier, \( \lambda = \sigma^2_u/\sigma^2_v \) and \( \sigma^2_v = \sigma_u^2 \). Battese and Corra (1997) defined \( \gamma = \sigma^2_u/\sigma^2_v \), so that \( 0 \leq \gamma \leq 1 \) and represents the total variation in output from the frontier attributable to technical efficiency. The farm specific measure of technical inefficiency can be determined from the conditional expectation of \( u_i \), given \( e_i \) as:

\[ E[u_i/e_i] = \frac{\sigma_u}{\sigma_v} \left[ \frac{f'(\lambda X/s)}{f'(\lambda X/s)} - \frac{\delta}{\sigma} \right] i = 1, \ldots, n \]  

where \( f \) and \( f' \) are the values of the standard normal density and distribution functions respectively, evaluated at \( e_i \). \( \alpha \) is the individual farmer’s level of technical efficiency \((TE_i) \) which is then calculated as:

\[ TE_i = \exp(-E[u_i/e_i]) \]  

such that \( 0 \leq TE_i \leq 1 \). The empirical model of the stochastic production frontier is specified as:

\[ l_n Y_{ij} = \alpha_0 + \alpha_1 l_n x_{ij} + \alpha_2 l_n X_{2ij} + \alpha_3 l_n X_{3ij} + \alpha_4 X_{4ij} + \alpha_5 X_{5ij} + \alpha_6 X_{6ij} + \alpha_7 X_{7ij} + \gamma V_{ij} - U_{ij} \]  

The subscripts \( i \) and \( j \) refer to the \( i^{th} \) farmers and \( j^{th} \) observation respectively while

\[ Y = \text{total farm output of beef cattle (Kg)} \] \[ x_1 = \text{Land for beef cattle production (Ha)} \] \[ x_2 = \text{Herd size of farmers (Kg)} \] \[ x_3 = \text{Quantity of forage consumed by cattle (Kg)} \] \[ x_4 = \text{Quantity of feeds/supplements consumed by cattle (Kg)} \] \[ x_5 = \text{Medicine/drugs administered on cattle (vials)} \] \[ x_6 = \text{Sum of labour (persons days)} \] \[ V_{ij} = \text{a random error term with normal distribution } N(0, \delta^2) \] \[ U_{ij} = \text{a non-negative random variables called technical inefficiency effects associated with the technical inefficiency of production of farmers involved} \] \[ l_n = \text{the natural logarithm (i.e. base e)} \] \[ \alpha_0, \alpha_6 = \text{parameters to be estimated} \]

This model was estimated for the three production technologies. Estimation of Equation 10 was accomplished by Maximum Likelihood Estimation (MLE) available in Frontier 4.1 and has been used extensively by various authors in estimating technical efficiency among farmers. Thus following Mliote et al., (2013) in which \( v_i \sim N(0, \delta^2) \) \( \gamma \), the following log likelihood function could be obtained:

\[ l_n X = \sum i I_n l_i = \sum i \left[ -l_n \delta - \frac{\delta^2}{2} \left( l_n - \frac{\delta}{2} \right) + l_n (C \delta^2) \right] \]  

Where \( i = \text{number of observations}, \delta = (\delta v^2 + \delta u^2)^{1/2} \)
Table 2. Maximum likelihood estimates of frontier model for nomads, agropastoralists and ranchers.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>T-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nomadic</td>
<td>Agropastoralist</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.6307**</td>
<td>0.8441***</td>
</tr>
<tr>
<td>Herd size</td>
<td>0.7993***</td>
<td>0.8391***</td>
</tr>
<tr>
<td>Forage</td>
<td>0.4492</td>
<td>0.7104***</td>
</tr>
<tr>
<td>Feed/supplement</td>
<td>0.0498*</td>
<td>0.8033***</td>
</tr>
<tr>
<td>Medicine/drugs</td>
<td>0.8883***</td>
<td>0.1112*</td>
</tr>
<tr>
<td>Labour</td>
<td>0.1959***</td>
<td>0.4012</td>
</tr>
<tr>
<td>AgroEzGu</td>
<td>0.1256</td>
<td>-0.2396***</td>
</tr>
<tr>
<td>AgroEzFo</td>
<td>0.6741*</td>
<td>0.5942</td>
</tr>
<tr>
<td>Age</td>
<td>-0.3543</td>
<td>-0.8862</td>
</tr>
<tr>
<td>Credit</td>
<td>-0.2200</td>
<td>-0.1214***</td>
</tr>
<tr>
<td>Experience</td>
<td>-0.9358</td>
<td>-0.2870***</td>
</tr>
<tr>
<td>Coopmembership</td>
<td>0.8680***</td>
<td>0.1140</td>
</tr>
<tr>
<td>Semi-formal-educ</td>
<td>-0.2686</td>
<td>0.1116</td>
</tr>
<tr>
<td>Formal-education</td>
<td>0.1125</td>
<td>0.2861</td>
</tr>
<tr>
<td>Sigma-square ($\sigma^2$)</td>
<td>0.2893***</td>
<td>0.2967***</td>
</tr>
<tr>
<td>Gamma ($\gamma$)</td>
<td>0.6376***</td>
<td>0.7278***</td>
</tr>
</tbody>
</table>

Source: Computed from Field Data (2014). AgroEzGu – Guinea savannah agroecological zone; AgroEzFo – Forest agroecological zone; Coopmembership – Cooperative membership; Semi-formal-educ – Semi-formal education; ***Significant at P ≤ 0.01; **Significant at P ≤ 0.05; *Significant at P ≤ 0.10.

\[ \lambda = \frac{\partial u}{\partial v}, \varepsilon_i = v_i - u_i \] and \( \theta \) is the normal distribution.

In addition to determining farmers’ technical efficiency in beef cattle production, the study also went further to identify the determinants of farmers’ technical efficiency in terms of socioeconomic variables and as such an inefficiency model was specified to examine the effect of these variables (z) on the technical efficiency (u_i) of the farmers in beef cattle production. The model which assumes that the inefficiency effects are independently distributed having \( N(0, \sigma^2) \) distribution and mean \( u_i \) of the form:

\[ u_i = \delta_0 + \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 \] (12)

where:

\( z_1 = \) Guinea Savanna agroecological zone (1 = Yes, 0 = No)
\( z_2 = \) Forest agroecological zone (1 = Yes, 0 = No)
\( z_3 = \) Age of farmers (years)
\( z_4 = \) Access to credit by farmers (1 = Yes, 0 = No)
\( z_5 = \) Farming experience of the farmers (years)
\( z_6 = \) Coopmembership = Membership of Cooperative society (1 = Yes, 0 = No)
\( z_7 = \) Semi-formal education = Attainment of semi-formal education (1 = Yes, 0 = No)
\( z_8 = \) Formal education = Attainment of formal education (1 = Yes, 0 = No)

**RESULTS AND DISCUSSION**

**Input and socioeconomic variables of beef cattle farmers by technology**

Average input use among the sampled farmers is presented in Table 1. Most of the beef cattle farmers are of the small and medium scale categories. Ranchers had relatively larger farms; it was observed that the average farm size of ranchers was 4.86 ha. The commercial ranching system is capital intensive and required specialized production skills and markets that demanded quality product, to ensure returns on investment. The average farm size among the agropastoralist was found to be 3.26 ha while that of nomads was found to be 1.64 ha. The mean herd size of the nomads was found to be 49 (TLU). It was also discovered that about 90.2% of nomads generally keep large herds of cattle of indigenous breeds such as Zebu and Boran, which were relatively well adapted to dry and hot areas, and are resistant to common local diseases but grow slowly and respond poorly to fattening. The average herd size of the agropastoralists was found to be 42 (TLU); the herd size which was found to be majorly made up of indigenous breeds is also like that of the nomads.

The proportion of mature males (bulls) in the agropastoralists’ herd composition was found to be extremely low, suggesting higher of take rates of males at relatively young age. The herd size of the agropastoralists was on the average smaller than those of the nomadic system, possibly because they did not solely rely on cattle production. The average herd size of the ranchers was found to be 53 (TLU). The animals were usually weaned, castrated and sprayed against tick-borne diseases. Compared with agropastoralists and...
Table 3. Frequency distribution of technical efficiency among the major beef cattle farmers.

<table>
<thead>
<tr>
<th>Range of technical efficiency</th>
<th>Frequency</th>
<th>Absolute percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nomadic</td>
<td>Agropastoral</td>
</tr>
<tr>
<td>&lt; 50</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>50 &lt; 60</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>60 &lt; 70</td>
<td>23</td>
<td>86</td>
</tr>
<tr>
<td>70 &lt; 80</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>80 &lt; 90</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>90 &lt; 100</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

Computed from Field Data (2014). Mean Technical Efficiency 59.00% (Nomadic); Mean Technical Efficiency 69.00% (Agropastoralists); Mean Technical Efficiency 83.00% (Ranching).

ranchers, nomads used less improved feeds (21 kg). This could be attributed to their nomadic nature, which made natural pasture more available to them. However, the ranchers used relatively less natural pasture (forage), per unit of output, which is an indication that they keep better cattle breeds. Agropastoralists incurred more veterinary costs (medicine/drugs), followed by the nomads. This could be due to the fact that agropastoralists’ farms are usually located in the interior, which made them to have relatively less access to subsidized veterinary services than the nomads and ranchers.

The nomads made use of 204 persons’ days of family labour, agropastoralists used 198 persons’ days of family labour while ranchers used 102 persons’ days. On the contrary, the ranchers used more of hired labour, followed by the nomads while the agropastoralists were the least in the use of hired labour. The amount of person’s days of labour recorded in each case for the three technology groups is a clear indication that Nigerian beef cattle production is still highly labour intensive. Ranchers however incurred more labour costs than the other production systems. This could be attributed to larger farm size and intensive production system employed by the ranchers. The average age of the nomads was estimated to be 47 years while that of the agropastoralists and ranchers was 47 and 44 years respectively. In the three production systems, it was discovered that the farmers were young and active; however, the average age is tending towards the declining productivity class of greater than 50 years. The implication of this is that except the occupation witnesses the injection of young able men, in the next one decade, many of these farmers would have reached the declining productivity level and beef cattle production in the country will suffer a setback.

The percentage of ranchers who had formal education was found to be 48.7% while that of nomads and agropastoralists was found to be 15.9 and 23.0% respectively. Nomads were found to be more experienced than the agropastoralists and ranchers with average of 20 and 17 years of farming experience respectively. Majority of the farmers in all the production systems were males; the mean household size across the production systems was found to be 11 persons. A higher percentage (59.0%) of ranchers used controlled cattle breeding, which involves use of artificial insemination (AI) or planned and monitored natural breeding rather than random natural breeding. This was consistent with the observation that the more commercially-oriented farmers (ie, ranchers and agropastoralists) preferred cattle breeding strategies that target market and/or profitability requirement, e.g. faster growth and higher gains in live weight, while the relatively less-commercialized nomads mainly focused on cattle survival traits such as drought resistance, hardness and disease tolerance (Otieno et al., 2012). It was finally discovered that about 71.8% of the ranchers had access to credit facilities while the agropastoralists had the least, followed closely by the nomads.

Technology and technical efficiency of farmers

Table 2 presents the result of the maximum likelihood estimates for the three groups of farmers while the distribution of technical efficiency among the farmers was presented in Table 3. The diagnostic statistics of the model showed log likelihood function of 73.221769, 107.89968 and 132.105385 for the nomadic, agropastoralist and ranching systems, which were significant at 1% level, indicating that the model had a good fit to the data. The mean efficiencies were found to be 0.59, 0.69 and 0.83 for the nomadic, agropastoralist and ranching production systems. From Table 3, herd size, feed-supplements, medicine/drug and labour contributed significantly to the technical efficiency of the farmers. The coefficient of the number of cattle (herd size) was positively significant at 1% level of significance across the three production systems, implying that herd size yielded a revenue increase of 0.79, 0.83 and 0.83 Naira in the nomadic, agropastoralist and ranching systems. In other words, the allocation and utilization of the herd size was in stage II of the production surface and thus it was efficiently allocated and utilized.
The coefficient of the feed/supplement for the nomadic system was 0.49 and positively significant at 10% level of significance, implying that feed/supplement yielded a revenue increase of 0.49 Naira. However, the coefficients of feed/supplement were 0.80 and 0.85 in the agropastoralist and ranching production systems and were significant at 1% level of significance, implying that feed/supplement yielded a revenue increase of 0.80 and 0.85 Naira in the agropastoralists and ranching systems. This result could be attributed to the fact that the nomadic system (nomadic pastoralist) which is a traditional cattle production system relies majorly on natural pasture (forage) for animal rearing; this is unlike the ranching system which is highly commercialized and also the agropastoralist system which usually face challenge from land pressure and limited pasture (forage) for their cattle due to the sedentary nature of the system.

The coefficient of medicine/drug were 0.88 and 0.79 for the nomadic and ranching systems respectively and was positively significant at 1% level of significance, implying that medicine/drugs yielded a revenue increase of 0.88 and 0.79 Naira for the two production systems respectively. In the case of the agropastoralist system, the coefficient of medicine/drug was 0.11 and positively significant at 10% level of significance, implying that it yielded a revenue increase of 0.11 Naira. The agropastoralists were found to expend more in purchasing medicine/drugs and other professional veterinary services as compared to ranchers and agropastoralists. This could be due to the fact that agropastoralist farms are usually located in the interior, which made them to have relatively less access to subsidized veterinary services than the nomads and ranchers.

The coefficient of labour were 0.19 and 0.99 for the nomadic and ranching systems respectively at 1% level of significance, implying that labour yielded a revenue increase of 0.19 and 0.99 Naira for the two production systems. However, it was discovered that labour was not significant in the agropastoralist system. The result could be attributed to the fact that agropastoralists usually own land rights which makes it possible for their farms to be located relatively close to their homesteads and therefore labour is more available to them than the nomadic and ranching production systems. It was also observed that forage which is a critical input in cattle rearing was not significant in the nomadic system. The result could be due to the fact that natural pasture (forage) is in abundance in the case of the nomadic pastoralists who migrate from place to place in search of pasture. However, forage was found to be significant in both the agropastoralist and ranching production systems.

There is presence of technical inefficiency effects in the beef cattle production systems in Nigeria; this is confirmed by the large and significant value of the gamma coefficient (γ). The signs and significance of the inefficiency model of the stochastic frontier production function had important implications on the technical efficiency of the production systems. In the nomadic production system, the coefficient of age, credit, farming experience and semi-formal education were found to be negative but less than unity. This indicated that these factors led to increase in technical efficiency. The coefficient of the agroecological zones and attainment of formal education were found to be positive and less than unity, which implies that these factors led to decrease in technical efficiency. These results can be attributed to their nomadic nature.

In the agropastoralist system, the coefficient of credit, farming experience and guinea savannah agroecological zones were found to be negative and more than unity. This indicated that these factors significantly led to increase in technical efficiency; the coefficient of age was also found to increase the technical efficiency. The coefficient of forest agroecological zone, cooperative membership and educational attainment were found to be positive and less than unity, which implies that these factors decrease the technical efficiency of the agropastoralist system. In the ranching system, the coefficient of guinea savannah agroecological zone, age, cooperative membership and educational attainment were found to be negative and more than unity. This indicates that these factors significantly led to increase in technical efficiency. However, forest agroecological zone and access to credit facility led to a decrease in technical efficiency in the ranching production system.

The mean technical efficiency of 0.59, 0.69 and 0.83 for the nomadic, agropastoralist and ranching systems showed that, given the level of technology of this group of farmers, there is still much to be done to increase their production capacity.

Limitations of the study

The collection of the needed data and its computation and subsequent analysis was a difficult part of the study. The unwillingness of some local sources (respondents) to provide necessary data, which led to the rejection of some questionnaire were also major limitations. Considering annual value of beef cattle output alone was also a limitation but due to measurement difficulties, physical weight of cattle could not be taken. Also due to measurement problem, the local herbs used, especially by the nomads in the treatment of their cattle were not considered.

Conclusion

The study examined the Technical Efficiency (TE) of the three major beef cattle production systems in Nigeria given the technologies. One major finding emanating from this study is the fact that increases in beef output in
Nigeria can be achieved by improving the performance of the production systems using the existing technologies since most of the critical inputs significantly influenced technical efficiency; also labour and herd size were identified as major inputs in beef production in Nigeria. Policy attention should therefore be directed towards providing labour saving technology to ease farm operation; emphasis should also be placed on hybrid development so as to increase the herd size of cattle. The study also showed that the technical efficiency of the three production technologies were significantly different at 5% level of significance; ranching system was found to have the highest mean efficiency of 83%, followed by the agropastoralists and then the nomadic system. There is need for further investigation into the factors that led to the difference in the technical efficiency of the systems; this kind of study will require different methodology and analytical approach. It will, however, provide better insight and useful explanations as regards the issue of technology adoption by the systems and why some farmers prefer to stick to the nomadic production systems in spite of its lower efficiency. Such study will also expose the difference in technology and perhaps environmental factors that could affect beef cattle production in Nigeria.

Conflict of interest

The authors have not declared any conflict of interest.

REFERENCES


Gayatri S, Gasso-tortajada V, Vaast M (2016). Assessing sustainability of Smallholder Beef Cattle Farming in Indonesia: A Case study using the FAO-SAFA Framework; J. Sustain. Dev. 9.3. ISSN 1913-9063 E-ISSN 1913-9071; Canadian Centre of Science and Education.


Isyanto AY, Semaen MI, Suyatril NH (2013). Measurement of Farm Level Efficiency of Beef Cattle Fattening in West Java Province, Indonesia; Journal of Economics and Sustainable Development; ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online) 4:10.


Priyanti A, Hanifah VM, Mahendri IGAP, Cahyadi F, Cramb RA (2012). Small-scale Beef Cattle Production in East Java, Indonesia; Contributed Paper prepared for presentation at the 56th AARES
Annual Conference, Fremantle, Western Australia, February 7-10, 2012.
Setianto NA, Cameron DC, Gaughan JB (2014). Structuring the problematic situation of smallholder beef farming in Central Java, Indonesia: using systems thinking as an entry point to taming complexity; Int. J. Agri. Manage. 3:3.