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Determinants of Profit Efficiency among Smallholder Beef Producers in Botswana

Sirak Bahta[ⓘa] and Derek Baker[b]

[a] *Agricultural Economist, International Livestock Research Institute, Private bag 0033, Gaborone, Botswana*

[b] *Professor of Agribusiness and Value Chains, University of New England Business School, Armidale, NSW 2351, Australia.*

Abstract

The livestock sector is vital to Botswana's rural economy comprising nearly two-thirds to the national agricultural sector. The goal of this research is to measure competitiveness and identify the factors affecting it, so as to advocate change in Botswana's smallholder livestock systems. The study examines a cross section of farm-level data gathered from 556 randomly selected livestock producers to investigate the profit efficiency and competitiveness of three farm size categories of small holder livestock farmers. Results found a considerable capacity to improve beef profitability. Scale effects on profit efficiency are generally positive, but the results indicate a number of interactions between scale and other variables such as off-farm income and the use of credit. Policy analysis and commercial decisions using models that assume efficiency are therefore presenting a misleading picture, particularly on the elusive subject of Botswana smallholders' beef supply response.

Keywords: competitiveness, stochastic frontier function, profit efficiency; inefficiency, policy, Botswana

[ⓘ]Corresponding author: Tel: + 2673668106
Email: S. Bahta: s.bahta@cgiar.org
D. Baker: Derek.Baker@une.edu.au

Introduction

Botswana's livestock sector provides about two thirds of national agricultural value added. Beef production is vital to the rural economy as a source of income and employment, and has been presented as a key investment and economic diversification opportunity (BIDPA 2006). Beef is moreover the country's major agricultural source of foreign exchange and generates about 80% of agriculture's contribution to GDP (NDP 2010), notably due to quota access to European markets.

Declining beef productivity during recent decades is seen as the basis of an erosion of competitiveness. Causal factors include many supply-side limitations surfacing as low off-take rates and high stock losses. Climatic constraints on arable crop production serve both to reinforce livestock's dominance of agricultural statistics and to limit options available for animal feeding. Beyond the farm gate, there is significant overcapacity in processing, with consequent low profitability in processing operations (FAO and MoA 2013, BIDPA 2006). Throughout the value chain, high costs of Sanitary and Phyto-sanitary (SPS) compliance are apparent, and on the demand side, reductions in EU beef support prices have adversely affected competitiveness. These factors have contributed in turn to the country's inability to utilize fully its preferential access to EU import markets.

The traditional livestock sector (featuring smallholder production), accounts for more than 80% of all Botswana's cattle (Nkhori 2004). However it faces numerous problems in production and marketing into export channels, which along with growing domestic beef demand result in an on-going shortage of beef for export. Constraints include high transaction costs, farmers' preferences for keeping animals to an advanced age, and lack of understanding of the various markets' quality requirements (Bahta et al. 2013).

Past studies of Botswana's beef competitiveness or profitability have investigated performance under various projected price regimes and trade agreements (BIDPA 2006, Jefferis 2007, ODI 2007), enterprise budgeting (Panin and Mahabile 1997, BIDPA 2006, FAO and MoA 2013), estimating multifactor productivity and technical inefficiency (Thirtle et al. 2000, Irz and Thirtle 2004) and exploring the beef value chain (FAO and MoA 2013, Bahta et al. 2013). Limitations of these studies include that they either failed to account for farmers' management-related adjustments to farm budgets in the presence of broader economic change, and/or that they assumed technical efficiency in terms of input use and production technology. Hence, efficiency has not been estimated and examined for its actual and potential influence on competitiveness and the factors affecting it. A further limitation of past work is the common treatment of the co-existing production systems: FAO and MoA (2013) demonstrates substantial differences in profitability across different technological models, but the analysis was based on a deterministic treatment of constructed household types rather than estimated from representative data. These limitations have meant that studies have not been made the basis for advocacy in terms of policy, technology, on-farm management, nor rural and regional policy.

The current study employs the profit efficiency approach (Delgado et al. 2008) to address these shortcomings using farm-level cross sectional survey data collected under the auspices of a development research project.[1] The survey was implemented in three districts (Southeast, Chobe and Central) of Botswana. It collected detailed information on costs of and returns to livestock production, along with selected technical, physical and demographic variables for farm household operations across a range of farm sizes.

The goal of this study is to measure competitiveness and identify the factors affecting it, so as to advocate change in Botswana's smallholder livestock systems. The approach taken is to derive a statistical measure of profit efficiency, using a stochastic profit frontier approach as a yardstick. The profit frontier represents a "best case", and results' shortfall within the frontier representing inefficiencies as a distance "below" the frontier. This approach in turn provides information that is useful in assessing the effect of social and economic indicators on profit inefficiency. The identification of the determinants of profitability/profit efficiency will assist in determining commercial and policy options for enhancing profitability of beef production and hence competitiveness at farm level. In order to understand better the underlying drivers of efficiency and inefficiency, and to motivate advocacy in pursuit of competitiveness, the study estimates profit efficiency separately for three farm size groups.

Subsequent parts of the paper are organized into as follows: literature review is discussed in section two, while the methodological approach, which includes the empirical estimation followed in the study and the descriptive analysis, is explained in the third section. Results are presented and discussed in section four. Finally some conclusions and policy implications of such findings are offered as a fifth section.

Literature Review

In agribusiness, a competitive firm/farm is one that has the ability to produce and sell quality products in a given market at a profit, over the life of the firm. Kennedy et al. (1998) define competitiveness as the ability of a business to profitably create and deliver value at prices equal to or lower than those offered by other sellers in a given market. Latruffe (2010) defines it as the ability to sell products that meet demand requirements in terms of price, quality and quantity and at the same time ensure profits over time that enable the firm to thrive. Agriculture Canada (1991) defines it as a sustained ability to profitably gain and maintain market share. Numerous studies have been undertaken to determine profitability of different agricultural enterprises, including livestock in both emerging and developing countries (Banse et al. 1999; Delgado et al. 2008; Emam and Salih 2011; Longwe-Ngwira et al. 2012; Staal 2002; Thorne et al. 2002). Productivity and efficiency are also often cited as indicators or measures of competitiveness or profitability (OECD 2011), and this is reflected in empirical approaches to the measurement of efficiency: essentially measuring the potential input reduction or potential output increase relative to a benchmark, or frontier (Alvarez and Arias 2014).

The frontier can be technically identified by non-parametric and parametric methods (Latruffe 2010). The non-parametric approach uses mathematical programming techniques, of which the

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most widely used is data envelopment analysis (DEA) (Mester 2003). This has the desirable empirical attributes of imposing neither functional form specification, nor assumptions about the nature of an error term (Tran 2009). However, its limitations include non-inclusion of prices so as to account only for technical inefficiency in the form of using too many inputs or producing too few outputs (Mester 2003); and its implicit assumption of the absence of random errors. The DEA technique uses two-stage estimation procedure where the production (or profit) function is estimated to derive the efficiency scores in the first stage. In the second stage the derived efficiency scores are used as explanatory variables in a profit function to be estimated econometrically. Further, DEA ignores a management-related issue in that the firm's input choices are potentially affected by that firm's knowledge of its level of technical efficiency (Chirwa 2007). Wang and Schmidt (2002) extend this reasoning to criticize the two-stage estimation process.

Parametric analysis of efficiency uses econometric techniques to estimate a frontier function. The stochastic frontier analysis (SFA) (Aigner et al. 1977) is the most commonly used parametric approach. SFA requires specification of a functional firm for the frontier production function. However, the major distinguishing feature between these two approaches lies on the assumptions about the distributions of the error terms (Hyuha 2006). SFA's major advantages are its estimation using a single-step procedure and its accommodation of measurement errors and other noise in the data (Kolawole 2006), and this is an important consideration in the current study which uses farm-level survey data.

The SFA approach estimates the frontier production (or profit) function and an inefficiency model simultaneously, in which inefficiency effects are specified as a function of other variables (Chirwa 2007). It effectively specifies the relationship between output and input levels and decomposes the error term into separate components representing random errors and inefficiency. The random error is assumed to be normally distributed with zero mean and a constant variance. Importantly, the random error term's distribution is symmetric, in contrast to that of the (asymmetric) inefficiency term which is expressed as a half-normal (truncated normal) exponential or two-parameter gamma distribution. Empirically, this approach distinguishes a functional form for the cost, profit, or production functions.

Selection of the SFA method then requires a choice between the direct (primal) and dual specification of the estimation (Mohammed et al. 2013). The direct approach specifies the production function, extended onwards to derive input demand and product supply functions with a priori specification of the production function. In contrast, these derived functions are obtained in the dual specification with no *a priori* specification of the production function. The current study adopts the SFA approach and the dual approach, due to the nature of the data. A profit, rather than cost, function is estimated because of the limitation of the latter in that it assumes output levels are unaffected by factor price changes (Lopez 1982). In addition, in the cost function, the dependent variable (by definition) does not allow consideration of revenues (Mester 2003). Development of advocacy from SFA studies is discussed by Alvarez and Arias (2014). Enterprises' movement toward the frontier by way of the most direct route (i.e. closing the distance by the shortest route) may in fact not enhance efficiency *per se* due to firms' unique resource endowment and unique price and cost environment. Rather, those authors discuss mechanisms for identification of peer groups of firms, albeit nearer the frontier, migration towards which may offer greater increases in efficiency. These considerations are valid in Botswana's cattle production systems where categorization has traditionally been by land tenure type, which has loosely approximated large and small sizes of operation. The current study offers an advance in this regard by first further subdividing farm size categories for separate SFA estimation, and second by rigorously examining between-farm differences for their influence on efficiency.

Methodological Approach

Empirical Model

The stochastic profit frontier, as explained above, requires two stages of reasoning. The first explains each observation's unit profit performance in terms of technical and allocative efficiency and the second stage explains differences in efficiency in terms of farm-specific variation.

The data set revealed few farms with zero or negative profit for the survey year, but where this occurred, the addition of a constant scalar *n* to the profit data was used to meet the requirement of non-zero positive profit values imposed by logarithmic transformation. This step was seen to be preferable to dropping observations, and the resulting bias from a non-linear transformation of the data is judged to be of minor importance (Delgado et al. 2008) compared to the bias that would arise from using a less appropriate functional form or arbitrarily dropping the sample's least efficient members.

Profit efficiency, in this study, is defined as profit gain from operating on the profit frontier, taking into account farm-specific prices and factors. And, considering a beef farm that operates to maximize its profit subject to perfectly competitive input and output markets and a singular output technology that is quasi-concave in the (n x 1) vector of variable inputs, and the (m x 1) vector of fixed factors, Z, the actual normalized profit function which is assumed to be well behaved can then be derived as follows:

Farm profit from beef is measured in terms of gross margin (GM)[2] which equals the difference between the total revenue (TR) and total variable cost (TVC) and is given by:

(1) $$GM\ (\pi) = \sum(TR - TVC) = \sum(PQ - WX_i)$$

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

$$GM(\pi) = \sum(TR - TVC) = \sum(PQ - WX_i)$$

[2] Considering the inclusion of fixed costs as independent variable in the equation, π is gross margin which is used as a proxy for profit. However, for the sake of consistency with the literature we referred π as profit as profit subsequently.

To normalize the profit function, gross margin (π) is divided throughout by P (the market price of beef output) to obtain:

$$(2) \qquad \frac{\pi}{P}(P,Z) = \frac{\sum(PQ - WX_i)}{P} = Q - \frac{WX_i}{P} = f(X_i, Z) - \sum P_i X_i$$

Where TR is the total revenue from cattle activity, TVC are total variable costs (feeds, fodder, hired labor, electricity, medicines and vaccines, water, transport etc.), of securing revenue (excluding family labor) per farm i; Q is beef output; X represents the (optimal) quantity of input used; Z represents fixed inputs, p_i = W/P which represents normalized price of input X_i while f (X_i, Z) represents the production function.

The attempt to use a translog production function approach used in Delgado et al. (2008) is failed due to high multicollinearity between the interaction and individual variables. In fact, Delgado et al. (2008) have neither mentioned any incidence of collinearity of independent variables nor indicated any treatments used in their work to avoid such cases.

Although the second order flexible form, such as translog function, quadratic e.tc, provide more flexibility due to supplementary parameters to estimate, it may give rise also to econometric difficulties (e.g., multicollinearity) (Coli et al. 2005). It is expected that the great number of parameters that have to be estimated in functional forms such as translog production function impose hard constraints on the result feasibility, since the occurrence of an extended collinearity is favored (Pavelescu 2011).

Our preliminary analysis[3] of translog production function showed the presence of high multicollinearity between interaction and individual variables, thus a Cobb-Douglas production function is considered for this study.

The Cobb-Douglas profit function was employed, which is expressed as:

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

where π, p_i, and Z are as defined above. The v_i is assumed to be independent and identically distributed random error, having normal $N(0, \sigma^2)$ distribution, independent of the u_i. The u_i is profit inefficiency effect, which is assumed to be non-negative truncation of the half-normal distribution$N(\mu, \sigma^2)$. In estimation we seek to capture, or assign to individual farms, farm-specific effects on inefficiency, following Battesse and Coelli (1995).
The Cobb-Douglas functional form for estimation is specified as:

$$(4) \quad ln\pi = ln\beta_0 + \beta_1 lnp_{1i} + \beta_1 lnp_{2i} + \beta_1 lnp_{3i} + \beta_1 lnZ_{1i} + \beta_1 lnZ_{2i} + \beta_1 lnxZ_{3i} + (v_i - u_i)$$

[3] Prior test of multicollinearity in STATA 11 show the presence of high multicollinearity between interaction and individual variables. (As a rule of thumb, a variable whose VIF values are greater than 10 may merit further investigation. Tolerance, defined as 1/VIF, is used by many researchers to check on the degree of collinearity (STATA Web books 2013)).

Where π represents the normalized profit, p_1 represents feed prices, p_2 represents veterinary prices, p_3 represents the wage prices, Z_1 represents total fixed capital, Z_2 represents total family labor hours, Z_3 represents crop land sizes and β's are the unknown parameters be estimated.
As indicated above the non-negative random variable (u_i) is independently distributed with a truncation at zero of the normal distribution, $u_i \sim {}^{+}N\ (\mu, \sigma^2_u)$ with mean μ, where $\mu_i = M_{ik}\delta_k$ as defined below.

The technical inefficiency effects (u_i) in equation (4), can then be specified as:

$$(5)\quad ui = \delta_0 + \sum_{k=0}^{l} M_{ik}\,\delta_k + v_i$$

where v_i is the inefficiency error term as defined earlier and the M_{ik} are k socio-economic and farm enterprise explanatory variables (age of household head, education of household head, annual household non-farm income, average distance to commonly used market, herd size measured in beef equivalent[4]and a dummy variables for gender, information access, farm location in FMD disease zone classification, access to income from crop activities and access to credit) observed for farm i, and δ is a vector of unknown coefficients to be estimated simultaneously with equation (4).

The variance of the random errors, σ_v^2 and that of the profit inefficiency effect σ_u^2, and the overall variance of the model σ^2 are related as follows: $\sigma^2 = \sigma_v^2 + \sigma_u^2,$ which measures the total variation in the deviation of profit from the frontier (Battese and Corra 1977). The Likelihood Ratio of the errors in equation (4) provides the log likelihood function (Battese and Coelli 1995) and estimates:

$$(6)\quad \gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$$

where γ (gamma) represents the share of inefficiency in the overall residual variance with values in the 0, 1 interval. Gamma between 0 and 1 indicates the presence of inefficiency. A value of 1 suggests a deterministic frontier and, that inefficiency effects are important explainers of profit across farms. Conversely a γ value of 0 indicates the absence of inefficiency. Such absence of inefficiency favors OLS estimation due to the absence of u_i in (3): this property of the specification is utilized below in model validation.

[4]Following (Otieno 2012; Hayami and Ruttan 1970; O'Donnell et al. 2008), beef cattle equivalents were computed by multiplying the number of cattle of various types by conversion factors. Following insights from discussions with BMC (Botswana Meat Commission), the conversion factors were calculated as the ratio of average slaughter weight of different cattle types to the average slaughter weight of a mature beef bull. The average slaughter weight of mature bull, considered to be suitable for beef in Botswana, is between 452-500kg. according to BMC, the average slaughter weights for castrated adult males (oxen>3 years), Immature males (< 3 years), Cows (calved at least once), Heifers(female ≥1yr,have not calved), Male calves (between 8 weeks&<1year),Female calves (between 8 weeks&<1year), , Pre weaning males (<8 weeks), Pre weaning females (<8 weeks) are 400kg, 350kg, 390kg,300kg,250kg, 220kg,95kg and 95 kg, respectively. The calculated average slaughter conversion factors were then: 1.0, 0.86, 0.76, 0.84, 0.65, 0.48, 0.54,0.21 and 0.21, for Bulls, castrated adult males, Immature males , Cows, heifers, Male calves, Female calves, Pre weaning males and Pre weaning females, respectively.

The profit frontier and inefficiency functions specified in equations (4) and (5) were jointly estimated using FRONTIER 4.1 (Coelli 1996), which combines the two-stage procedure into one: the maximum likelihood method estimates the parameters of the profit function, and those of the inefficiency model. Two estimation procedures, OLS and ML were used to establish whether or not profit efficiency in beef production in Botswana is affected by farm-specific characteristics. The first model is the traditional OLS response function in which the efficiency effects are not present (u_i=0), which is a special case of a stochastic frontier production function model in which the total variation of output due to technical inefficiency is zero, recorded as $\gamma=0$. The second model is the general model with $\gamma\neq0$. The two models were compared for the presence of profit inefficiency effects using the generalized likelihood ratio test which is defined by the chi-square test statistic $\chi^2=-2\ln\{H_o/H_a\}$, where χ^2 has a mixed Chi-square distribution set at α% per cent level of significance and k+1 degrees of freedom, where k is equal to the number of parameters (M_k) used in the inefficiency model (Ngwenya et al. 1997). H_o is the model under the null hypothesis that $\gamma=0$, and is entered as the value of the likelihood function for the frontier model under H_o. H_a has similar interpretation under the alternative hypothesis that $\gamma\neq0$.

Determinants of Competitiveness and Profit Efficiency

Several researchers have identified an inverse relationship between farm size and productivity (Buckwell and Davidova 1993, Cornia 1985; and, Staal 2002), with supporting arguments involving small farms' not requiring labor supervision and other organisational delegation, and also the clear profit motivation of family labor. Lapar et al. (2005) focused on cost structures to find that small dairy farms were more cost efficient than were large ones, and hence more profit efficient. However, a counter-argument in the developing country context draws on large farms' available economies of scale and superior access to both output and input markets. Correlation between farm size and profitability and/or efficiency has on this basis been demonstrated (Delgado et al. 2008, Hall and LeVeen 1978, Kolawole et al. 2006, Nganga et al. 2010). A continuum of farm size may also be associated to some degree with forms of production systems, and indeed this is the way in which FAO and MoA (2013) chose to subdivide farms into deterministic subsets. Social capital has been used to explain farm performance as a proxy for farmer's management capacities which are not directly observable (Latruffe 2010). Evidence on the effect of farm managers' ages on technical efficiency or productivity is ambiguous. Negative effects may be due to older farmers' resistance to change and unwillingness and inability to adopt technological innovations (Brummer and Loy 2000). Moreover, older farmers are at or near their exit stage may reduce their commitment to business and profit maximisation as other priorities appear (Rakipova et al. 2003, Nganga et al. 2010). Age may also influence farm performance positively as older farmers are more experienced, and notably, can apply accumulated knowledge to the efficient use of inputs (Kalowole et al. 2006, Lapar et al. 2005, Mathijs and Vranken 2001, Otieno et al. 2012, Amara et al. 1999).

Farmers' education level is expected to positively influence farm performance. Kolawole et al. (2006), Latruffe (2010), Nganga et al. (2010), Mathijs and Vranken (2001), and Otieno et al. (2012) found a positive relationship between education and technical efficiency. Stonikov (1998) however, found the opposite and explains this counter-intuitive relationship on the specificity of agricultural education in Russia at that time, which concentrated more on technological aspects of production than on management practices.

Chavas et al. (2005) found that gender cannot explain differences in farm technical efficiency. However, Timothy and Adoti (2006) found that female cassava farmers in Nigeria showed superior technical efficiency than did their male counterparts, but lower allocative efficiency. These latter authors attribute differences in efficiency between female and male farmers to differential access to inputs.

Off-farm work is likely to influence the efficiency of a farm, but the sign of the relationship may be disputed: farmers who spend time doing off-farm work reduce their time spent on efficiency-improving managerial activities. Conversely, spending time off the farm might improve farmer's ability through the acquisition of information and knowledge and hence farm performance. Further, off-farm work can assist in accumulating capital which when invested on the farm can increase efficiency. Otieno et al. (2012) found a positive relationship between off farm income and profit efficiency and argue that this suggests that there is considerable re-investment of off-farm earnings into farm production. Rakipova et al. (2003) argue that this is consistent with the hypothesis that producers with off-farm work must compensate for the time they spend off-farm, making more efficient use of their own labor and management. Thus, they become better managers and are more efficient in the use of resources.

Descriptive Analysis of the Study Area

A multi-stage cluster (area) sampling approach (Horppila and Peltonen 1992) was used to select a sample from the population. First, to account the differences in farming system, ecology and soil type, to form six clusters, the Central district (Botswana's largest district) was divided into four sub districts, namely Serowe, Letlhakane, Selebi-Phikwe and Nata.[5] Within a cluster, extension areas[6] were randomly selected from lists of all extension areas, taking into account the general distribution of cattle in the study area. Subsequent stages involved a random selection of crushes[7] or sample of locations, from which a number of farmers were randomly selected.
The Central agricultural district as a whole kept 25.9 per cent of the national cattle herd in the traditional sector. The reason for this is that the region has vast tracts of land suitable for cattle farming, and that some parts of the region, around Nata and Selebi-Phikwe, are largely free of transboundary diseases.

The South East administrative region is adjacent to Gaborone, the capital of Botswana, and its district headquarters (Ramotswa) is about 40 kilometres from Gaborone. The agricultural district is known as Bamelete/Tlokweng and is one of the five districts forming the Gaborone Agricultural Region (Statistics Botswana 2014). The district held 32,433 cattle which represented 1.6 per cent of Botswana's total cattle herd, while the cattle holdings represented 3.6 per cent of the total cattle holdings (Table 1).

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[5] The data for the study was collected from three districts in the agricultural region; Serowe, Selebi-Phikwe, Letlhakane and Nata in Central Administrative District, but falling under Tutume Agricultural District in Francistown Agricultural Region. The Central Agricultural Region had a total of 654,058 cattle of which 125,086 in Serowe, 207,681 in Letlhakane, 71,144 were in Selibe-Phikwe, and 181,411 in Nata (Table 1).

[6] Extension areas are areas with in districts that are classified based on delivery of agricultural extension services.

[7] A crush is essentially an administrative area for national livestock administration. Normally the veterinary district offices keep list of farmers by crushes. Thus, list of farmers was provided by crushes for each extension area in respective district/sub district.

The Chobe district lies on the north western part of Botswana and is predominately a tourist area with rich wildlife resources. The district forms the Maun Agricultural Region, together with Ngamiland East and Ngamiland West. Table 1 show that in 2012 the proportion of the national cattle herd held in the district was 0.15 per cent.

Table 1. Cattle Holdings and Population District and Region

District/region	Cattle Holdings	Cattle Population	Traditional Cattle Holdings (%)	Traditional Cattle Population (%)
Southeast	1,379	32,433	3.6	1.6
Serowe	2,727	125,086	3.8	5.5
Letlhakane	2,497	207,681	3.5	9.2
Selebi-Phikwe	1,392	71,144	1.9	3.1
Nata	6,632	181,411	9.2	8.0
Central region*	13,248	654,058	18.4	25.9
Chobe	253	3,348	0.4	0.15
Total in sampled area	14,880	675,052	22.3	27.6
Botswana total	72,116	2,260,262	100.0	100.0

This figure for central district includes the in the figures in Nata, which falls under Tutume Agricultural Region.
Source. Statistics Botswana (2014)

This low proportion of cattle in the Chobe area is due to the large national parks and forest conservation areas, and Tsetse fly infestation. Lastly, the area is home to buffaloes, which carry Foot and Mouth Disease (FMD) and so is considered a “red zone” or “FMD area” by the World Organization of Animal Health (OIE) and Botswana’s Department of Veterinary Services in association with export market access conditions. Farmers in the area are not allowed to trade to other regions, nor deliver to BMC, without 21 days’ quarantine. The Chobe area was included in this study to explore the differences in competitiveness of farmers in FMD and non-FMD areas. The locations sampled, and details of cattle numbers, are presented in Table 1.

Figure 1 show the share of cattle outflows in the total cattle population of smallholder and commercial ranches for the year 2012. During the period under review, the traditional (smallholder) farms experienced higher mortality than the commercial farms. Cattle sales in the traditional sector are very low; accounting for less than half of commercial sector’s sales. The larger share of sales and lower shares of losses, in the commercial sector are relevant to efficiency considerations.

During the study period[8], the traditional (smallholder) farms experienced higher mortality than did the commercial farms. Cattle off-take rates and sales in the traditional sector are very low; accounting for less than half of the commercial sector’s off-take rate and sales, respectively. The larger share of sales and lower shares of losses in the commercial sector are relevant to efficiency considerations.

[8] The field survey was conducted from June to end of July 2013. The information collected is based on the past 12 months (June-July 2012- June-July 2013).

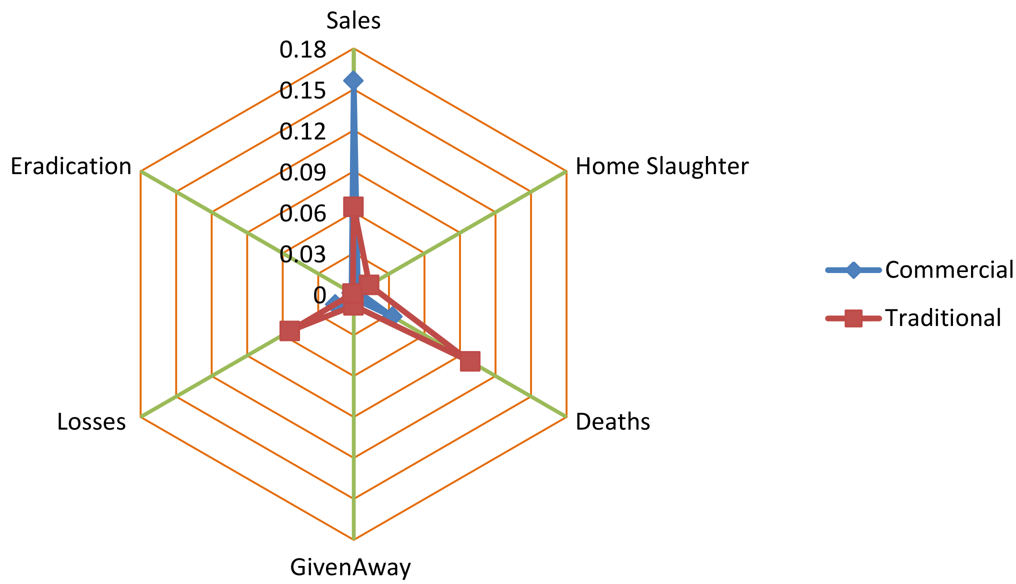

Figure 1. Cattle outflow in smallholder and commercial livestock farms in Botswana
Source. 2012 Annual Agricultural Survey Report (2014)

A structured questionnaire was used to record data. The main variables captured included detailed information on costs of production inputs such as feeds, veterinary supplies and advisory services and labor and fixed inputs, and returns to beef farming. Information on input costs was collected based on farm households' expenditures. Output prices on each type of animal sold in the various market channels are used to calculate an average output price and hence returns to beef production. In addition to the cost and revenue information necessary to calculate profits, the questionnaire elicited information on cattle breeding method, disease prevalence and mitigation, access to extension services and markets, and household demographic characteristics.

Selected characteristics of the farm survey sample, subdivided according to herd size[9], are shown in Table 2. Farmers who own more than 20 beef equivalent (herd size category 3 =HS3) have significantly higher annual values of beef cattle output than do those in other size groups. Similarly, as shown by ANOVA analysis indicated by F-Statistic value, average prices received per head (beef equivalent) varies significantly across the three categories of herd sizes.

Costs of variable inputs for livestock production significantly increase with increasing herd size with farms with over 20 beef equivalent cattle (HS3) incurring highest input costs. Across the whole sample, an average household/farm annually spends P605.57[10] for feed, P650.89 for veterinary requisites and P2853.32 for paid labor. Expressed per month, paid labor amounts to about 238 Pula, which is lower than the government-approved farm workers' minimum wage of P408 for 2011/12 and P445 for 2012/13. The reason for this could be explained by non-monetary

[9] The sample is divided in to four groups of herd size. Herd size 1 (HS1) include farms that own less than 10 beef equivalent cattle, Herd size 2 (HS2) include farms who own between 10 to 20 beef equivalent cattle and Herd size 3 (HS3) includes farms who own above 20 beef equivalent cattle. The pooled sample is sample that includes all observations.
[10] Pula abbreviated by P is the currency Botswana with the exchange rate to USD at 1P=0.1159USD (FNB, 2013)

rewards and the known widespread use of family labor, with each farm reporting 210 hours spent monthly.

About 48% of the survey respondents reported that they have received income from crop farming and on average a farm household reports owning about 6.19 ha of crop land. Income from crop production and land size for crop production both slightly increase with the increase in herd size categories, however, there are no significant differences among the three farm groups in this regard. On average a farm household has an annual non-farm income of about 54,815.57 Pula with herd size group 3 receiving almost twice that of herd size group one. Generally farmers have little access to credit: just 2.3% of farmers report having accessed credit during the study period.

Table 2. Sample Summary Characteristics

Variables	HS1 (N=238)	HS2 (N=140)	HS3 (N=178)	Pooled (N=556)	F- statistics
Value of beef Cattle output (Pula per year)	2,076.4	58,60.1	11,215.8	5,955.0	0.000
Average Beef cattle price (Pula)	1,772.3	2,081.4	2,218.7	1,993.0	0.000
Feed cost (Pula per year)	264.6	782.71	922.18	605.6	0.002
Veterinary cost (Pula per year)	296.0	565.92	1,192.2	650.9	0.000
Paid labor cost (Pula per year)	1,450.5	2,765.83	4,797.8	2,853.3	0.000
Cost of other inputs (Pula per year)	3,53.9	725.36	1158.0	704.9	
Value of fixed capital (Pula)	22,170.9	48,869.9	343,544.6	131,779.5	0.006
Total crop land area (Hectares)	4.9	6.88	7.30	6.19	0.198
Family labor (hours per month)	201.5	226.85	209.17	210.3	0.585
Age of household head (Years)	58.9	59.9	60.9	59.8	0.440
Gender (% female farmers)	31.1%	22.1%	10.1%	22.1%	0.000
Education of Household head (years)	4.1	4.24	6.62	4.95	0.000
Household Off farm income (Pula per year)	41,372.6	48,535.9	77,728.8	54,815.6	0.000
Distance to market (Km)	28.9	29.58	61.83	39.7	0.000
Herd size (Beef cattle equivalent)	5.3	14.45	55.99	23.9	0.000
Information access (Yes=1, No=2)	73.5%	79.3%	79.2%	76.8%	0.288
FMD disease zone (Yes=1, No=2)	36.6%	39.3%	53.9%	42.8%	0.001
Crop income (Yes=1, No=2)	43.3%	52.9%	51.7%	48.4%	0.112
Credit access	1.3%	2.9%	3.4%	2.3%	0.333

Note. [1] Pula = 0.1159 USD (FNB, 2013)

In terms of demographic characteristics, Table 2 shows that the average age of the household head is 59.79 years with no significant differences across the farm groups, implying that the majority of the farmers are elderly.

The respondents report on average 4.95 years of schooling. Farmers in herd size category 3 (the largest operations) have significantly more educational background (6.62 years) than the other groups. However, overall it appears that the majority did not attend schooling or attended only up to primary school level (which takes seven years).

The overwhelming majority are male (69, 78 and 90 per cent in herd size category 1, 2 and 3, respectively), suggesting that cattle farming is predominately a male activity. This figure is however, higher than the figure reported by the 2012 Annual Agricultural Statistics (Statistics Botswana 2014) survey which reported national average of 65 per cent cattle holdings being held by males.

When asked about access to information on their livestock enterprises and marketing, the majority (76.8 per cent) indicated that they had such access. The average distance from the commonly-used market is 42.8 kilometres, but farmers owning less than 10 (HS1) and 10-20 (HS2) beef equivalent cattle report accessing markets within 30 kilometres while farmers who own large size of herds (HS3) report much greater distances to markets, as far away as about 62 kilometres. On one hand this implies that smaller scale livestock farmers do not use distant markets as they are less endowed with assets such as car/truck, but may also suggest that distance to an attractive market is a constraint for larger farms. The sizeable proportion (43 per cent in the pooled sample and 53% in HS3) of farms located in FMD areas (Chobe, Selibe-Phikwe, and Nata) also may suffer from isolation from markets due to exclusion from supply to BMC and quarantine-related movement control as described above.

Results and Discussion

Profit Frontier Estimates

Profit inefficiency as indicated by the value of value of gamma (γ) was detected by the generalized Log Likelihood Ratio test as described above. Table 3 shows that the estimated value of γ is significantly different from zero, suggesting that, depending on the magnitude of γ, the profit variations occur both as a result of farmer inefficiency and exogenous factors outside the farmers' control. This effect strongly dominates measurement error and other random disturbances.

Table 3. Stochastic Profit Frontier Estimates

Variables	HS1	HS2	HS3	Pooled
Constant	-0.08	1.11	2.01	2.61
Ln (Feed)	-0.24*	-0.30**	-0.23	-0.26***
Ln (Veterinary costs)	-0.23	-0.43**	-0.43**	-0.44***
Ln (Labor)	-0.15***	-0.11	-0.18**	-0.004
Ln (Fixed capital)	0.03**	0.02	0.02	0.01
Ln (Family labor Hours)	0.06*	-0.07	-0.16*	0.003
Ln (Crop land area)	0.05	0.05**	0.08*	0.05***
σ^2	0.21***	0.44***	0.69***	0.44***
Gamma (γ)	0.72***	0.65*	0.68*	0.74***
log likelihood function	-147.6	-138.59	-219.35	-561.98
LR test of the one-sided error	-24.6	17.12186	21.20	70.25

Notes. Statistical significance levels: ***1%; **5%; *10%. HS1= Herd size group, HS2=Herd size group1and HS3= Herd size group[1]

That is, the variation in actual profit from maximum profit (profit frontier) between farms (about 72%, 65%, 68% and 74% per cent in HS1, HS2, HS3 and pooled sample, respectively.) mainly arises from differences in farmers'practices rather than from random variation.

The generalized Log Likelihood Ratio test defined by a Chi-square (x^2) distribution set at 1% level of significance and 11 degrees of freedom was significantly different from zero in all models (Kodde and Palm 1986). The null hypothesis was thus rejected indicating that the stochastic frontier production function fits the data. The value of σ^2 is also significant implying that the technical efficiency equation can explain the differences between each farm's profit and the profit on the frontier function.

Table 3 further shows that the parameter estimates for the first stage explanatory variables have the expected signs and are statistically significant, except family labor in the herd category three (HS3).

The effects of all input prices (except labor) are negative and statistically significant in the pooled sample. Feed prices have a significantly negative effect on profits in all herd size categories. The parameter estimates for fixed factors: capital (fixed capital); family labor (family labor); and crop land size (crop land area); have the expected signs except that family labor is negative in both herd sizes category 2 and 3.

However, statistical significance is apparent for just fixed capital in HS1, family labor in HS1 and HS3, and crop land size in all herd size categories except HS1.

This latter result is presumably due to small land areas being used for subsistence crops rather than for feed production. The positive and significant impact of crop land size on profit in herd size categories 2 and 3 and in the pooled sample implies an increase in crop land size increases farm profit significantly. It is common in rural Botswana that farmers who have large size of crop land have more farm crop residues available to feed their animal, which serves to abate feed costs.

Determinants of Profit Inefficiency

Table 4 presents the estimates of the coefficients for the efficiency drivers, expressed as δ in (4) above. It should be noted that a positive coefficient on δs signifies profit inefficiency because the value of *u* would be higher when the farm is further away below the profit frontier (Delgado et al. 2008).

The coefficient of age of the household head is positive and statistically significant in HS1 and HS2, from which we infer that profit inefficiency increases with increasing farmer age. In other words younger farmers are more efficient than older ones. This finding is consistent with previously published work, as outlined above. However, age is not statistically significant when the whole sample is considered, nor for the herd size category HS3 (larger herds). This result suggests that within the sub-sample for larger herd sizes, older farmers are no more efficient than younger ones possibly because of their degree of commercial establishment, utilisation of human and social capital by way of delegation and effective input and product marketing management.

Across the entire sample, it is likely that these two contradictory influences of age on profitability are both in evidence and cancel each other out to the extent that the parameter estimate is not significantly different from zero. The parameter estimates for gender show mixed results and are not statistically significant.

The coefficient for education of the household head is negative as expected, and statistically significant for large farms and the pooled sample. This confirms an intuitive result that more educated farmers are more efficient, and is also likely to affect social and human capital effects that education can help mobilize.

Farmers (only in HS1) who earn high non-farm income are more efficient than other farmers, *ceteris paribus*. This result confirms the importance of non-farm income among subsistence farmers, who are relatively less endowed with household assets which might be mobilised in abating transaction and other costs faced by the farm.

Table 4. Determinants of Profit Inefficiency among Beef Farmers

Variables	HS1	HS2	HS3	Pooled
Constant	-0.10	0.30	2.09	2.80
Age of household head	0.15***	0.89**	0.07	0.02
Education of household head	-0.01	0.02	-0.04**	-0.04*
Annual household non-farm income	-0.02**	0.01	0.04	0.004
Distance market (commonly used)	0.02	-0.14*	-0.12**	-0.03**
Herd size	-0.09	-1.27**	-0.53***	-0.23***
Gender (% female farmers)	-0.13	-0.06	0.07	0.10
Information access (Yes=1, No=0)	0.10*	0.08	0.33	0.11*
FMD disease zone (Yes=1, No=0)	-0.35***	-0.16	0.09	0.04
Crop income (Yes=1, No=0)	-0.03	-0.23	-0.31**	-0.17***
Credit access (Yes=1, No=0)	-0.14	0.26	-0.08	-0.17

Notes. Statistical significance levels: ***1%; **5%; *10%.

It is also worth noting that off-farm earnings may be re-introduced to farm enterprises as fixed or working capital, which may in turn boost farm efficiency in the short term, and more profoundly in the long term. The parameter estimates for credit access show mixed results in terms of the direction of their impact on profit efficiency but are in any case not statistically significant: this provides some indication that off-farm employment may substitute for borrowing by farmers. Although Botswana's farmers are known to engage in other businesses and income generation from non-farm activities, differential effects across size grouping of farms have not before been identified.

The parameter estimate for distance to the most commonly-used market is negative and significant for all farm size categories except HS1. This confirms an intuitive result that farmers who access distant markets are more efficient, in that despite transport costs, efficient farmers access distant markets in search of better prices for their animals. Bahta et al. (2013) report that when farmers sell their animals near to their villages, they prefer to sell to individuals (other farmers, consumers) as price is agreed by mutual negotiation and payment is immediate and in cash. However, the same study also showed that this transaction channel is available for small numbers of animals only. Therefore, farmers who want to access more profitable market channels or sell larger numbers of animals (such as would occur for HS2 and HS3), do so in distant towns, where BMC[11] collection points and other potential buyers such as butcheries are located. The coefficient on herd size (again except in HS1) is negative and statistically significant. This implies that farmers who own large cattle herds are more efficient in terms of profit, suggesting economies of scale. However, the relation between herd size and gross margin in Botswana is a complex one, probably governed by differences in technology and associated management systems, labor management, and other factors revealed in the current study to differ amongst size class groups (Bahta et al. 2013, BIDPA 2006). The effect may be due to latent variables depicting technology, management or an aspect of constraints that corresponds, more or less, to herd class.

The results in Table 4 depict a positive relationship between access to market information and inefficiency in HS1 and the pooled sample. This is unexpected as it implies that farmers with less access to market information are more efficient. A possible reason for this finding could be associated with the quality of information dissemination to farmers in the study area, particularly those with small herds.

A further unexpected result is that farmers within the FMD zones are more efficient (except for the herd size category 2) than are farmers outside the FMD zone in HS1. This is likely to be because farmers within the FMD zone are accessing alternative buyers, such as butcheries (see Bahta et al. 2013). If farmers from FMD areas want to sell to BMC, they need to deliver their animals to BMC collection points for further quarantine procedures which can last up to 90 days. The coefficient of crop income is negative and statistically significant only for large size farms and the pooled sample. This implies that farmers who earn income from crop production are more efficient than those who earn less or no income from crop production. It may be that income from crop farming is reinvested into livestock farming. Moreover, farmers who have crop farms could also use crop residues to feed their animals, thereby reducing feed costs. As suggested by the parameter estimates, this effect is likely to be particularly important when farmers own large herds.

Figure 2 shows estimates of inefficiencies of beef cattle producers within herd size groups, and for the whole sample.

[11] The BMC agents (including feedlot operators) regularly visit cattle posts and villages to buy only young animals (weaners) and purchase older animals only if farmers delivered the animals to local BMC collection points (Bahta et al. 2013)

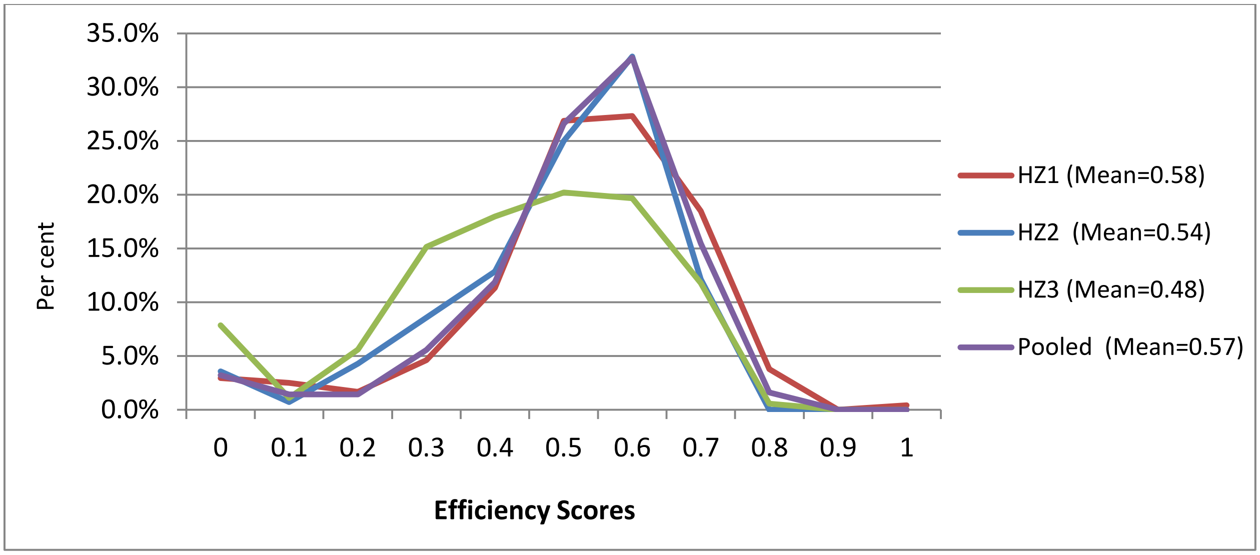

Figure 2. Distribution of Profit Efficiency Estimates for Beef Cattle Farmers

The average profit efficiency score is 0.58 for the whole sample and 0.56, 0.62, and 0.68 for the herd size category one, two, and three, respectively, with the majority of the farms' efficiency scores lying between 0.3 to 0.8. This indicates that there is a considerable scope to improve beef farm profitability under the prevailing input mix and production technology among beef cattle producers in Botswana.

Conclusion and Policy Implications

This paper applied a stochastic profit frontier model to a large sample of beef-producing households to identify the drivers of profit efficiency in smallholder beef production in Botswana. The model preforms well in identifying inefficiency, and in explaining it in terms of farm-specific variables as identified in similar studies in other countries. Building on previous work in Botswana, the current study sub-divides the sample by herd size so as to examine the hypothesised influences on profit efficiency both within and between herd size classes. This reflects the apparent differences in technology and organisation, as well as in asset ownership and human capital, between size classes. Such subdivisions, and others that may be revealed in future research, provide a much-needed counterpoint to past policy commentary on Botswana's beef production systems which have focused only on labels such as "traditional" and "commercial".

Predictably, the profit model suggests that profit of smallholder beef producers can be increased through and reduction of input prices. This is particularly the case for feed prices. In a related result, access to crop lands is positively related to profits and this effect is particularly strong for the larger farm enterprises for whom feed requirements are both greater and more regular during the season. A further effect of access to crop land is that crop revenues offer a source of working and fixed capital to the livestock enterprise that is likely to enhance its profitability. Despite substantial government efforts to enhance animal health, veterinary costs appear to have significantly impacted the profits of all herd size categories. This result was not found to be the case for the smallest farms, probably because they use few veterinary inputs.

Examination of the influence of scale on profitability yielded mixed results which suggest that the relationship differs between herd size groups. This result is vital in utilising historical analyses in Botswana addressing scale, and the details of how boundaries are drawn between size classes and production systems should be examined in further research. Scale also affects the availability of crop residues, and patterns of input use: these in turn influence response to prices and investments. An understanding of these mechanisms would greatly enhance the capacity for provision of management advice to producers, particularly of the form generated by efficiency analysis.

The influences of off-farm employment on efficiency are presented, and mostly focus on the smaller herd size groups. This is of substantial interest to smallholder studies, for several reasons. First, farmers with the smallest herds are likely to be more available for off-farm employment than are their peers with larger herds. Second, the capital-providing roles of off-farm employment show some evidence of interaction with credit markets and so offer alternative mechanisms for loan-based sources of capital for those that are least equipped for commercial borrowing. Third, efficiency effects of distance from the market, the management decision for which is likely to be influenced by payment delays, is also likely to be related to the cash flow situation on the farm. It follows that off-farm employment may better equip smaller farmers to supply more distant markets, or others with payment delays such as the BMC sales channels for export markets. Lastly, this study’s findings on the importance of crop activities on profit efficiency may have different implications for the various herd size classes if the role of off-farm labor also differs. This last point requires further research not only for crop-livestock interaction but also for small farms’ livestock mix as small stock might be expected to be more labor intensive than are cattle.

The presence of inefficiency detected in the study lends support to the proposition that production models that assume absolute efficiency could lead to misleading conclusions. This was indicated by the Likelihood Ratio test result in all models which rejected the model without inefficiency in favour of the one that incorporates inefficiency. Moreover, the study showed that the variation in actual profit from maximum profit (profit frontier) between farms, ranged from 65 to 74 per cent, mainly arose from differences in farmers’ practices rather than from random variation.

The calculated mean profit efficiency scores are 0.58 for the whole sample and 0.56, 0.62 and 0.68 for the herd size category 1, 2 and 3, respectively. The study’s results identify efficiency drivers, including education level, distance to commonly-used market, herd size, access to information and income from crop production. These results revealed some interesting commonalities and differences across the herd size sub-groups used in the study. One such result is that referring to location in the FMD zone, which is apparently associated with higher profits than location elsewhere, *ceteris paribus*. Although such results should be interpreted with caution, they do support two important lines of advocacy. First, that training and education are vital routes to improved efficiency and second, that peer groups of producers which occur both within and across arbitrary size groupings may offer models for application to less efficient producers. The abovementioned impact of cost items on profitability is also relevant in terms of potential collective action that may be centred on such peer groupings.

Several elements of this analysis of profit efficiency indicate that improved infrastructure and government services can contribute to beef producers' profit efficiency. Marketing improved infrastructure such as roads and collection points of livestock, market information, and technical aspects of access to crop lands and feed production, are all of apparent high priority. Such results suggest avenues for improving the efficiency of smallholder beef farms in Botswana without necessarily requiring changes in the current technological package of production inputs. Notably, this study has highlighted several differences in these impacts, across the herd size categories used. An example is the apparent efficiency-reducing influence of market information for farmers with the smallest herds. This argues for differential formulation of information packages to achieve better uptake and use by such farmers.

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References

Alvarez, A. and C. Arias. 2014. A selection of relevant issues in applied stochastic frontier analysis. *Economics and Business Letters* 3 (1): 3-11.

Agriculture Canada. 1991. Task force on Competitiveness in Agro-Food Industry: Growing Together, Report to Ministers of Agriculture, Ottawa: Agriculture Canada.

Aigner, D.J., C.A.K. Lovell and P. Schmidt. 1977 Formulation and Estimation of stochastic frontier production models. *Journal of Econometrics* 6:21-37.

Amara, N., N. Traore, R. Landry, and R. Romain. 1999. Technical efficiency and farmers' attitudes toward technical innovation: The case of the potato farmers in Quebec. *Canadian Journal of Agricultural Economics* 47(1): 31-43.

Bahta, S., D. Baker, B. Podisi and O. Marobela. 2013. Competitive smallholder livestock in Botswana: Results of a livestock value chain survey in the Central district of Botswana. ILRI Project Report. Nairobi, Kenya:

Battese, G.E., and T.J. Coelli. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20(2): 325-332.

Battese, G.E., and G.S. Corra. 1977. Estimation of a Production Function Model with Applied to the Pastoral Zone of Eastern Australia. *Australian Journal of Agricultural Economics* 21(3):169-179.

Banse, M., M. Gordon, J. Hartell, J, G. Hughes, J. Kockler, T. Mollman, and W. Munch. 1999. The evolution of competitiveness in Hungarian Agriculture: from transition to accession. Paper presented at IXth EAAE Congress in Warsaw, August.

BIDPA. 2006. Final Report on the Viability and Long-term Development Strategy for the Livestock (Beef) sub-sector in Botswana. Botswana Institute for Development and Policy Analysis, Gaborone.

Brummer, B., and J.P. Loy. 2000. The technical efficiency impact of farm credit programmes: A case study in Northern Germany. *Journal of Agricultural Economics* 51(3): 405-418.

Buckwell, A., and S. Davidova. 1993. Potential implications for productivity of land reform in Bulgaria. *Food Policy* 18(6): 493-506.

Coelli, T.J., D.S.P. Rao, C.J. O'Donnell and G.E. Battese. 2005. *An Introduction to Efficiency and Productivity Analysis*. USA: Springer.

Coelli, T.J. 1996. *A guide to FRONTIER VERSION 4.1c*. A computer program for stochastic frontier production and cost function Estimation, mimeo, Department of Econometrics University of New England, Armidale, Australia.

Cornia, G. A. 1985. Farm size, land yields and the agricultural production function: An analysis of fifteen developing countries. *World Development*-13(4):513-534.

Chavas, J.P., R. Petrie and M. Roth. 2005. Farm household production efficiency: Evidence from the Gambia. *American Journal of Agricultural Economics* 87(1): 160-179.

Chirwa, E.W. 2007. Sources of technical efficiency among smallholder maize farmers in Southern Malawi. *AERC Research* 172. http://dspace.africaportal.org/jspui/bitstream/123456789/32355/1/RP172.pdf?1

Delgado, C.L., C.A. Narrod, M.M. Tiongco and G.S.A. de Camargo Barros. 2008. Determinants and Implications of the Growing Scale of Livestock Farms in Four Fast-Growing Developing Countries. International Food Policy Research Institute. Washington DC.

Emam, A.A., and M.H. Salih. 2011. Measuring competitiveness of Sudanese Sheep Exports. *American Journal of Experimental Agriculture* 1(3): 69-78.

Food and Agriculture Organisation (FAO) and Ministry of Agriculture (MoA). 2013. *Botswana Agrifood Value Chain Project: Beef Value Chain Study*. Rome, Italy and Gaborone, Botswana.

Hall, B., and P. LeVeen. 1978. Farm size and economic efficiency: The case of California. *American Journal of Agricultural Economics* 60(4): 79-93.

Hayami, Y., and V. W. Ruttan. 1970. Agricultural productivity differences among countries. *American Economic Review* 60(5): 895-911.

Hyuha, T.S. 2006. Analysis of Profit Efficiency in Rice Production in Eastern and Northern Uganda. A Ph.D. Diss. Department of Agricultural Economics and Agribusiness Makerere University, Uganda. 146.

Horppila, J., and H. Peltonen. 1992. Optimizing sampling from trawl catches: Contemporaneous multistage sampling for age and length structures. *Canadian Journal of Fisheries and Aquatic Science* 49(8): 1555-1559.

Irz, X., and C. Thirtle. 2004. Dual Technological development in Botswana agriculture: a stochastic input distance function approach. *Journal of Agricultural Economics* 55(3): 455-478.

Jefferis, K. 2007. The Impact of Cattle/beef prices on incomes and poverty in Botswana: Report submitted to USAID / Southern Africa, Gaborone, Botswana, February.

Kennedy, P.L., R.W. Harrison and M. A. Piedra. 1998.Analysing Agribusiness competitiveness: the case of United States Sugar Industry. *International Food and Agribusiness Review* 1(2): 245-253.

Kodde, D.A., and Palm, F.C. 1986. 'Wald Criteria for Jointly Testing Equality and Inequality Restrictions'. *Econometrica* 54:243-1248.

Kolawole, O. 2006. Determinants of profit efficiency among small scale rice farmers in Nigeria: A profit function approach. Poster paper for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August.

Lapar, A.L. Ma., A. Garcia, S. Aditto, and P. Suriya, 2005. Measuring cost efficiency in smallholder dairy: empirical evidence from Northeast Thailand. Paper presented at American Agricultural Economics Association Annual Meeting. Rhode Island, USA. July.

Lopez, R.E. 1982. Applications of duality theory to agriculture. *Western Journal of Agricultural Economics* 21: 353–365.

Latruffe, L. 2010. Competitiveness, Productivity and Efficiency in Agricultural and Agri-Food Sectors. *OECD Food, Agriculture and Fisheries Papers*. No. 30. OECD Publishing. http://dx.doi.org/10.1787/5km91nkdt6d6-en.

Longwe-Ngwira, A., F. Simtowe and M. Scambi. 2012. Assessing the competitiveness of groundnut production in Malawi: a Policy Analysis Matrix Approach. Selected paper for presentation at the International Association of Agricultural Economists (IAAE), Triennial Conference, Foz do lguana, Brazil, August.

Mathijs, E., and L. Vranken. 2001. Human capital, gender and organisation in transition agriculture: Measuring and explaining technical efficiency of Bulgarian and Hungarian farms. *Post-Communist Economies* 13(2): 171-187.

Mester, L.J. 2003. Applying Efficiency Measurement Techniques to Central Banks. Paper Presented at the Workshop on Central Bank Efficiency. Warton Financial Institutional Center. Working Paper. No. 03-13. http://fic.wharton.upenn.edu/fic/papers/03/0325.pdf

Mohammed, S.T., Y. Bila and P.S. Amaza. 2013. Application of Stochastic Frontier Function in Estimating Production Efficiency: A Dual Approach. *Global Journal of Biodiversity Science and Management* 3(1): 11-19.

National Development Plan (NDP) 10. 2010. *Botswana's National Development Plan* Online: http://www.finance.gov.bw

Nganga, S.K., J. Kungu, N. de Ridder and M. Herrero. 2010. Profit efficiency among Kenyan smallholders milk producers: a case study of Meru-South district, Kenya. *African Journal of Agricultural Research* 5(3): 332-337.

Nkhori, P.A. 2004. The impact of transaction costs on the choice of cattle markets in Mahalapye District Botswana. . Unpublished Diss. University of Pretoria, Pretoria.

ODI (Overseas Development Institute). 2007. Analysis of the economic and social effects of Botswana's loss of preferential market access for beef exports to the European Union. London. http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/4154.pdf

OECD. 2011. *Fostering Productivity and Competitiveness in Agriculture.* OECD Publishing. Paris. http://dx.doi.org/10.1787/9789264166820-en

O'Donnell, C.J., D.S.P. Rao and G.E. Battese. 2008. Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics* 34(2): 231-255.

Otieno, D.J., L. Hubbard and E. Ruto. 2012. Determinants of technical efficiency in beef cattle production in Kenya. Paper presented at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguacu, Brazil, August.

Panin, A., and Mahabile, M. 1997. Profitability and household income contribution of small ruminant production in Botswana. *Small Ruminant Research* 25(1):9-15.

Pavelescu, F. 2011. Some aspects of the translog production function estimation. *Romanian Journal of Economics* 32 (1):131-150.

Rakipova, A.N., J.M. Gillespie and D.E. Franke. 2003. Determinants of technical efficiency in Louisiana beef cattle production. *Journal of the ASFMRA* 99-107. http://www.asfmra.org/2003-journal-of-the-asfmra/

Statistics Botswana. 2014. *2012 Annual Agricultural Survey*. Gaborone. Botswana. http://www.cso.gov.bw/templates/cso/file/File/Agriculture%20Main%20Report%202012_Apr%204%202014.pdf

Staal, S.J. 2002. The competitiveness of smallholder dairy production: Evidence from Sub-Sahara Africa, Asia and Latin America. In *Smallholder dairy production and marketing-Opportunities and constraints. Proceedings of a South–South workshop,* edited by D. Rangnekar, D. and Thorpe, 250-264. NDDB (National Dairy Development Board), Anand, India, and ILRI (International Livestock Research Institute), Nairobi, Kenya.

Stonikov, S. 1998. Evaluating the effects of price and trade liberalisation on the technical efficiency of agricultural production in a transition economy. The case of Russia. *European Review of Agricultural Economics* 25(3): 412-431.

Thirtle, C., Lusigi, A., Piesse, J., K. Suhariyanto. 2000. Multi-factor productivity and convergence in Botswana, 1981–96. *Agrekon* 39: 686–698.

Thorne, F.S., Kelly, P.W., Maher, M.J. and L.N. Harte. 2002. The Irish Hardy Nursery Stock Industry: Recent Trends and Competitive Position. Dublin: Reports. http://www.teagasc.ie/research/reports/ruraldevelopment/4748/eopr-4748.asp

Timothy, A., and A. Adeoti. 2006. Gender inequalities and economic efficiency: New evidence from cassava-based farm holdings in rural southern Nigeria. *African Development Review* 18(3): 428-443.

Tran, N.D. 2009. Transition to Organic Tea Production in Thai Nguyen Province, Vietnam: Economic and Environmental Impacts. EEPSEA Research Report (2008-RR8). http://www.eepsea.org/pub/rr/12446029131Tran_FINAL(Feb_09).pdf

Wang, H.J., and P. Schmidt. 2002. One-step and two-step estimation of the effects of exogenous variables in technical efficiency levels. *Journal of Productivity Analysis*. 18: 129-144.

