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Estimating Technical and Scale Efficiency of Red Meat Production: A South African Case Study

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ABSTRACT The purpose of the study is to use data from a case study to build a data envelopment analysis (DEA) model to compare the financial performances of South African boer goat with cattle and sheep production, respectively. Data was collected by calculating the financial performance, which is broken up into six measurements. These measurements formed the output variables and various levels of capital employed were used as the input variable to determine the technical and scale efficiencies of the comparative red meat product lines. Data was developed for 65 different scenarios, resulting in a total of 455 data points. The study firstly concludes that South African boer goat production outperforms cattle and sheep production financially, and secondly, that it is easier for sheep production to operate at a scale that maximises productivity, followed by South African boer goat and then cattle production.

INTRODUCTION

This paper forms part of a greater research project into the financial viability of goat farming in South Africa, by presenting a comparative investigation into alternative South African red meat farming options. As such it is part of a case study of which the outcomes are used to evaluate the technical and scale efficiencies of red meat farming in South Africa. The case study was developed to evaluate (among other) the financial performances of conventional cattle or sheep farming in contrast to South African (SA) boer goat farming in a typical farm scenario in the North West Province of South Africa. According to Schoeman et al. (2010), approximately 80% of South African agricultural land is unsuitable for crop production, with much of such agricultural land also not suitable for grazing for large livestock species such as cattle. Smaller livestock species such as the SA boer goat consequently offer alternative farming options. The SA boer goat is a specialised meat goat breed that is well known for its adaptability, hardiness and ability to utilise marginal land generally rejected by other livestock species (Mahgoub et al. 2012). Furthermore, the livestock system is known to enhance the sustainable livelihoods for farmers (Biradar et al. 2013).

In this study, the term *SA boer goat* is used to collectively refer to several distinct but related species, namely i) the South African boer goat, ii) the South African savanna goat, and iii) the South African Kalahari red goat species. These species are bred and graded in South Africa and are known under the collective noun of the 'SA boer goat' (SA Boer Goat Breeders Association, 2011). The backdrop of the study is therefore the up-coming SA boer goat farming sector, which has to compete against other well-established red meat production lines such as cattle and sheep. Unlike other livestock species, no official readily available market indicators exist for these goats in South Africa (Landbouweekblad 2014).

The study followed a route of statistical modelling in which data envelopment analysis (DEA) has been applied to estimate the relative efficiency to convert the capital employed into a number of financial performance indicators for each of the three livestock species under consideration, i.e. cattle, sheep and SA boer goats. The financial performance measures consist of selected variables determining profitability, asset management, capital investment appraisal

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and sensitivity. The importance of this is found in its evaluation of the relative financial performances of farming with the livestock species, by aggregating such performances into a single measurement using the DEA methodology. These results can provide farmers with better insight when i) having to choose between the three livestock options, and ii) after the afore-mentioned selection has been made, to decide on the most appropriate capital level to ensure optimum levels of productivity.

A number of earlier studies have focused on various aspects of boer goat farming, including its economic aspects and viability (Casey and van Niekerk 1988; Mason 1988; Midgley 2007; Mwebe et al. 2011; Oberholzer et al. 2014), its socio-economic benefits in the informal sector (Gwaze et al. 2009; Kumar et al. 2014), a comparison of meat and dairy goats (Olivier et al. 2005), different breeds within the species (Shrestha and Fahmy 2005; Gwaze et al. 2008; Dubeuf and Boyazoglu 2009; Mbuku et al. 2014), the commercialisation aspects thereof (Malan 2000; Gouws 2002; Roets and Kirsten 2005), evaluating applicable and relevant economic aspects (Schoeman et al. 2010), and meat quality (Tsabalala et al. 2003). No study, however, could be found that investigated the comparative viability of cattle, sheep and goat production.

The problem under consideration is that a large part of South African agricultural land is only suitable for small livestock such as the boer goat, which has to compete against other well-established livestock options. Therefore, the main objective of the study is to use data from the afore-mentioned case study to build a DEA model to aggregate performance measures into a single measurement indicator. This will enable an agricultural producer to differentiate between the financial performances of three livestock species, namely SA boer goat with cattle and sheep production. To achieve this objective, data was firstly collected to determine the financial performance, and categorised into six measurement indicators, which, in turn, formed the output variables of the DEA model. In terms of inputs, the various levels of capital employed were used. Data was developed for 65 different scenarios, with each having six output variables and one input variable, providing a total of 455 data points. The 65 scenarios, which used different levels of capital, are broken up into 23, 18 and 24 scenarios for cattle, sheep and goat production, respectively.

DEA, as an efficiency measurement technique, lends itself to aggregate a firm's performances into a single measure where multiple inputs and multiple outputs are used (Coelli et al. 2005). This study focused on technical and scale efficiency, respectively, where technical efficiency is an indication of how well inputs are converted into outputs while scale efficiency estimates whether a production line operates on a scale that maximises productivity (Tchereni et al. 2012; Murthy et al. 2009). This study contributes to the literature by proposing a model to assist in the choice among production lines and choosing between appropriate capital levels. The importance of the contribution is the estimation of the technical efficiency and scale efficiency. Therefore, answers are provided as to which of these production lines is the most efficient to convert capital employed into financial performance and what level(s) of capital should be used by a production line to operate on a scale that maximises productivity.

The rest of the paper is organised as follows: The next section provides a background of the study, followed by an explanation of the theory, the method of the study, empirical results and a conclusion. In the study, the terms SA boer goat, sheep and cattle are used. They refer, unless stated otherwise, specifically to the Boer goat, mutton breeds and beef cattle breeds.

Defining DEA

The concept of measuring efficiency and to estimate how far a firm can increase its outputs without absorbing further resources was first introduced by Farrell (1957). Charnes et al. (1978) challenged the idea laid down by Farrell and developed DEA, which is a powerful methodology to measure the efficiency of multiple input multiple output production units (Cook and Seinford 2009). Therefore, DEA is a relatively efficient measure that accommodates multiple inputs, multiple outputs and other factors in a single model (Halkos and Salamouris 2004). DEA is defined as a non-parametric linear programming technique that measures the relative efficiency of a comparative ratio of outputs to inputs for each decision-making unit (DMU), such as a firm (Van der Westhuizen, 2008; Dramani et al 2011). The main usefulness is its ability to identify inefficient DMUs and potential improvement areas for them, either by reducing inputs or increasing outputs, as well as highlighting efficient DMUs that could be used as benchmarks by less efficient DMUs (Avkiran 1999; Liu and Wang 2009).

Defining technical and scale efficiency

As mentioned, technical efficiency (TE) estimates how well inputs are converted into outputs, while scale efficiency (SE) estimates whether a DMU operates on a scale that maximises productivity. According to Avkiran (1999), analysts typically choose between using constant return to scale (CRS) or variable return to scale (VRS). The CRS implies a proportionate rise in outputs when inputs are increased, or, in other words, a scenario's efficiency is not influenced by the scale of its operations (Avkiran 1999). On the other hand, Avkiran (1999) states that VRS implies a disproportionate rise or fall in outputs when inputs are increased, or, in other words, if a scenario grows in size, its efficiency will not remain constant, but it will either rise or fall. Using CRS, a scenario is automatically considered fully scale efficient, while using the VRS approach, the degree of scale efficiency should be estimated, i.e. where a scenario is too small in its scale operations, which falls within the increasing return to scale (irs) part of the production function, and a scenario is too large if it falls within the decreasing return to scale (drs) part of the production function. These inefficient scenarios can be improved by keeping the same input mix, but changing the size of operations (Coelli et al. 2005; Theunissen 2012).

To illustrate, Figure 1 assumes that the observed data consists of a single-input, single-output with five DMUs, namely A, B, C, D and E. 0BC is the CRS frontier. A, D and E are not on the efficiency frontier and therefore they are considered non-efficient. E, for example, should move from an input-orientated view, horizontally, to point E" to become fully efficient. The less restricted VRC frontier is indicated by ABCD. Under this approach, E only needs to move horizontally to point E'. To summarise, TE_{VRS} = FE'/FE, implying E'E is the technical inefficiency distance. TE_{CRS} = FE"/FE indicates the overall improvement that is possible. SE = TE_{CRS}/TE_{VRS} means that the distance E"E' represents the scale inefficiency, which should be improved by keeping the same input mix, but changing the size of operations (Coelli et al. 2005; Zhu 2009).

Conceptual scope

The main objective of the paper is to build a DEA model to aggregate financial performances of cattle, sheep and SA boer goat production into a single measurement. This model could assist an agricultural producer to optimise production decisions between the afore-mentioned

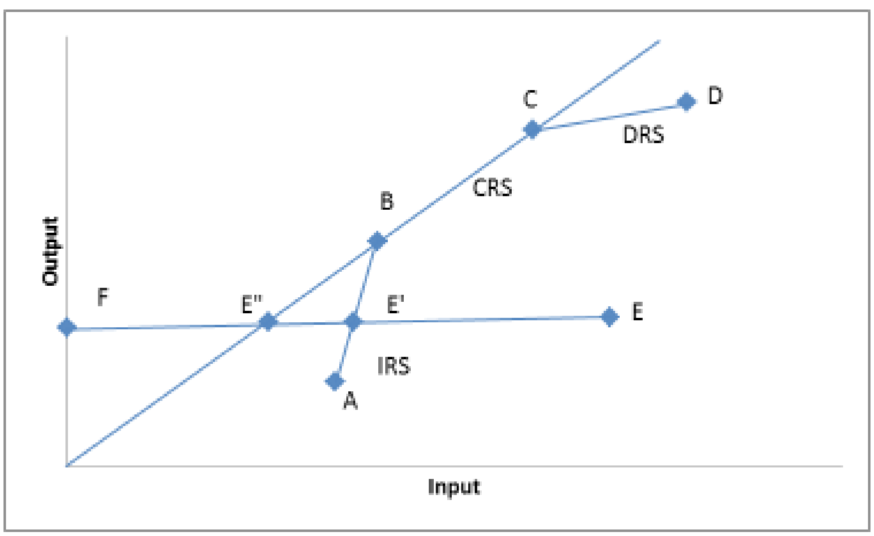

Fig. 1. CRS and VRS efficiency frontiers

livestock species. However, building a model requires a number of data points. The VRS and CRS approaches are applied to estimate technical and scale efficiency, respectively. Furthermore, the study reveals which production line is the most efficient in creating financial benefits, and which production line operates on a scale that maximises productivity. Within the context of this study, the open question is how does the efficiency of producing Boer goat meat compare with those of cattle and sheep. To answer the question, the following two null-hypotheses are stated:

H1: There is no difference between the mean technical efficiency estimates of SA Boer goat production and cattle and sheep production, respectively.

H2: There is no difference between the mean scale efficiency estimates of SA Boer goat production and cattle and sheep production, respectively.

Theory

The first section explains how the case study data in the appendix were used to measure the financial performance, while the second section explains how DEA measures efficiency.

Measure Financial Performance

In this study, six financial performance measures were selected, namely two profitability measures, return on investment and contribution per hectare, an asset management measure, asset turnover, two capital investment appraisal measures, payback period and net present value, and a sensitivity measure, i.e. break-even (Lovemore and Brümmer 2005; Correia et al. 2010).

According to Hawawini and Viallet (2011), *relevant* cashflow is merely the change in the overall cash position that could be attributed to the investment decision. The different red meat industries all have expenses that are similar, irrespective of the type of farming; for example, land, phone and vehicle expenses. These have not been taken into account because they are not determined by the type of farming. For the purpose of the case study, a contribution statement that therefore only takes *relevant* income and expenses into account was used in the calculations. On the other hand, capital employed consists of the purchase cost of the herd and relevant capital expenditures such as feeding troughs, fencing and stock handling facilities. All calculations of the financial performance measures were done for a period of five years. The appendix indicates how these financial measures were calculated.

DEA as a Measure of Efficiency

The fundamental assumption of DEA is that if a producer (DMU) is capable of producing Y(A) units of output with X(A) inputs, then other producers should also be able to do the same if they are operating efficiently. The fundamental objective of the DEA modelling exercise is to find the 'best' virtual producer for each real producer and then to compare the producer to its best virtual producer in order to determine its efficiency. The best virtual producer is found by means of linear programming (Anderson 1996). Analysing the efficiency of a number of DMUs requires a formulation of a linear programming problem for each DMU. DEA effectively estimates the frontier by finding a set of linear segments that envelop the observed data. DEA can determine efficiencies from an input-orientated (input minimisation) or output-orientated (output maximisation) point of view (Coelli et al. 2005).

In this study, an input-orientated approach was followed, including both the VRS and CRS approaches. The following DEA equation is used to create the model (Zhu 2009):

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

$$\textit{subject to}$$

$$\sum_{j=1}^{n} \lambda_j \chi_{ij} + s_i^- = \theta \chi_{io} \qquad i = 1,2,\ldots,m;$$

$$\sum_{j=1}^{n} \lambda_j \gamma_{ri} - s_r^+ = \gamma_{ro} \qquad r = 1,2,\ldots,s;$$

$$CRS \qquad \lambda_j \geq 0 \qquad j = 1,2,\ldots,n.$$

$$VRS: Add \sum_{j=1}^{n} \lambda_j = 1$$

The above input-orientated formula calculates input minimisation (where è indicates the efficiency score). Each observation, DMU_j (j = 1, ..., n), uses m inputs X_{ij} (i = 1, 2, ...,m) to produce s outputs Y_{rj}(r = 1, 2, ...,s), where DMU_o represents one of the n DMUs under evaluation, and X_{io} and Y_{ro} are the ith input and rth output for DMU_o, respectively. In order to take any slack into consideration, the inclusion of the non-

Archimedean e effectively allows the minimisation over q to pre-empt the optimisation involving the slacks, s_i^- and s_r^+. [For a more detailed discussion on the DEA methodology, see Coelli et al. (2005), Theunissen (2012) and Zhu (2009).]

METHOD

The case study (appendix) provided the basis to develop desired data to build the DEA model. To ensure sufficient variety of capital employed levels, a wide range of capital needs were randomly chosen. Firstly, the maximum capital needs (100%) for each production line were calculated, i.e. to pay for the improvement of fences, stock handling facilities and to buy the maximum number of animals according to the bearing power of the farm. Secondly, different levels of capital were calculated for each of the three production lines using the following randomly chosen levels, namely 80%, 70%, 62.5%, 50%, 42.5%, 30% and 25%. These eight percentages were converted into monetary values and applied to all the production lines. In total, 24 capital amounts were calculated to be applied to each production line. As a result of significant differences between the maximum capital needs of the production line, the 80% capital employed for SA Boer goats is higher than the maximum needs of cattle and sheep production. Therefore, this amount was only applied to SA Boer goats and not to cattle and sheep, because it is first senseless to attribute inactive capital to a production line and secondly, it will result in a distortion in the DEA results where production lines require low capital input levels to be efficient. The 80% capital levels of both SA Boer goats and cattle exceeded the maximum needs of sheep and the 70% and 62% capital levels of SA Boer goats also exceeded the maximum needs of sheep. The final result is that only 65 of a possible 72 capital scenarios were used, namely 23, 18 and 24 for cattle, sheep and SA Boer goats, respectively. These 65 scenarios include capital employed and six financial performance measurements, providing a total of 455 data points.

Table 1 exhibits the descriptive statistics for all the variables. The only input variable is the capital employed (R = Rand or ZAR, the South African currency). Note that this capital amount excludes working capital. The output variables are the six financial performance indicators. For a production line to be relatively efficient, it should have low inputs and high outputs. For all these financial performance indicators, except the payback period, a higher value implies a higher performance, where the payback period implies a higher value and a lower performance. Therefore, the payback period is indicated in terms of reciprocal values.

From the variables in Table 1, the following DEA model was built:

Input: x_1 = capital employed (R = ZAR)

Output: y_1 = return on investment (ROI)

Table 1: Descriptive statistics of variables

	Capital R	*ROI*	*ATO*	*C/HAR*	*1/pay-back*	*NPVR*	*BE*
Cattle (n = 23)							
Mean	412110	1.32	1.81	1176	0.39	18625	0.72
Median	393019	1.23	1.74	964	0.41	-32861	0.70
S.D.*	183274	0.27	0.30	725	0.08	80203	0.03
Minimum	140363	0.87	1.24	244	0.29	-45528	0.70
Maximum	767300	1.70	2.22	2554	0.58	172720	0.78
Sheep (n = 23)							
Mean	339465	2.07	3.89	1417	0.25	160940	0.53
Median	338506	2.19	3.94	1550	0.23	198729	0.55
S.D.	127369	0.25	0.40	530	0.04	74005	0.05
Minimum	140363	1.44	3.20	406	0.22	5156	0.43
Maximum	561455	2.31	4.36	2109	0.35	225593	0.59
Goat (n = 18)							
Mean	433900	2.47	3.98	2165	0.21	309326	0.62
Median	395212	2.57	4.24	2262	0.19	359933	0.64
S.D.	208625	0.47	0.61	974	0.06	158140	0.06
Minimum	140363	1.23	2.61	344	0.17	-17281	0.47
Maximum	935073	2.93	4.71	3720	0.41	467592	0.69

* Standard deviation

y_2 = asset turnover (ATO)
y_3 = contribution per hectare (C/HA)
y_4 = 1/payback period
y_5 = net present value (NPV)
y_6 = break-even (BE)

RESULTS AND DISCUSSION

The software purposefully developed by Zhu (2009) was used to calculate the input-orientated technical efficiency according to the VRS and CRS approaches and scale efficiency estimates. Table 2 indicates the 23, 18 and 24 scenarios for cattle, sheep and SA Boer goat production, respectively. The second column indicates the percentage capital employed as a percentage of the maximum capital needs, e.g. the first two scenarios under 'Cattle', C100 and C97, indicates that 100% and 97% of the maximum capital needs are used. To determine how efficient each production line converted the various levels of capital into the six financial measurement indicators, the technical efficiency (TE_{VRS}), according to the VRS approach, was firstly calculated. The results indicate that cattle production was seven times fully technically efficient with a score of 1, whereas sheep and SA Boer goat were four and 20 times fully technically efficient, respectively. The mean TE_{VRS} are 0.865, 0.863 and 0.991 for cattle, sheep and SA Boer goat production, respectively, implying that, on average, their inputs should be reduced by 13.5%, 13.7% and 0.9% to become fully efficient. Cattle are fully efficient when capital levels of 73% and more are employed. Sheep and SA Boer goat are fully efficient when capital levels of 41% and less and 26% and more are employed, respectively.

TE_{CRS} indicates the overall aggregated efficiency, with cattle and sheep each being only once fully efficient and SA Boer goat being fully efficient four times. Although the CRS approach is based on the assumption that scenarios are able to linearly scale their inputs and outputs without changing their efficiency, its value is that it helped to arrive at the conclusion that the production of 22, 17 and 20 of the scenarios for cattle, sheep and SA Boer goat production did not achieve economies of scale. Regarding all three product lines, the trend is remarkable that the SE scores increase when the capital levels decrease. On average, sheep production has the highest scale efficiency, with a score of 0.970, followed by SA Boer goat and cattle with scores of 0.928 and 0.770, respectively. SE, which is calculated by = TE_{CRS}/TE_{VRS}, indicates that cattle and sheep were only one time fully scale efficient and for both it is at the lowest level of capital employed. SA Boer goat production was four times fully scale efficient, where the capital employed levels are between 26 and 35% of the maximum capital needs. These inefficiencies are mostly due to a decreasing return to scale (drs), for cattle, sheep and SA Boer goat production (22, 15 and 17 times, respectively), which implies that these scenarios are too large in their scale of operations. Sheep and SA Boer goat production was twice and three times on the increasing return to scale (irs) side of the production function, implying that these scenarios are too small in their scale of operations. To explain this, consider an example where a scenario can achieve economies of scale by producing R1 000 within a specific period. When producing on the decreasing to scale part of the production function, they may require, for example, three times as much input only to double the outputs to R200. On the opposite side, if they are producing on an increasing return to scale part of the production function, they may, for example, require half of the inputs to produce only a quarter of the outputs, namely R250.

To determine whether the mean differences between SA Boer goat and cattle, and SA Boer goat and sheep are significant, the null-hypotheses state that there is no difference between the mean technical and scale efficiency estimates of SA Boer goat and cattle production and SA Boer goat and sheep production, respectively. Table 3 exhibits the results of this hypothesis test where the t-test was performed to determine whether the differences between these two independent groups' means are significant. Since Microsoft Excel was used, the F-test was first performed to determine whether a t-test, assuming equal variances, or a t-test, assuming unequal variances, should be run (Arthur, 2009). A null-hypothesis stated that there is no difference between the means of the two sets of data. A significance level of $\rho < \alpha = 0.05$ is used, implying that $p < 0.05$ assumes unequal variances and $p > 0.05$ assumes equal variances. Except for the p-value of the F-test for the scale efficiency between cattle and SA Boer goat, which is slightly higher than 0.05, all the others are significantly less than 0.05, assuming unequal

Table 2: Efficiency estimates and returns to scale for the 65 scenarios

	Cattle efficiency						*Sheep efficiency*						*Goats efficiency*				
No.	*Scen-ario*	*TE VRS*	*TE CRS*	*SE*	*RTS*	*No.*	*Scen-ario*	*TE VRS*	*TE CRS*	*SE*	*RTS*	*No.*	*Scen-ario*	*TE VRS*	*TE CRS*	*SE*	*RTS*
1	C100	1.000	0.585	0.585	drs	1	S100	0.715	0.666	0.931	drs	1	G100	1.000	0.679	0.679	drs
2	C97	1.000	0.589	0.589	drs	2	S96	0.718	0.680	0.947	drs	2	G82	1.000	0.757	0.757	drs
3	C85	1.000	0.607	0.607	drs	3	S85	0.747	0.719	0.963	drs	3	G80	1.000	0.768	0.768	drs
4	C80	1.000	0.611	0.611	drs	4	S83	0.754	0.729	0.966	drs	4	G70	1.000	0.832	0.832	drs
5	C76	1.000	0.610	0.610	drs	5	S80	0.765	0.744	0.972	drs	5	G66	1.000	0.853	0.853	drs
6	C73	1.000	0.608	0.608	drs	6	S71	0.786	0.780	0.992	drs	6	G63	1.000	0.869	0.869	drs
7	C70	0.999	0.609	0.610	drs	7	S70	0.788	0.783	0.994	drs	7	G60	1.000	0.882	0.882	drs
8	C63	0.849	0.583	0.686	drs	8	S68	0.791	0.790	0.998	drs	8	G57	1.000	0.898	0.898	drs
9	C61	0.804	0.573	0.713	drs	9	S63	0.822	0.818	0.995	irs	9	G51	1.000	0.941	0.941	drs
10	C59	0.728	0.559	0.768	drs	10	S58	0.845	0.842	0.996	irs	10	G50	1.000	0.951	0.951	drs
11	C52	0.698	0.573	0.821	drs	11	S50	0.910	0.892	0.980	drs	11	G48	1.000	0.963	0.963	drs
12	C51	0.700	0.575	0.822	drs	12	S49	0.911	0.892	0.980	drs	12	G43	1.000	0.976	0.976	drs
13	C50	0.704	0.581	0.826	drs	13	S43	0.988	0.940	0.951	drs	13	G42	1.000	0.977	0.977	drs
14	C46	0.720	0.604	0.839	drs	14	S42	0.995	0.947	0.952	drs	14	G41	1.000	0.980	0.980	drs
15	C43	0.734	0.624	0.850	drs	15	S41	1.000	0.952	0.952	drs	15	G38	1.000	0.991	0.991	drs
16	C37	0.768	0.670	0.872	drs	16	S34	1.000	0.962	0.962	drs	16	G35	1.000	1.000	1.000	crs
17	C37	0.769	0.670	0.872	drs	17	S30	1.000	0.928	0.928	drs	17	G31	1.000	1.000	1.000	crs
18	C32	0.831	0.728	0.876	drs	18	S25	1.000	1.000	1.000	crs	18	G30	1.000	1.000	1.000	crs
19	C31	0.841	0.736	0.875	drs							19	G26	1.000	1.000	1.000	crs
20	C30	0.849	0.742	0.875	drs							20	G25	0.996	0.995	0.998	drs
21	C25	0.929	0.823	0.886	drs							21	G24	0.993	0.991	0.998	drs
22	C22	0.973	0.890	0.915	drs							22	G21	0.895	0.886	0.990	irs
23	C18	1.000	1.000	1.000	crs							23	G18	0.892	0.879	0.986	irs
												24	G15	1.000	0.973	0.973	irs
	Mean	0.865	0.659	0.770			Mean	0.863	0.837	0.970			Mean	0.991	0.918	0.928	
	Min.	0.698	0.559	0.585			Min.	0.715	0.666	0.928			Min.	0.892	0.679	0.679	
	Max.	1.000	1.000	1.000			Max.	1.000	1.000	1.000			Max.	1.000	1.000	1.000	

Table 3: Hypotheses test

	TE Cattle and Goat		*TE Sheep and Goat*		*SE Cattle and Goat*		*SE Cattle and Goat*	
	Cattle	*Goat*	*Sheep*	*Goat*	*Cattle*	*Goat*	*Sheep*	*Goat*
Mean	0.865	0.991	0.863	0.991	0.770	0.928	0.970	0.928
Variance	0.015	0.001	0.012	0.001	0.017	0.008	0.001	0.008
F-test								
p-value	<0.001		<0.001		0.052		<0.001	
t-test								
p-value	<0.001		0.001		<0.001		0.038	
Significance	***		***		***		**	

** Significant at 5% and *** significant at 1% (two-tailed)

variances. The t-test was based on the following significance levels, where $\rho < \alpha = 0.01$ and á = 0.05, respectively (two-tailed) implying that there is overwhelming and strong evidence, respectively, that the null-hypothesis should be rejected in favour of the alternative hypothesis (Wegner 2007). The p-values of the t-tests indicate that the differences between TE_{VRS} and SE means are significant between SA Boer goat and cattle production and SA Boer goat and sheep production.

CONCLUSION

The key research problem under consideration centres on the efficiency of farming with SA Boer goat in comparison with farming with more conventional cattle and sheep. The research firstly found that cattle, sheep and goat production was seven, four and 20 times fully technically efficient with average scores of 0.865, 0.863 and 0.991, respectively. The cattle and goat farming was found to be fully technically efficient when more than 73% and 26% of capital needs are employed, respectively, and sheep are fully efficient when less than 26% of capital needs are employed. The study also found that there is overwhelming evidence that the differences between the scores of SA Boer goats are significantly higher than the scores of cattle and sheep (H1). Therefore, the study concludes that goat production outperforms cattle and sheep production financially.

The study secondly found that cattle, sheep and goat production did not achieve economies of scale in 22, 17 and 20 of the scenarios. The trend is also remarkable that the SE scores increase when the capital levels decrease. On average, sheep production has the highest scale efficiency with a score of 0.970, followed by goat and cattle with scores of 0.928 and 0.770, respectively. The study also found that there is overwhelming evidence that the scores of SA Boer goats are significantly higher than cattle and there is strong evidence that the score of sheep is significantly higher than the score of SA Boer goats. Therefore, the study concludes that it is easier for sheep production to operate at a scale that maximises productivity, followed by SA Boer goat and then cattle production.

RECOMMENDATIONS

The primary recommendation of this paper is that agricultural producers can use the findings of the study in their decision-making between whether to focus on SA Boer goat, cattle or sheep production. The value of the paper is furthermore that this is the first effort to build a DEA model to compare the relative technical and scale efficiencies between SA Boer goat production and cattle and sheep production.

LIMITATION OF THE STUDY

The primary limitation of the study is that it did not investigate combinations of SA Boer goat production with other species such as sheep and cattle.

FUTURE RESEARCH

The areas for future research address the limitation of the study, namely that future studies can be conducted where a combination of species are produced on the same farm.

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APPENDIX

CASE STUDY

Assumptions

With SA Boer goat and sheep farming, the assumption is that the SA Boer goats and sheep graze in the field and sleep in a small camp during nights. During the lambing season, the ewes are placed in a lambing camp. Cattle farming assumes that the cattle graze and sleep in the field. There are a number of technical factors that affects financial evaluations of the different types of farming. In order to conduct the study, assumptions have been made, based on oral communication during 2011 with experts on farming, fencing, dosing medicines and dosing periods and stock handling facilities (Boshoff J, Cilliers J, De Chalain F, Naude F, Mouton J, Van Zyl A, Van Zyl B 2011.), and are discussed below:

- Farm location: The farm is situated in the North West Province in the Potchefstroom area. In the North West Province, livestock farming is general and it is the province of South Africa with the fourth most livestock. There is adequate support such as markets, auctions, livestock experts, dosing products and livestock handling facilities in this area.
- Field type: It consists mainly of grassland with scattered Karoo-like shrubs and is described as Cymbopogon-Themeda Field (Acocks 1988).
- Farm size: For research purposes, it was assumed that all farms have a perfect square shape.
- Fencing: The cost of fencing includes only the physical supplies and not the labour. For the purpose of this study, the researcher has assumed that the farm is enclosed by a fence consisting of five strands of wire already. The recommended number of strands of wire for the different species involved is as follows: cattle five strands-, sheep six strands- and SA Boer goat ten strands of wire. The capital required for fencing is therefore only applicable to sheep and SA Boer goats. The cost of single barbed fence is R0.56 per meter.
- Herd diversity: For the purpose of this study, the researcher has assumed that the herd exists of females, all being set for conception already and that they would be pregnant within one month from the beginning of the study. For the purpose of the study, they have assumed that there are enough male breeding animals, but that their small numbers are omissible.
- Herd growth: It has been assumed that the age of animals in the herd is evenly distributed from the age ready to produce up to tailings. The researcher has accepted that culling will be sold annually. The breeding size of the herd will be filled by offspring from the flock. The species involved can produce offspring at the following ages: Cattle from two to eight years, sheep from one to eight years and SA Boer goats from one to ten years. The following rates are applicable to the determination of the percentage of the herd that will be sold as waste annually: Cattle: 14 per cent; sheep: 17 per cent; and SA Boer goat: 11 per cent.
- Breeding rate per year: Cattle 76 per cent, sheep 98 per cent and SA Boer goats 120 per cent.
- Selling prices: The selling prices of cattle and sheep, as published in the Landbouweekblad (2011): Weaning calves: R17.80 per kilogram (on the hoof), culling: R26.14 per kilogram, weaning lambs: R20.83 per kilogram (on the hoof), and culling: R44.13 per kilogram. As there is no formal market indicator for the price of SA Boer goats, the opinions of experts were used: Gelded SA Boer goats: R26 per kilogram (on the hoof); and culling: R32 per kilogram.
- Purchase price: The purchase price of females is as follows: Cattle: R7 125 per unit; sheep: R1 045 per unit; and SA Boer goats: R1 500 per unit.
- Weight: Cattle: Weaning weight (on the hoof) 235 kilograms and culling weight (carcass) 250 kilograms. Sheep: Weaning weight (on the hoof) 30 kilograms and culling weight (carcass) 28.75 kilograms. SA Boer goats are as follows: Weaning weight (on the hoof) 30 kilograms and culling weight (carcass) 23 kilograms.
- Bearing power: The bearing power in this area is as follows: Cattle: five hectare per unit; sheep: one hectare per unit; and SA Boer goat: 0.86 hectare per unit.
- Labour: Although the labour intensity of the different farming industries differs, there is not a constant amount of labour for each farm as farmers' views pertaining to labour needs differ. For purposes of the study, the following amounts per unit per year were used: Cattle: R168; sheep: R57.60; and SA Boer goats: R57.60.
- Capital: The capital available is sufficient to set up the farm for the keeping and handling of the animals, as well as to purchase the initial herd.
- Stock handling facilities: Since there are various factors that play a role in setting up stock handling facilities (e.g. crush-pens), it has been decided to use the average amount provided by the bank for the three herd sizes (farm sizes): Cattle: R54 800; sheep: R33 947; and SA Boer goat: R37 937.
- Dosing: A list of dosing medicines and dosing periods was compiled and the cost per female breeding animal calculated accordingly: Cattle: R215.61; sheep: R76.17; and SA Boer goats: R70.55.
- Mineral supplements per year: The authors mentioned have determined it as follows: Cattle: R356.00; sheep: R163.11; and SA Boer goats: R163.11.

Financial Measures

- Return on investment: The equation for this calculation is the operating profit divided by invested capital profitability relative to total assets used for the measurement (Correia et al. 2010; Hawawini and Viallet 2011). For this study, the operating profit has been replaced by the relevant contribution. Invested capital consists of the purchase cost of the herd and relevant capital expenditures such as feeding troughs, fencing and stock handling facilities.

- Asset turnover: It is determined by dividing the turnover of an entity by its total assets to determine the usage of the assets relative to turnover (Hawawini and Viallet 2011; Correia et al. 2010). The total assets have been replaced with capital invested (as defined above) and output is the same as sales revenue above.
- Contribution per hectare: The purpose of this ratio is to determine output that the farmer obtains from the land-input, by dividing the relevant contribution by the farm size. It is therefore the profitability relative to farm size.
- Payback period: The original equation to determine the payback period is capital investment divided by annual cashflow (Correia et al. 2010), where the latter is replaced by the annual relevant contribution.
- Net present value: The net present value is calculated by discounting the annual relevant contribution and capital investments over a number of years to the present value. It has been determined over a period of five years and the rate used is an inflation rate of four per cent plus six per cent returns during a period of relatively low inflation, as a widely accepted standard (Correia et al. 2010).
- Break-even point: According to Correia et al. (2010), the break-even point of a project is the number of units that a project has to sell to produce a zero net present value.