A METAFRONTIER ANALYSIS OF SHEEP PRODUCTION IN THE N8 DEVELOPMENT CORRIDOR

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DECLARATION

I, Yong Sebastian Nyam, hereby declare that:

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Yong Sebastian Nyam Date

Bloemfontein

February 2017

DEDICATION

I dedicate this work to the memory of my beloved mother, Nain Margate Anchang. I know you are looking down on us with a lot of joy. We love you.

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ABSTRACT

In South Africa, sheep enterprises play an important role as a source of livelihood for many farmers, especially smallholder farmers. The productivity of sheep farmers in South Africa is very low. The lack of analytical evidence on efficiency levels of smallholder sheep farmers in the different sheep production systems limits policy-making on optimal allocation of resources. In addition, these smallholder farmers are faced with numerous constraints regarding production, which is considered to be one of the many factors impeding their productivity and livelihood. Very little is known empirically about the constraints faced by these farmers and how they can be overcome.

This study analysed the factors that influence the productivity of sheep production to enhance the livelihoods of smallholder sheep producers in the N8 development corridor and to identify and rank the constraints faced by smallholder sheep farmers along the N8 development corridor. Data for this study was collected with the use of structured questionnaires. A sample size of 217 smallholder sheep farmers comprising 157 from Thaba Nchu and 60 from Botshabelo was used. The stochastic metafrontier model was used to estimate technical efficiency and technology gaps across the different farms in the study areas. The Kendall's coefficient of concordance was used to identify and rank the constraints faced by smallholder farmers.

The empirical results of the study revealed that farmers in both Thaba Nchu and Botshabelo are technically inefficient. The empirical results show that herd size and feed cost had significant positive effects on sheep output in Thaba Nchu municipal district, indicating that these variables are vital for enhancing sheep production in Thaba Nchu. However, land size and sheep loss were found to have a significant negative effect on sheep output in Thaba Nchu. The negative effect of land size on sheep output was completely unexpected. It is assumed that these farmers have relatively small herds, and increasing land size will only add to the cost of managing the land. On the other hand, land and transport costs had significant positive effects on sheep output Botshabelo, indicating that these inputs are vital to enhancing sheep production in this district municipality. Sheep loss had the expected significant negative effect on sheep production in Botshabelo. In the pooled sample, herd size, feed cost and labour were found to have significant positive effects on sheep production in the study areas. However, land size and sheep loss were found to have a significant negative effect on sheep output in the pooled sample.

The gamma value of 0.679 means that about 67.9% of the variation in sheep output in Thaba Nchu is explained by technical inefficiency, while 32.10% of the variation is due to random shocks and statistical noise. For Botshabelo, the gamma value (0.779) was relatively higher than in Thaba Nchu, indicating that the effects of inefficiency on variation of the sheep output is far larger than that of random shocks. The pooled sample had a gamma value of 0.799. This means that 79.9% of the variation in sheep production in the study areas is due to inefficiency and 11.1% is due to random shocks. The variation in sheep production for the study areas is generally due to technical inefficiency on the part of the sheep farmers. The stochastic production frontier analysis showed that the average technical efficiency of Thaba Nchu farmers was 67.3% and 65.7% for farmers in Botshabelo. This result indicates that there is 32.7% potential for Thaba Nchu farmers to expand their production by operating at full technical efficiency level, while the scope for Botshabelo to increase the level of efficiency using available farm resources and technologies is about 34.3%. The variables that influence the technical efficiency level of Thaba Nchu farmers are indigenous sheep breed, education level, veterinary services and market distance. Indigenous sheep and market distance had a significant negative effect on technical efficiency in Botshabelo while farm experience and crossbreeding method had significant positive effects on technical inefficiency. Theft, lack of capital, diseases and parasite were found to be the most severe constraints facing the sheep farmers.

The average technical efficiency scores estimated relative to the metafrontier (TE_m) for Thaba Nchu was 0.495 while for Botshabelo was 0.442. The results indicate further that a regional production frontier is necessary to advise farmers in each district on ways to improve the productivity and efficiency of sheep production. It can be concluded from the results of the study that farmers in the study area are producing well below the production frontier. This means that farmers have the potential to increase their productivity and efficiency in order to produce at full capacity.

The policy recommendation arising from this study is that farmers should be trained on proper farm management techniques and that proper market channels should be developed for farmers to sell their products. Building new fences and improving old ones will help prevent theft and will increase sheep outputs.

Key Words: Technical efficiency, determinants of technical inefficiency, South Africa, N8 development corridor, metafrontier, productivity, smallholder sheep production, technology gap ratio, stochastic metafrontier model.

OPSOMMING

In Suid-Afrika speel ondernemings wat by skaapboerdery betrokke is 'n belangrike rol as bron van lewensonderhoud, veral onder kleinboere. Die produktiwiteit van skaapboere in Suid-Afrika is baie laag. Daar is 'n tekort aan analitiese inligting oor die doeltreffendheid van kleinboere, wat verskillende skaapproduksiestelsels vir skaapboerdery toepas. Dit beperk beleidmaking oor optimale toewysing van hulpbronne. Verder word hierdie kleinboere deur 'n verskeidenheid beperkings ten opsigte van produksie gekonfronteer, en dit is een van die baie faktore wat hulle produktiwiteit en lewensbestaan strem. Baie min empiriese inligting is bekend oor die beperkinge wat dié boere konfronteer en hoe hulle oorkom kan word.

Hierdie studie ontleed die faktore wat die produktiwiteit van skaapproduksie beïnvloed, met die doel om die lewensbestaan van kleinboere wat in die N8 ontwikkelingskorridor met skape boer, te verbeter, en om die beperkinge wat die klein- skaapboere in die N8 ontwikkelingskorridor konfronteer, te rangorden. Data vir hierdie studie is deur middel van 'n gestruktureerde vraelys, in Engels, versamel. 'n Datastel bestaande uit 217 klein-skaapboere is gebruik: 157 van Thaba Nchu en 60 van Botshabelo. Die stogastiese metagrensmodel is gebruik om tegniese doeltreffendheid en tegnologiegapings by die verskillende plase in die studieareas te beraam. Kendall se koëffisiënt van konkordansie is gebruik om die beperkinge wat kleinboere konfronteer, te identifiseer en rangorden.

Die resultate van die studie dui aan dat boere in sowel Thaba Nchu as Botshabelo tegnies ondoeltreffend is. Die empiriese resultate dui aan dat kuddegrootte en die koste van veevoer 'n beduidende positiewe effek het op skaapuitset in die Thaba Nchu munisipale distrik, wat beteken dat hierdie veranderlikes noodsaaklik is om skaapproduksie in Thaba Nchu te verbeter. Daar is bevind dat grondgrootte en skaapverliese 'n beduidende negatiewe effek op skaapuitset in Thaba Nchu het. Dit beteken dat 'n toename in die gebruik van of die grootte van grond, en groter skaapverliese, skaapuitset sal verminder. Die negatiewe effek van grondgrootte op skaapuitset was heeltemal onverwags. Daar word aanvaar dat hierdie boere se kuddes relatief klein is, en as hulle meer grond vir boerdery het sal dit die koste van bestuur van 'n groot gebied met 'n klein kudde, verhoog. Aan die ander kant het grond en vervoerkoste 'n beduidende positiewe effek op skaapuitset in Botshabelo, wat beteken dat hierdie insette noodsaaklik is vir die verbetering van skaapproduksie in dié distriksmunisipaliteit. Skaapverliese het 'n beduidende negatiewe effek op skaapproduksie in Botshabelo. 'n Toename in skaapverliese sal skaapuitset in die distriksmunisipaliteit

verminder. Ten opsigte van die volledige datastel is bevind dat kuddegrootte, koste van voer en arbeid 'n beduidende positiewe uitwerking op skaapproduksie in die studieareas het, wat beteken dat 'n toename in die gebruik van enige van dié veranderlikes sal veroorsaak dat skaapuitset in die studieareas sal toeneem. Daar is egter bevind dat grondgrootte en skaapverliese 'n beduidende negatiewe effek op skaapuitset van die totale datastel het.

Die beraamde gammawaarde vir Thaba Nchu was 0.679 beteken dat ongeveer 67.9% van die variasie in skaapuitset deur tegniese ondoeltreffendheid verduidelik word, terwyl 32.10% van die variasie te wyte is aan willekeurige skokke en statistiese geraas. Vir Botshabelo was die gammawaarde (0.779) relatief hoër as in Thaba Nchu, wat aandui dat die effekte van ondoeltreffendheid op variasie van skaapuitset baie groter is as dit wat deur willekeurige skokke veroorsaak word. Die saamgestelde datastel het 'n gammawaarde van 0.799 gehad. Dit beteken dat 79.9% van die variasie in skaapproduksie in die studieareas te wyte is aan ondoeltreffendheid en 11.1% is weens willkeurige skokke. Die variasie in skaapproduksie vir die studieareas is oor die algemeen te wyte aan tegniese ondoeltreffendheid aan die kant van die skaapboere. Die stogastiese produksiefgrensanalise toon dat die gemiddelde tegniese doeltreffendheid van boere in Thaba Nchu 67.3% was -- hoër as dié van Botshabelo, wat 'n gemiddelde tegniese doeltreffendheid van 65.7% gehad het. Hierdie bevinding toon dat daar 'n potensiaal van 32.7% is vir boere in Thaba Nchu om hulle produksie uit te brei deur teen volle tegniese doeltreffendheid te werk. Die moontlikheid vir boere in Botshabelo om hulle vlak van doeltreffendheid te verhoog deur beskikbare plaashulpbronne en tegnologie te gebruik, is ongeveer 34.3%. Die veranderlikes wat die tegniese doeltreffendheidsvlak van Thaba Nchu se boere beïnvloed is inheemse skaaprasse, opvoedingsvlak, veeartsenydienste en afstand van die mark af. Inheemse skaaprasse, opvoeding en afstand van die mark af het 'n beduidende negatiewe uitwerking op tegniese ondoeltreffendheid van skaapboere in Thaba Nchu, wat aandui dat hierdie veranderlikes nodig is om doeltreffendheidsvlakke in die distrik te verhoog. Veeartsenydienste het 'n beduidende positiewe invloed op tegniese ondoeltreffendheid, wat suggereer dat hierdie veranderlike geneig is om die doeltreffendheidsvlak van die boere te verlaag. Inheemse skape en afstand van die mark af het 'n beduidende negatiewe effek op tegniese doeltreffendheid in Botshabelo terwyl ervaring van boer en kruisteelmetode 'n beduidende positiewe effek op tegniese ondoeltreffendheid het. Diefstal, tekort aan kapitaal, siektes en

Die gemiddelde tegniese doeltreffendheid, wat ten opsigte van die metagrens bereken is, is vir Thaba Nchu (TE_m) 0.495, terwyl die gemiddelde TE_m vir Botshabelo 0.442 was. Die resultate dui aan data 'n produksiegrens vir die streek nodig om boere in elke distrik te adviseer oor hoe om die produktiwiteit en doeltreffendheid van skaapproduksie te verbeter.

Die gevolgtrekking uit die resultate is dat boere in die studiearea ver onder die produksiegrens presteer. Dit beteken dat boere die potensiaal het om hulle produktiwiteit en doeltreffendheid te verhoog ten einde teen volle kapasiteit te produseer.

Die beleidsaanbeveling wat uit dié studie voortvloei is dat boere opgelei moet word om behoorlike boerderybestuurstegnieke toe te pas, en dat die regte markkanale ontwikkel moet word waar boere hulle produkte kan verkoop. Diefstal kan beperk word en skaapuitsette kan verhoog word as nuwe heinings opgerig word en oues herstel word.

Sleutelterme: Tegniese doeltreffendheid, bepalers van tegniese doeltreffendheid, Suid-Afrika, N8 ontwikkelingskorridor, metagrens, produktiwiteit, kleinboer skaapproduksie, tegnologiegapingsverhouding, stochastiese metagrensmodel.

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LIST OF ABBREVIATIONS AND ACRONYMS

AE	Allocative efficiency
ARC	Agricultural Research Council
DA	Department of Agriculture
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Data Envelopment Analysis
FAO	Food and Agricultural Organisation
GDP	Gross Domestic Product
ILO	International Labour Organisation
LP	Linear Programming
LDP	Livestock Development Plan
MDGs	Millennium Development Goals
MFP	Multi Factor Product
MLE	Maximum Likelihood Estimator
MTR	Meta-Technology Ratio
NDP	National Development Plan
NPC	National Planning Commission
PFP	Partial Factor Product
SA	South Africa
SFA	Stochastic Frontier Analysis
SFP	Single factor Productivity
TE	Technical Efficiency
TEM	Technical Efficiency relative to the Metafrontier
TFP	Total Factor Productivity
TGR	Technological Gap Ration

CHAPTER 1: INTRODUCTION

1.1 Background of study

Livestock production makes an important contribution to most economies around the world, especially developing economies that depend largely on livestock production for their livelihoods (Tamirat, 2013). Various livestock production systems occupy an estimated 30% of the world's total surface area. The sector is well structured, with long market value chains that employ roughly 1.3 billion people globally; the sector contributes directly to the livelihoods of 600 million smallholder farmers in developing countries (Thornton, 2010). The role of livestock farming has increased significantly throughout the world and particularly in developing countries – it plays a major role in agriculture and sustainable development in Africa too (Thornton, 2010). As demand for livestock products is expected to increase in developing countries, there is a unique opportunity for sustainable intensification of livestock systems as an instrument for reducing poverty and improving the management of the environment (McDermott *et al*., 2010; Ogunkoya, 2014). Growing demand for livestock in developing countries provides an opportunity for livestock producers in those countries to increase production. This growth in agricultural production will have to take place in a way that affords smallholder farmers the opportunity to benefit from increased demand by applying environmentally sustainable production methods (Thornton, 2010).

Sheep production plays a very important role in the South African livestock industry, because it is a source of cash income and therefore contributes to smallholder farmers' livelihood (Brundyn *et al.,* 2005; Mapiliyao *et al.,* 2012). Livestock production holds a great potential to alleviate household food insecurity and poverty in South Africa (Mapiliyao *et al.,* 2012). The livestock industry contributes approximately 45% of South Africa's agricultural output and employs approximately 500 000 people nationwide (DAFF, 2012). Land used for agriculture comprises approximately 82.3% of the total land area of South Africa, and approximately 68.6% of the agricultural land in South Africa is used for extensive livestock grazing (DAFF, 2016). Livestock is by far the largest agricultural sub-sector in South Africa, contributing an estimated 25 – 30% to the total agricultural output per year (Blignaut *et al.*, 2014). Cattle, sheep and goat farming in South Africa occupy approximately 53% of all agricultural land (Blignaut *et al.*, 2014). Sheep production provides food security, enhances crop production (by providing manure), generates income for smallholder farmers, provides fuel for transport and produces value-added goods that can have a multiplier effect and help create a need for further services (FAO, 2012).

In 2015, South Africa's sheep product exports stood at an estimated 2 000 tons. The country's imports of sheep products for the same period stood at an estimated 10 000 tons, which shows that South Africa is a net importer of sheep (DAFF, 2016). Production and consumption of meat from sheep in South Africa varied significantly during the period 2004 to 2015 (DAFF, 2016). Figure 1.1 shows the production and consumption of sheep meat in South Africa from 2004 to 2015. The figure shows that the consumption of sheep exceeded the local production for the years 2004 to 2015. This implies that there is an excess demand for sheep meat in South Africa. Hence, there is the need for sheep farmers to increase their production to meet the excess demand. In order to meet the excess demand, South Africa imports sheep meat from countries such as New Zealand and Australia (DAFF, 2016).

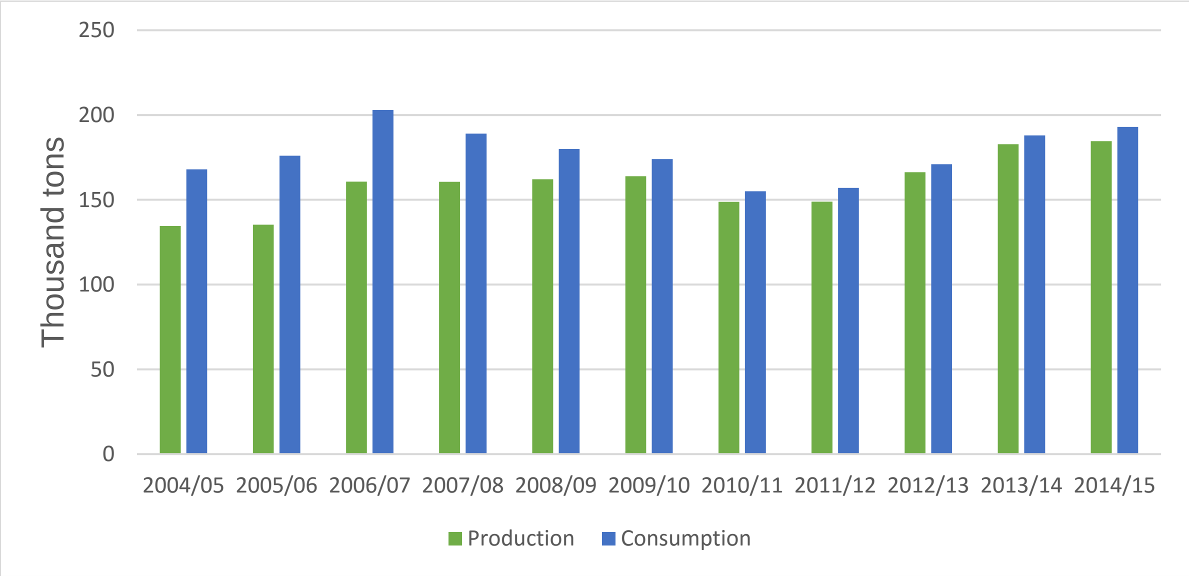


FIGURE 1.1 PRODUCTION AND CONSUMPTION OF SHEEP MEAT IN SOUTH AFRICA

SOURCE: DAFF (2016).

Sheep production increased from 135 000 tons in 2004 to 161 000 tons in 2006, whereas consumption increased from 168 000 tons to 203 000 tons during the same period. In the period 2006 to 2009 there was a continuous increase in sheep production, from 161 000 tons to 164 000 tons, and in this period consumption decreased too; consumption decreased continuously from 2007 to 2014, from 189 000 tons to 188 000 tons. Production was steady between 2006 and 2007, at 161 000 tons, and decreased steadily between 2011 and 2012. Production increased again between 2013 and 2015 compared to 2010, from 149 000 tons in 2010 to 185 000 tons in 2015. Consumption decreased continuously between 2009 and 2013 and increased again in 2014 and 2015 but was always more than production. Therefore, these figures show that South Africa is a net importer of sheep as more is consumed locally than it is produced.

This high expenditure on importing sheep products has become a great concern because of its negative impact on the country’s economic development. The amount South Africa spends importing sheep and sheep products also exert pressure on the foreign currency reserves. Therefore, the South African government desires to reduce importation of sheep products by promoting domestic sheep production through productivity and efficiency-enhancement measures (DAFF, 2016). Enhancing domestic sheep production will reduce South Africa's foreign expenditure on the importation of sheep products. Promotion of domestic sheep production will also enhance the output and income levels of farmers and eventually improve their standards of living through the provision of employment for farmers, processors and marketers. Enhancing the output of farmers means an increase in sheep production to meet the demands of the local market and export. Increased demand will drive prices upward and as a result the income levels and livelihoods of farmers are improved.

Mixed livestock (such as sheep, cattle, goats and horses) and crop farming are the main agricultural activities in the Free State province (DAFF, 2012; Maphalla and Salman, 2012). The N8 development corridor (Thaba Nchu and Botshabelo) and most central parts of the province are regarded as good livestock grazing areas. An estimated 8.7 million hectares (approximately 58.2%) of land in the Free State is used for veld and grazing, while approximately 3.2 million hectares (approximately 32.6%) is used for cultivation (Maphalla and Salman, 2012). The province produces and supplies approximately 20% of all the beef, wool and milk in South Africa, making the province one of the biggest players in the livestock industry (Ogunkoya, 2014).

There is a reasonable amount of literature available on the various production practices of and constraints facing smallholder sheep farmers in most communal areas (see Abebe *et al.*, 2013; Mapiliyao *et al.*, 2012; Ogunkoya, 2014). However, very limited information on the productivity and technical efficiency of smallholder sheep farmers[1] in South Africa in general and the N8 development corridor in particular was found. Because of this lack of information, it is very difficult to design and implement developmental programmes that will benefit smallholder sheep farmers. Should the production of smallholder farmers be enhanced, the production and consumption deficit in South Africa could be reduced. It is very important, therefore, to understand the current status of these smallholder sheep farmers in the N8 development corridor in terms of their productivity and technical efficiency, and to investigate the constraints they are possibly facing in the production process. Sheep production in the N8 development corridor is characterised by small-scale production. Developing the sheep

[1] Smallholder farmers are farmers who produce relatively small output and are mostly located in rural areas. Most of these farmers are poor and depend largely on agriculture for their livelihoods.

industry can be a sustainable way of improving food security and livelihoods of smallholder sheep farmers (Mapiliyao *et al.,* 2012; Miao *et al.,* 2005). Increased productivity and efficiency of lamb and mutton production is vital to improving the competitiveness of the sheep meat industry (Montossi *et al.,* 2013).

1.2 Statement of Problem

Declining sheep numbers, combined with increasing population growth in South Africa, have led to an increase in demand for sheep and a shortage in supply in the local market (ARC, 2013). Sheep production must be enhanced to meet the demand of the local market. Considering prevailing poverty rates and high food insecurity in Africa and South Africa, better and more efficient production techniques are needed to feed the growing population. The National Development Plan (NDP) vision 2030 of South Africa seeks to reduce poverty rates and food insecurity in rural communities around the country by enhancing the productivity of the livestock industry. Animal production is a source of nutrients necessary for food security, and employs many people in rural communities (NPC, 2011). This is in line with the Sustainable Development Goals (SDGs) (2030 Agenda) of the United Nations, which place a great deal of emphasis on ending poverty in all its forms, everywhere, ending hunger, achieving food security and improving nutrition, and promoting sustainable agriculture (Loewe and Rippin, 2015). The South African government, through the livestock development strategy, is working to end poverty and food insecurity in the country by enhancing the productivity of smallholder livestock farmers. Expanding the livestock industry will lead to employment, improved income and socio-economic development in the country, and particularly in rural areas where livestock production dominates (DAFF, 2014).

The Free State is the third largest sheep producing province in South Africa, with a share of 20.6% of all the sheep in the country; however, most of the production is on a small scale (DAFF, 2012). Sheep farming is a significant agricultural activity in the N8 development corridor of the Free State province. Many households are engaged in sheep farming and they depend on sheep production for their livelihoods. Approximately 36% of the agricultural land in the N8 development corridor is covered by natural grazing, making the area very suitable for extensive livestock farming (ILO, 2012).

However, very little is known about the productivity of sheep farmers in the Free State as a whole and N8 development corridor in particular. The lack of analytical evidence on the efficiency levels of farmers in various sheep production systems in the Free State and N8 development corridor in particular constrains the development of programs geared towards assisting smallholder sheep farmers

Although the government of South Africa/Free State Department of Agriculture seeks to improve sheep production in the N8 development and the Free State in general, lack of empirical evidence on the factors affecting the productivity of smallholder sheep production, constraints the development of appropriate strategies to eradicate the constraints faced by smallholder sheep farmers. While others studies have estimated the technical efficiency of livestock production (see Bahta *et al.,* 2015; Bahta and Hikuepi, 2015; Otieno *et al.,* 2012; Temoso *et al., 2016*), the productivity of smallholder sheep farmers in the N8 development corridor and the Free State province in general remains unknown.

Research on technical efficiency (TE) of sheep-production systems is important to fill the gap in knowledge and offer insights into farmers' decisions about resource allocation. Improving efficiency might afford developing countries, like South Africa, the opportunity to produce enough output for the local market and for export. The N8 development corridor is distinguished by geographical location, access to markets, availability of factors of production, availability of information etc.

Fitting the metafrontier for the livestock industry would reveal the technological gap between the district municipalities and the extent to which the two district municipalities' stochastic frontiers depart from the metafrontier. Knowledge on the technology gap would inform stakeholders in the livestock industry about technological advances in the industry, which will help them devise appropriate strategies to promote agricultural technologies that would enhance farmers' productivity.

A number of studies have been done on livestock production in Africa and particularly in South Africa. Most of these studies investigated livestock-production practices, marketing, and the constraints to livestock production (see Abebe *et al.,* 2013; Burger *et al.,* 2013; Mapiliyao *et al.,* 2012; Ogunkoya 2014; Steinfeld *et al.,* 2006; Urgessa *et al.,* 2012). Others, however, focused their attention on the technical efficiency of livestock production (see Bahta *et al.,* 2015; Bravo-Ureta *et al.,* 2008; Ojo, 2003; Otieno *et al.,* 2012; Villano *et al.,* 2010). Empirical evidence shows that smallholder sheep farmers follow different production practices and are faced with numerous constraints that inhibit production of their livestock. Empirical evidence also shows that these smallholder farmers are technically inefficient. Ojo (2003) concluded that the technical efficiency of smallholder poultry farmers in Nigeria varied due to technical inefficiency effects in production, with a TE range of 0.239 and 0.933. This means, therefore, that there is scope for improvement among these smallholder farmers. Most of the studies on TE used stochastic frontier analysis, which investigates technical efficiency in a region and assumes the use of the same technology across different regions or districts. Nevertheless, production environments and technologies may differ from region to region.

1.3 Main Objective

The main objective of this study was to determine the factors that influence the productivity of sheep production, to enhance the livelihood of sheep producers in the N8 development corridor.

The specific objectives of this study were to:

- Estimate the TEs and determine the factors that influence TE of smallholder sheep farmers in two district municipalities along the N8 development corridor (Thaba Nchu and Botshabelo) using a stochastic frontier model (SFM);
- Estimate the metafrontier efficiencies and technology gap ratio for the smallholder sheep farmers in the two district municipalities (Thaba Nchu and Botshabelo); and
- Identify and rank constraints faced by sheep producers (farmers) using Kendall's Coefficient of Concordance.

1.4 Methodology and data used

In order to analyse the technical efficiency of smallholder sheep farmers in the N8 development corridor, the stochastic metafrontier model was employed. The stochastic metafrontier model can estimate the TE of heterogeneous (different) groups based on their distance from a common and identical frontier. During the last decade the stochastic metafrontier has become the approach that accounts for technological variation of both cross-sectional and panel data, and it has been used extensively in empirical research (Otieno, 2011). The estimation of a metafrontier is necessary since the study area consists of two district municipalities along the N8 development corridor. The expectation is that farmers in the two district municipalities do not use the same technology for sheep production; therefore, measurement errors might occur if same technology is assumed. The individual production frontiers for Thaba Nchu and Botshabelo indicate the state of technology regarding the transformation of factor inputs into sheep output. Kendall's Coefficient of Concordance will be used to identify and rank the constraints facing smallholder sheep farmers along the N8 development corridor.

Data for this study was collected by means of structured questionnaires. In both district municipalities of the N8 development corridor the Department of Agriculture (DA) assisted to obtain permission from the heads of rural households and herdsmen to conduct the survey under the farmers in the areas. The target respondents were smallholder sheep farmers in the N8 development corridor. Data was collected from both Thaba Nchu and Botshabelo along the N8 development corridor. These two district municipalities were chosen because of the number of livestock farmers, especially sheep farmers, in both districts and suitability of livestock production in the districts.

1.5 Organisation of the study

The study is structured into six main chapters. The relevant literature related to the research is discussed in Chapter 2. Chapter 3 presents the description of the study areas, sources of data, sampling procedure and socio-economic characteristics of the sheep farmers. Procedures used to address the stated research objectives are explained in Chapter 4. Chapter 5 discusses the results of the study and the last chapter outlines the summary, conclusion and policy recommendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Production is the process of transforming resources (raw materials: inputs) into commodities (outputs) using a given level of technology. The production process can be measured using a production function, while efficiency can be estimated through deterministic and/or parametric approaches, depending on the type of technology used (Otieno, 2011). Sheep production in South Africa is reviewed in the first section of this chapter. Agricultural productivity and its measurement are introduced in the second section. The third section presents the concept of efficiency and the various types of efficiencies, such as technical, allocative and economic efficiencies. A discussion on the different approaches to measuring efficiency follows, then methods to address technology differences in efficiency estimation and its empirical application is discussed. The final section investigates Kendall's Coefficient of Concordance and discusses the constraints faced by smallholder farmers; references are made to empirical literature to identify the determinants of agricultural productivity and efficiency.

2.2 Sheep Production in South Africa

Sheep production is very common in South Africa and is practiced throughout the country. Although all nine provinces are involved in sheep production, five provinces house the vast majority of the sheep in the country. These provinces are; the Eastern Cape, with 29% of all the sheep in South Africa, Northern Cape with 25%, Free State with 20%, Western Cape with 11% and Mpumalanga with 7% (DAFF, 2014). These five provinces account for 92% of all the sheep in South Africa, while the other four provinces share the remaining 8%. According to DAFF (2015) estimates, there were approximately 24.1 million sheep in South Africa, with Dorper being the most successful mutton breed; this breed was developed specially for the more arid areas of the country. Other breeds include Damara, Meatmaster, IIle de France, Dormer, Suffolk, Van Rooy and Vandor.

Table 2.1 shows the total number of sheep in South Africa between 2014 and 2015 production seasons and their percentage share in 2015.

TABLE 2.1 SHEEP DISTRIBUTION IN SOUTH AFRICA

Province	2014	2015	% of total 2015
Western Cape	2 810 505	2 811 456	11.7
Northern Cape	6 017 374	6 011 650	25.0
Free State	4 784 747	4 757 160	19.8
Eastern Cape	7 015 162	6 992 423	29.1
KwaZulu-Natal	755 171	737 686	3.1
Mpumalanga	1 761 110	1 737 543	7.2
Limpopo	256 966	255 302	1.1
Gauteng	98 369	100 071	0.4
North West	642 955	653 280	2.7
TOTAL	24 164 598	24 059 904	100

SOURCE: DAFF (2014).

The total number of sheep in South Africa decreased from 24 164 598 in 2014 to 24 059 904 in 2015. The sheep numbers in Western Cape, Northern Cape, Free State, Eastern Cape and Mpumalanga declined in 2015 compared to 2014 (Table 2.1). Sheep numbers in South Africa as a whole declined because four of the major sheep producing provinces experienced a decline in sheep numbers; furthermore, some of the provinces with fewer sheep, namely, Mpumalanga and Limpopo, also experienced a decline in numbers.

2.2.1 Livestock Marketing and Value Chains

Livestock systems afford smallholder farmers in developing countries a potential pathway out of poverty (Singh *et al.,* 2012). A significant proportion of the rural poor and most of the urban poor around the world, and Africa, in particular, keep livestock and use it in a variety of ways that sometimes stretches beyond income generation (Singh *et al.,* 2012). Most smallholder livestock farmers in Africa become involved in livestock production for income generation, in order to enhance their livelihoods and that of their families (Otieno *et al.,* 2012). Smallholder livestock farmers in general and sheep farmers along the N8 development corridor market their sheep products through various market channels (e.g. directly to abattoirs, feedlots, auctions or to the open market). We should note, however, that the formal marketing of sheep by smallholder farmers is sometimes characterised by absent or ill-functioning markets (Mapiliyao *et al.,* 2012). The paragraphs below presents discussion on sheep (lamb and mutton) and wool value chains in South Africa, which shows clearly the production and/or market channels through which sheep and wool pass before these products reach end consumers.

2.2.1.1 Sheep Supply Chain in South Africa

The supply-chain process normally begins with the farmer who produces sheep and lambs. In South Africa sheep farming is practiced mostly for wool and mutton/lamb production (DAFF, 2014). According to the Department of Agriculture, Forestry and Fisheries (DAFF), sheep are sold directly to feedlots (in small numbers) or abattoirs after about five to six years of shearing; or sold directly through auctions to the general public. Live sheep and lambs can be imported either by the farmer himself or the feedlot or the abattoir. Figure 2.1 provides a graphical representation of the sheep supply chain in South Africa

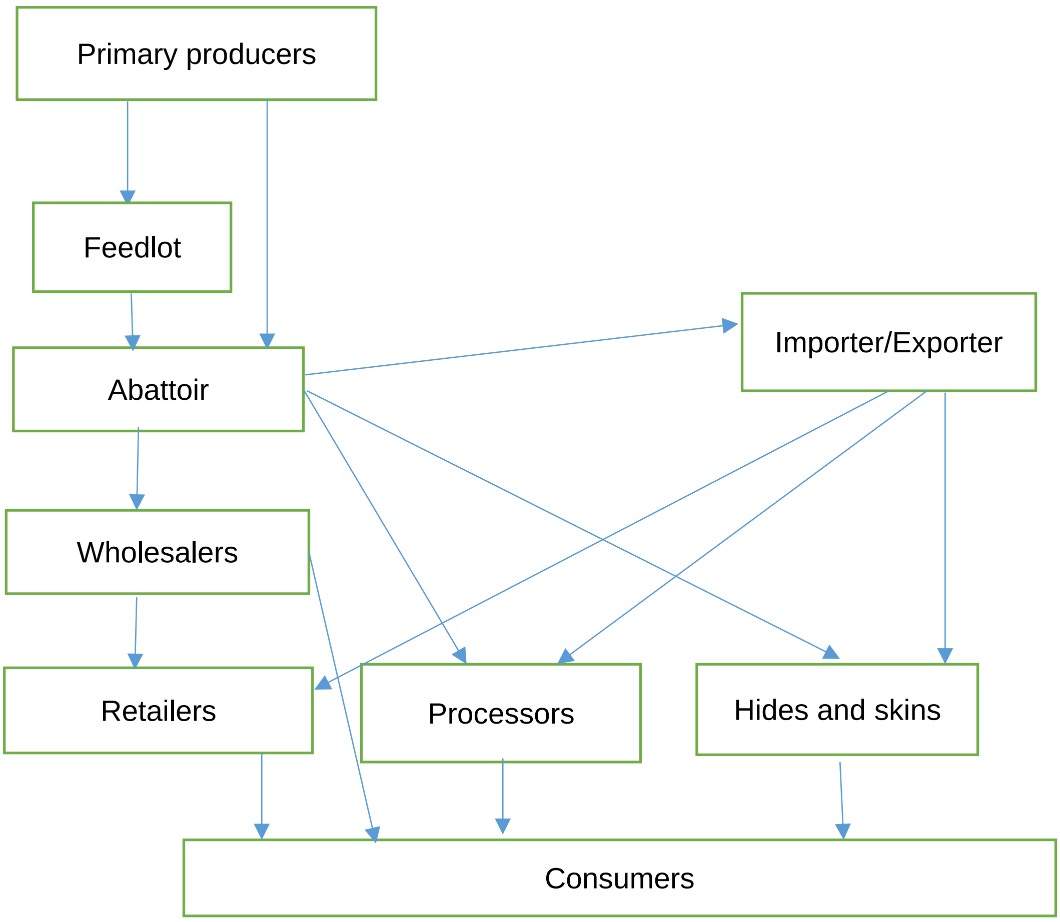


FIGURE 2.1 SHEEP MARKET VALUE CHAIN IN SOUTH AFRICA

SOURCE: ADOPTED FROM SAFA (2003).

The value chain of sheep production starts with the primary sheep producers, as indicated in Figure 2.1. These producers can sell sheep to either feedlots or to abattoirs. The feedlots provide sheep for slaughter to abattoirs. Abattoirs deliver to meat, hides and skins. Meat is the primary product that abattoirs deliver to either exporters for foreign markets, wholesalers provide to various retailers or processors (DAFF, 2014). Importation of meat is often done by retailer outlets, wholesalers and processors, while abattoirs export meat. The final stage of the supply chain ends with the end consumer.

2.2.1.2 Wool Supply Chain in South Africa

Wool is a fibre that is derived from the specialised skin cells, called follicles, of animals, principally sheep. Wool is crimped and has different textures or handles, it is elastic and grows in staples, making it different from hair and fur (DAFF, 2014). Wool reaches the consumer in different forms when processed. It passes through different market channels before reaching consumers, thereby affording wool producers (especially smallholders) various options to choose between when marketing their wool. Normally, wool is sold to buyers/traders or brokers. The buyers/brokers sell the wool based on its quality. Figure 2.2 is a graphical representation of the wool supply chain in South Africa.

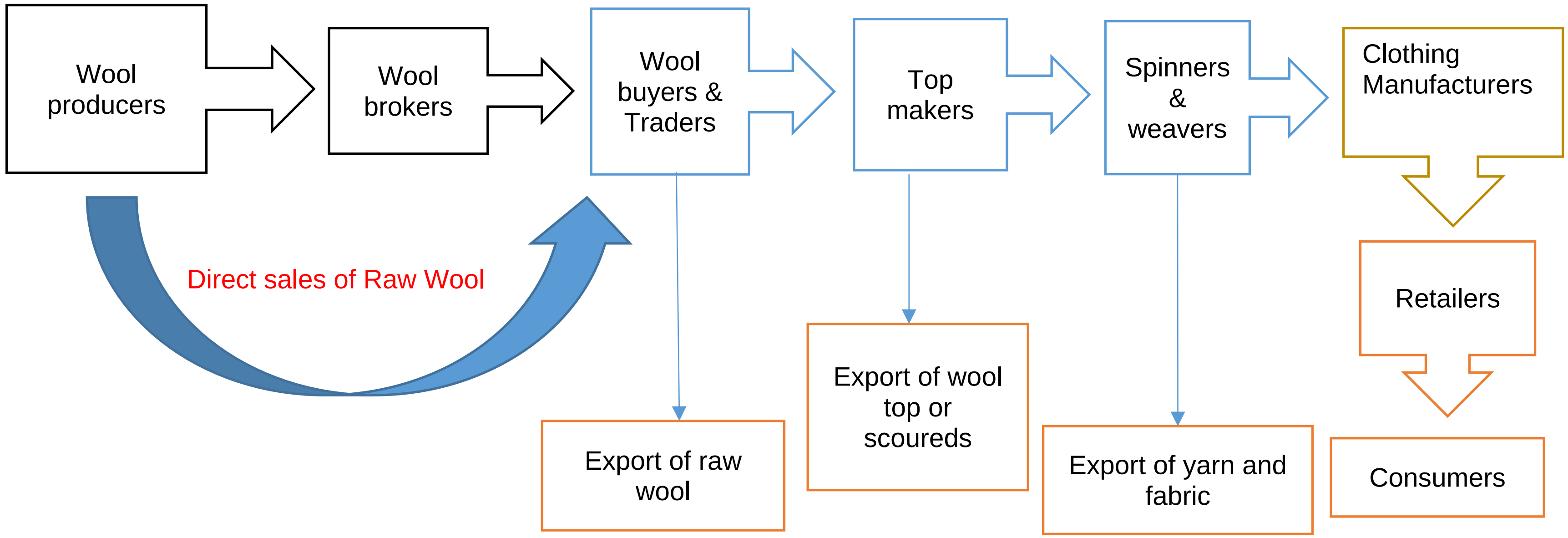


FIGURE 2.2 WOOL MARKET VALUE CHAIN IN SOUTH AFRICA

SOURCE: DAFF (2014).

The wool value chain starts with wool producers, who either sell to wool brokers or directly to wool buyers and traders. Wool traders export raw wool or sell to top makers, who also export wool top or scoured. Top makers sell to spinners and weavers, who export yarn and fabric and also sell to clothing manufacturers. Clothing manufacturers deal with retailers who sell to final consumers (Figure 2.2).

2.3 Agricultural Productivity and its Measurement

The world population is estimated to be 9.2 billion people in 2050, so the demand for food is expected to increase by at least 60% (FAO, 2012). This is a big challenge facing the world and the increasing world population has given rise to considerable attention being given to agricultural productivity. FAO (2012) argues that livestock production in general and sheep production in particular is among the mechanisms that can be utilised to feed the growing world population, given that livestock production is practiced in most parts of the world, especially in most parts of Africa. This shows the importance of livestock production to the agricultural development in Africa. Red meat is a source of protein. However, there claims that red meat (such as beef, lamb and mutton), especially processed meat, causes colorectal cancer (IARC, 2015). At this point, it is not clear exactly how red meat and processed meat cause cancer.

In various economics literature, aggregate productivity is defined as the amount of output gained from given levels of inputs in a given economy or a production sector (Otieno, 2011). Productivity is a fundamental source of larger income streams for farmers; and thus savings, which enable more inputs to be employed (Pascoe and Tingley, 2003). Agricultural efficiency plays a critical role in the welfare of the rural poor, and in the economic development of sub-Saharan African countries. Through its influence on long-run real wages, agricultural productivity of labour directly and indirectly determines the standards of living of at least 70% of Africans, who are largely dependent on agriculture for their cash income and livelihood (Otieno, 2011). Agricultural productivity helps to increase agricultural output sufficiently and at a rate fast enough to meet the ever-increasing demands for food and raw materials for production (Bruce *et al.,* 2007; Ehui and Pender, 2005).

There is a growing demand for food globally due to the increase in population and this compels researchers to focus on improving agricultural productivity. Researchers have come to the realisation that, if they are to solve the problem of food insecurity, a suitable way of addressing the problem would be to increase food production per unit of land area (Lenis *et al.,* 2010; Mapula *et al.,* 2011; Rangalal, 2013).

Productivity growth in agriculture caught the attention of economists a long time ago, because agricultural growth releases resources to other sectors (Ludena, 2010). Productivity has been measured quite extensively in the past, and researchers measured it using different methods based on their personal views and experiences of productivity. Two concepts have been used to measure agricultural productivity; partial and total factor productivity (Malmquist index). Partial factor productivity, sometimes called single factor productivity, is the ratio of physical output to a unit of input used in production, usually land, capital or labour (Odhiambo and Nyangito, 2003). Mathematically, partial factor productivity can be stated as:

$$PFP = \frac{y}{x_i};$$

Where y is output and x_i is input. The main advantage of estimating partial productivity measures is that they are crucial indicators of welfare, thus, they can be used to address a specific welfare issue. For example, labour productivity can be used as an indicator of rural welfare (which is measured as per capita income) and land productivity can be used by policy-makers to address national food security issues. Though frequently used, the partial productivity or single factor productivity measure has a flaw in that it has absolutely no control over the level of additional inputs employed. Single factor productivity measures are very good at addressing specific questions, but they are not complete parameters of agricultural productivity, because they can only measure the productivity of a single factor of production (Odhiambo and Nyangito, 2003).

Total factor productivity, however, estimates the level of output per unit of all the total factor inputs. Therefore, total factor productivity is a broad view of partial factor productivity measures, such as labour productivity or land productivity (Odhiambo and Nyangito, 2003). Total factor productivity or multifactor productivity completes the partial factor productivity by simply measuring the changes and levels in the aggregate agricultural output in relation to changes in the total index of multiple inputs (Thirtle *et al.,* 1993). Total factor productivity is centred primarily on the notion of a function that measures the distance from a given input/output vector to the technically efficient frontier in a particular direction defined by the relative levels of the alternative outputs (Ludena, 2010). The main weakness of total factor productivity, however, is that, in aggregating farm inputs, it becomes a challenge, particularly when price data is not readily unavailable.

The concepts of productivity and efficiency have been used quite often, and different studies have been done to measure these two concepts. However, there is a great deal of confusion when it comes to these concepts, and understanding them is very important. Smallholder farmers are often faced with challenges relating to farm productivity and ways to enhance productivity to uplift livelihoods (Bruce *et al.,* 2007). Nonetheless, many researchers fail to understand the differences and the interdependencies between productivity and efficiency. Productivity and efficiency are used interchangeably because they are closely related in meaning. Productivity changes are due to variances in production technology, variances in production efficiency, and variances in the production environment (Odhiambo and Nyangito, 2003). Efficiency is, therefore, a very significant factor of productivity and must be integrated in productivity analyses. The challenge is to empirically measure productive efficiency and to allocate its portion in the productivity differences (Odhiambo and Nyangito, 2003).

2.4 The Efficiency Concept

Efficiency is one of the most important concepts relating to production, be it agricultural or industrial. Farrell (1957) defines efficiency as a firm's success in producing the largest output possible from a given set of inputs holding all other factors constant. In a further analysis, Farrell (1957) explains that his definition is acceptable, provided that all inputs and outputs are measured correctly. Efficiency can also be described as the best possible combination of the amount of output and input, and the amount of input and output that defines a production frontier of a firm within an industry. According to Lovell (1993), the comparison between observed and optimal values of output and input is known as efficiency of a production unit. This comparison can be in the form of the ratio of minimum potential to observed, input required to produce the given output, or the ratio of observed to maximum potential output obtainable from the given input. Productive efficiency is a very important component of increasing productivity growth in developing economies where productive resources are limited (Alvarez and Arias, 2004). It is very important for developing economies to understand the concept of efficiency, so that they can take advantage of it by determining the point to which it is possible to increase efficiency using the existing resource base or technology (Alvarez and Arias, 2004). Therefore, understanding the concept of efficiency and the various types of efficiencies is very important. Various economic theories have identified at least three types of efficiency, namely, technical, allocative and economic efficiencies, with TE being the most important.

2.4.1 Technical Efficiency

TE compares observed and optimal values of output and inputs of a production unit (Odhiambo and Nyangito, 2003). TE can be a measure of the ratio between observed output and the maximum output, under the assumption of fixed input, or, as the ratio between the observed input and the minimum input under the assumption of fixed output. In literature, there are two main definitions of technical efficiency; pure and relative efficiencies (Porcelli, 2009). Pure technical efficiency is also called the Koopmans measure of technical efficiency, while relative efficiency is termed as the Debreu-Farrell measure of technical efficiency (Cooper *et al.,* 2004; Greene, 2005; Porcelli, 2009).

Koopmans (1951), defined TE by saying that an input-output vector is technically efficient if an increase in any output or a decrease in any input is possible only by reducing some other output or increasing some other input. Charnes *et al.* (1984) and Farrell (1957) later reviewed Koopmans' definition empirically and gave their own definition of technical efficiency as a notion that is relative to a best observed practice in the set or comparison group (Porcelli, 2009). Relative technical efficiency in production is a situation where a producer is fully efficient on the basis of available evidence if, and only if, the performance of other producers does not show that some inputs or outputs can be improved without worsening some of its other inputs or outputs (Cooper *et al.,* 2004). This definition provides a better way of distinguishing an efficient producer from an inefficient producer, but offers no guidance regarding either the degree of inefficiency of an inefficient producer or the identification of an efficient producer (Porcelli, 2009). Debreu (1951) was the first to measure efficient productive units using the coefficient of resource utilisation (Porcelli, 2009). Debreu's measure is a radial measure of technical efficiency. Radial measures focus on the maximum possible proportionate reduction in all variable inputs, or the maximum possible proportionate expansion of all outputs (Cooper *et al.,* 2004; Porcelli, 2009). In economic theory, the concept of technical efficiency is closely related to the notion of Pareto optimality. An input-output bundle is not Pareto optimal if there remains the chance of any net increase in productivity and efficiency (Porcelli, 2009).

2.4.2 Allocative Efficiency

A production unit is allocatively efficient when it maximises the use of input combinations that would minimise the cost of producing a given level of output (Odhiambo and Nyangito, 2003). AE, also referred to as price efficiency, shows the ability of a producer to use inputs in optimal combinations, given prices of the respective inputs (Cooper *et al.,* 2004). Farrell (1957) decided to extend the work started by Debreu and Koopmans by noting that the second component of productive efficiency reflects on producers’ capacity to choose the "right" technically efficient input-output vector given the respective prices of the input and output. This led Farrell (1957) to describe overall productive efficiency as the product of TE and AE (Porcelli, 2009). Farrell (1957) defined AE as the choice consistent with the optimum combination of inputs and their relative factor prices.

AE is an economic theory that measures a firm's success in selecting an optimal set of inputs relative to their prices – this is different from the TE theory, which is concerned with the production frontier that measures the firm's success in efficiently producing maximum output from a given set of inputs (Porcelli, 2009). The concept of AE captures the idea that society is concerned with, a) how output is produced; and b) with the respective prices of inputs.

2.4.3 Economic Efficiency

Economic efficiency (EE), on the other hand, broadly measures the extent to which a sector keeps up with the performance of its own best-practice firms; it is therefore a measure of the extent to which firms within a production sector are of optimum size: it is a combination of TE and AE. The framework of Farrell (1957) states that EE is an overall performance measure and is equal to the product of TE and AE (that is, EE=TE x AE). This means that TE and AE are components of EE (Dia *et al.,* 2010). According to Nargis and Lee (2013), even though economic efficiency is the product of TE and AE, it also indicates the ability of a production unit to produce a well-specified output at minimum cost. An economically efficient firm should be both technically and allocatively efficient.

2.5 Measurement of Technical Efficiency

A number of techniques exist to measure TE. Figure 2.3 provides a summary of some of the measurements of TE. The various measurements have been divided into parametric and non-parametric approaches of TE. The parametric approaches consist of the stochastic frontier approach (SFA), Latent Class SFA, the Bayesian and non-parametric SFA while the data envelopment analysis (DEA) is the only non-parametric approach included in this study. The metafrontier is the only approach that measures TE across different production systems (Figure 2.3.) All the other approaches are unable to account for technological differences in distinct production environments.

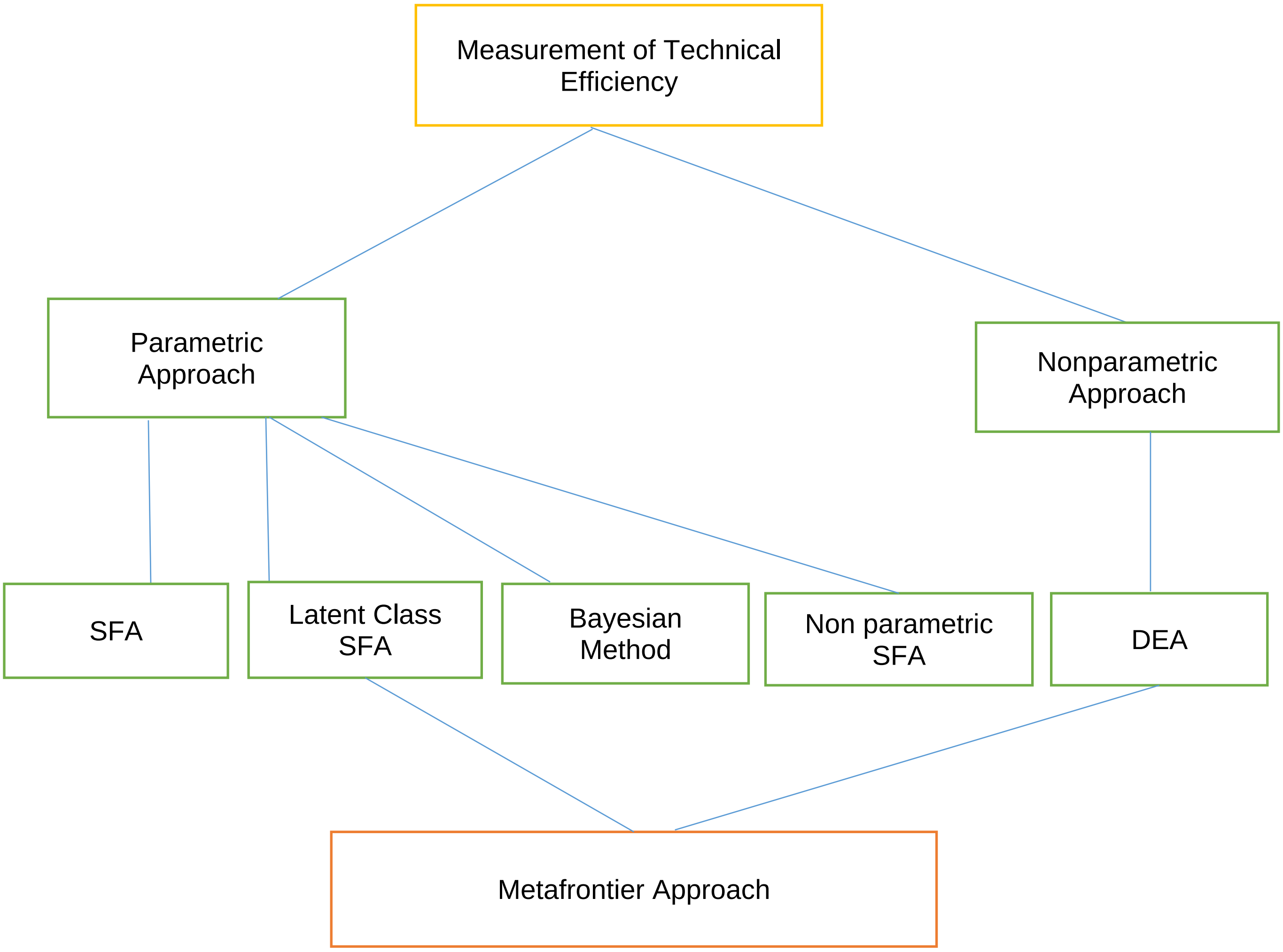


FIGURE 2.3 A SUMMARY OF THE TECHNIQUES USED TO MEASURE EFFICIENCY

SOURCE: ADAPTED FROM SARAFIDIS (2002).

Measurement of TE can be broadly categorised into parametric and non-parametric approaches. After the work of Farrell (1957), TE has been analysed using two principal approaches: the non-parametric data envelopment analysis, which was first proposed by Charnes *et al.* (1978), and the parametric SFA proposed by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977). The parametric approach specifies a particular functional form for the production or cost function, while the non-parametric approach does not specify any functional form of the production function (Sarafidis, 2002). The parametric approach uses econometric techniques, which include the use of stochastic frontier analysis and simple regression analysis (Otieno, 2011). The non-parametric approach, on the other hand, uses mathematical programming techniques. The most commonly used parametric approach is the SFA and the non-parametric approach is the DEA.

2.5.1 Data Envelopment Analysis

The DEA is a deterministic, non-parametric approach to measuring efficiency, that is, it assumes that any deviations from optimal levels of output are due to inefficiency, rather than errors (Otieno, 2011). This approach was first introduced by Farrell (1957) and was later developed by Charnes *et al.* (1978), who extended the relative efficiency concept of Farrell (1957) to incorporate many inputs and outputs simultaneously (Otieno, 2011). The DEA makes use of mathematical linear programming techniques to find the sets of weights for firms that maximise their efficiency scores, subject to the constraints that none of the firms has an efficiency score greater than 100% (or 1, as used in most cases) at those weights (Sarafidis, 2002). A firm is said to be inefficient if it has a score less than 100% (less than 1) at the estimated set of weights that will maximise the relative efficiency of the firm. For any inefficient firm, at least one other firm will be more efficient given the set of estimated weights. These efficient firms are identified as the peer group for all the inefficient firms (Sarafidis, 2002).

Analysis of efficiency is considered to be input-oriented if the objective of the producer is to produce the same amount of output with fewer inputs, or output-oriented if the aim of the producer is to continue using the same quantity of inputs while producing a higher level of output (Otieno, 2011). The two measures provide the same TE scores when a constant-returns-to-scale technology applies, but are unequal when variable returns-to-scale technology holds.

The DEA model introduced by Charnes *et al.* (1978) was input-oriented and assumed constant returns to scale. Charnes *et al.* (1984) introduced the variable returns to scale into the DEA model; the variable returns to scale model (it encompasses both increasing and decreasing returns to scale) allows the best practice level of output to inputs to vary with the size of decision-making units (Rangalal, 2013). The use of variable returns to scale specification eliminates scale effects in calculating TE (Otieno, 2011).

The main advantage associated with using the DEA is that it does not require *a prior* specification of the functional form for the production frontier. The DEA, further, does not require any specific assumptions about distributions of error terms. The main weakness of using the DEA is that it attributes any deviation of an observation from the frontier to inefficiency and does not account for statistical noise or measurement error in the model (Coelli *et al.,* 2005; Heady *et al.,* 2010; Otieno, 2011; Rangalal, 2013; Ray, 2004).

2.5.2 Stochastic Frontier Analysis

Studies by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) were crucial in providing a framework for parametric analysis of how policy variables might influence the production process. They proposed a stochastic frontier analysis (SFA), which separates the error term into technical inefficiency effects and random variations due to statistical noise (Otieno, 2011). By differentiating the effect of stochastic noise from the inefficiency effects, the SFA enables hypotheses to be tested for the production structure and extent of inefficiency, unlike the DEA (Coelli *et al.,* 2005). SFA mainly makes use of the maximum likelihood estimation technique to estimate the frontier function in a given sample (Sarafidis, 2002).

The SFA has the ability to separate error components, such measurement error and statistical noise, from inefficiency components. A separate assumption is made regarding the distribution of the inefficiency component and error term, subsequently leading to more accurate measures of relative efficiency (Otieno, 2011). This gives SFA an edge over DEA as a component of estimation. The SFA, however, is disadvantaged by the fact that there is, in fact, no a priori justification for the selection of any particular distributional form for the inefficiency component of the error term, and the SFA is unable to calculate individual inefficiencies (Greene, 1990). SFA has been employed in a number of studies (see Al-Sharafat, 2013; Chiona *et al.,* 2014; Masunda and Chiweshe, 2015; Ojo 2003; Ojo, 2009; Trestini, 2006). Ojo (2003) analysed productivity and technical efficiency of small-scale poultry egg farmers in Nigeria using the SFA. The average TE was 76.3%, which suggests that 23.7% of egg yield was lost due to inefficiency. Chiona *et al.* (2014) employed the Cobb-Douglas SFA to estimate TE of maize farmer in Central Zambia. The average TE was estimated to be 50%, implying that 50% of potential maximum output was lost owing to technical inefficiency. Al-Sharafat (2013), applied the Cobb-Douglas SFA to examine the TE of diary production in Jordan. Al-Sharafat (2013) estimated the TE to be 39.5%. Masunda and Chiweshe (2015) used SFA to analyse the TE of smallholder dairy farmers in Zimbabwe. The dairy farmers were found to be technically inefficient, with an average efficiency level of 54.9%. Trestini (2006) applied the SFA to estimate the TE of beef cattle farmers in the Upper Region of Italy. Trestini (2006) estimated the average TE to be 78.6%, indicating that beef farmers show high levels of efficiency. Similarly, Ojo (2009) used the Cobb-Douglas SFA to examine TE of backyard farmers in Nigeria and found the overall average TE to be 87.5%.

2.5.2.1 Continuous Parameters Method

The stochastic frontiers alone offer many different versions of cross-farm heterogeneity that can be modelled as a continuous parameter variation (Otieno, 2011). Recently, much attention has been devoted to the use of Bayesian methods for making inference in SFMs. The Bayesian method was first proposed by Van den Broeck *et al.* (1994) and later by Koop *et al*. (1997), who set out the advantages of using the Bayesian approach. The Bayesian method makes use of exacts or otherwise small-sample inferences on efficiencies, easy incorporation of previous ideas and restrictions, such as regularity conditions and formal treatment of parameter and model uncertainty (Griffin and Steel, 2007). The Bayesian stochastic frontier makes use of Monte Carlo integration or Gibbs sampling techniques to assess the influence of exogenous or non-conventional factors on either the production function (common efficiency distribution) or inefficiency component (varying efficiency distribution) (Otieno, 2011). The advantage of using the Bayesian approach is that it provides point and interval estimates of TE and exact finite-sample results can be obtained, and the estimation conforms well to economic theory (Otieno, 2011). However, this approach has a weakness in that the Bayesian frontier analysis presents many restrictions in its use. For example, it assumes that the inefficiency term is distributed exponentially, it imposes regularity conditions on the data and an informative prior value has to be chosen for the median of the efficiency distribution (Otieno, 2011). This makes it increasingly complex to use in estimation and also reduces the ability to grasp the “true” characteristics of the sample data (Coelli *et al.,* 2005; Otieno, 2011).

2.5.2.2 Nonparametric Stochastic Frontier

Nonparametric SFMs are based on local maximum likelihood techniques that incorporate some anchorage parametric models in a nonparametric way (Kumbhakar *et al.,* 2007). This is done by, first, deriving asymptotic properties for estimators in the general case (i.e. local linear approximations). The results are then tailored to a SFM where the convoluted error term (efficiency plus noise) is the sum of a half normal and a normal random variable (Kumbhakar *et al.,* 2007). The nonparametric SFM has been applied in a number of studies, such as the one by Serra and Goodwin (2009) but, in general, it is as limited in its application as the continuous parameters method discussed in Paragraph 2.5.2.1.

2.5.2.3 Latent Class Stochastic Frontier

The latent class stochastic frontier is an alternative model that separates the sample and the estimate of technology for each group in one stage only (Alvarez and Corral, 2010; Cameron and Trivedi, 2005). It classifies data into segments or groups, based on unobservable characteristics depicted by the data (Otieno, 2011) and then estimates a production frontier for each group in one stage (Otieno, 2011). This process is known as latent class modelling, which assumes a finite number of structures (classes) underlying the data. There might be some unobserved differences in technologies that might be inappropriately labelled as inefficiency. If there is a variation in technology that is not taken into account, the wrong assumptions might be made about the productive capability of some production units. This problem, however, can be addressed by estimating a latent class SFM in a panel data framework. The major advantages associated with latent class modelling is that it entails the use of statistical tests to choose the appropriate number of groups that fits the data, and allows for the use of inter-group information to explain similarities and differences, for instance, in technology across groups (Alvarez and Corral, 2010; Otieno, 2011). Latent class modelling has been applied in many studies and it is preferred by many researchers. Latent class modelling works well with panel data and, as a result, is not suitable for this study.

2.5.3 Addressing Technological Differences in Efficiency Estimation

2.5.3.1 Metafrontier Analysis and Empirical Application

The DEA and SFA, discussed in Paragraphs 2.5.1 and 2.5.2 respectively, have been applied extensively in a number of studies for estimating TE in agricultural productivity. Studies by Abatania *et al.* (2012), Coelli *et al.* (2002) and Rios and Shively (2005) all applied the DEA approach to their research to estimate TE in agricultural productivity. Due to DEA’s inability to decompose the error term properly into measurement error and inefficiency effect, it is therefore not suitable for this study. Though the following researchers applied the SFA to their studies but SFA is however not suitable for this study because of its inability of account for different production systems: Aung (2011); Ogundari (2008); Shamsudeen *et al.* (2011); Seidu (2012); Yiadom-Boakye *et al.* (2013). SFA and DEA can sometimes produce inaccurate and inconsistent results if data samples are taken from different production environments where different production techniques are used (technological difference).

Over the last decade, the metafrontier has become very popular as a new approach to accounting for technology variations in both cross-section and panel data. The metafrontier has been developed into two approaches: DEA-metafrontier and stochastic metafrontier (Otieno, 2011). First introduced by Battese *et al.* (2004), the metafrontier approach was used to quantify the efficiency of heterogeneous groups based on their distance from a common and identical frontier. The metafrontier analysis is an extension of the SFA and the DEA, which takes into account differences in technology and production techniques.

The original idea behind metafrontier analysis was presented by Hayami (1969), and Hayami and Ruttan (1970), who used a meta-production, function as a production function to envelop the production frontiers of all the heterogeneous technological sets. This idea was later developed by Battese and Rao (2002), who presented the SFA approach as an estimation of metafrontiers that is implicitly captured by two different data-generating mechanisms. O'Donnell *et al.* (2008) and Battese *et al.* (2004) specified a single data-generating process that helps to explain the deviations between observed outputs and group frontiers, and defined the metafrontier to be used as a function that envelops the deterministic components of the group frontiers (O'Donnell and Griffiths*,* 2006).

According to Lau and Yotopoulos (1989) the meta-production function approach is based on the idea that all producers in different production areas potentially have access to the same level of technology, in which case each producer has the freedom to choose to operate on a different part of the metafrontier, depending on circumstances, such as natural endowments, relative prices of inputs, and the economic environment. A meta-technology gap ratio was derived and has been developed from the metafrontier, which is defined as the ratio of a specific farmer's output from a particular group to the metafrontier output with the same inputs (Saeedian *et al.,* 2013). However, a higher meta-technology gap ratio denotes less of a technological gap between the individual frontier and metafrontier.

A number of studies have used the metafrontier approach to estimate the technical efficiency (TE) of agricultural productivity in Africa and the world (see Awotide *et al.,* 2015; Bahta *et al.,* 2015*;* Bahta and Hikuepi, 2015; Battese *et al.,* 2004; Boshrabadi *et al.,* 2006; O'Donnell *et al.,* 2008; Otieno *et al.,* 2012; Villano *et al.* 2010). Awotide *et al.* (2015) applied the metafrontier to analyse access to credit and TE among smallholder cocoa farmers in southwest Nigeria. Bahta and Hikuepi, (2015) applied metafrontier to measure TE and technological gaps of beef farmers in three (South East, Chobe and Central) provinces of Botswana. The results of their study show that the average TE level was 0.496 for the whole sample and 0.194, 0.331 and 0.318 for beef farms for the three regions, which means that there is ample scope for improvement among these farmers. Boshrabadi *et al.* (2006) applied the metafrontier approach to estimate the TE of wheat farmers in Kerman province with a trans-log production function. Otieno *et al.* (2012) evaluated the determinants of TE in beef cattle production in Kenya using metafrontier. The results show that the average efficiency level is 0.69, suggesting that there is considerable scope to improve production of beef in Kenya. Villano *et al.* (2010) examined factors that contribute to metafrontier production by most farmers in the long run. The research considered physical conditions, environmental constraints, access to capital and production cycle span (season), especially for perennial crops, and unprofitability of changing current varieties as factors that contribute to production on the metafrontier. By way of conclusion, Villano *et al.* (2010) confirmed that the aforementioned factors were the most important indicators that should be considered if farmers desire to reach the metafrontier.

Dadzie and Dasmani (2010) examined gender difference and farm-level efficiency using the metafrontier production function approach. The study found that the estimated technical efficiencies showed that food-crop farmers in the Juaboso District of Ghana were not efficient in production. While farms under male management produced, on average, more food crops than farms with female management, the farms managed by female household heads were found to be more efficient and also closer to the potential output level defined by the metafrontier. The study also found that gender, age, household size, and years of farming experience, access to credit, education and consultation with extension staff influenced TE significantly.

Villano *et al.* (2008) measured regional productivity differences in the Australian wool industry using a metafrontier approach. The major findings presented by this study are that environment-technology gaps exist in the various regions, but that these gaps are relatively small. There are apparently greater variations within the regions. Variation in TE seems to depend on the harshness of the production environment and whether consultancy advice is regularly received by the benchmarking group.

2.6 Kendall's Coefficient of Concordance

Kendall's Coefficient of Concordance test is a non-parametric statistical test that is used to identify a given set of constraints or difficulties (faced by farmers), from the most severe (most influential) to the least severe (least influential), as well as measure the degree to which respondents agree, or concord, with one another on the constraints faced (Anang *et al.,* 2013). First proposed by Kendall and Smith (1939), Kendall's Coefficient of Concordance (W) is a measure of the agreement among several (m) quantitative or semi-quantitative variables that assess a set of infinite (n) objects of interest. The variables are often people, in social sciences called judges, who assess different subjects or circumstances. It has been applied in many areas of research, from social science to biological science to mathematics and statistics and general scientific studies.

The original work of Kendall and Smith (1939) has been extended by scholars in recent times. Durbin (1951) and Willerman (1955) provided a statistical formula for calculating Kendall's Coefficient of Concordance, along with a table of critical values for the test statistic supposing a beta distribution (Verbič and Kuzmin, 2009). Furthermore, Kraemer (1981), in his study, proposed a coefficient for intergroup concordance that has a direct relationship with the concept of intragroup concordance as measured by Kendall's Coefficient of Concordance (Verbič and Kuzmin, 2009).

Kendall's Coefficient of Concordance has been applied in a number of studies (see Anang *et al.,* 2013; Legendre, 2005; Verbič and Kuzmin, 2009). Anang *et al.* (2013) examined the production constraints and measures to enhance the competitiveness of the tomato industry in Wenchi Municipal District of Ghana. Anang *et al.* (2013) found that small-scale tomato producers in the Wenchi municipal district of Ghana were faced with numerous production constraints, which reduces their ability to increase production. These constraints included lack of capital, high cost of inputs and low produce price. Verbič and Kuzmin (2009) examined Coefficient of Structural Concordance and its application to labour productivity and wages in Slovenia. They were able to confirm the hypothesis (higher wages increase labour productivity) of high concordance between wages and labour productivity, which indicates the incentive role of wages in production of market-traded goods and services.

2.7 Factors Affecting Agricultural Productivity and Efficiency

The productivity of smallholder farmers, especially in the livestock sector, are low and, as a result, studies have investigated the factors affecting farmers' inability to produce at full capacity. Certain factors have been identified to cause low productivity in this sector. This section will review some of the factors that affect the productivity of smallholder livestock farmers, with particular reference to smallholder sheep farmers in South Africa and Africa in general. The factors will be sub-divided into production, inefficiency and socio-economic factors.

2.7.1 Production Factors

This section reviews literature on factors affecting sheep production in the world, Africa and South Africa. Factors of production are technical factors that promote agricultural productivity. The factors of production include climate change, disease and parasites, labour, and land.

2.7.1.1 Climate

Of the numerous factors that affect the productivity of livestock (sheep) farmers, climate change and location are significant. According to IPCC (2007), climate change refers to any change in climatic conditions over time, whether due to natural variability or as a result of human activity. However, the United Nations Framework Convention on Climate Change (UNFCCC, 2007), defers to the IPCC's definition, and defines climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over a comparable time period".

The effects of climate change on food production are not limited to crops and other agricultural production. Climate change has damaging consequences for dairy, meat and wool production, mainly due to its impact on grassland and rangeland (IFAD, 2012). Livestock production contributes negatively to climate change, and climate change, in return, also poses a serious threat to the ecosystem and global livestock production. More often, changes in climatic conditions, such as changes in temperature and rainfall, result in extreme natural occurrences, such as drought, floods and windstorms, which are believed to affect the productivity and overall performance of livestock in terms of vulnerability to diseases, decreased birth rates; growth rates; and feed and water availability (Ogunkoya, 2014). Animals (especially sheep) who suffer heat distress will reduce their feed intake and this affect the normal growth performance of the animal (IFAD, 2012; Rowlinson, 2008). Water shortages and the frequent occurrence of drought in certain countries (sub-Saharan Africa) has led to a loss of natural, human and economic resources. Therefore, as demonstrated by most African countries, climate change aggravates existing food insecurity and conflict over scarce resources.

2.7.1.2 Disease and Parasites

Animal diseases have a severe impact on livestock production, trade and commerce, and global human health (Lamy *et al.,* 2013). Diseases and parasites are a major source of economic loss in livestock production, especially in tropical areas and developing countries (Tisdell *et al.,* 1999). The most common diseases and parasites that affect livestock in general and sheep in particular in South Africa include wireworm, brown-stomach worm, flukes, tapeworms, bovine malignant catarrh ("snotsiekte") and vibriosis (Mapiliyao *et al.,* 2012).

The economic impacts of diseases and parasites on livestock production can be either direct or indirect. Direct impacts can be the result of the presence of the parasite in the animal, which will reduce the economic productivity of the livestock or cause economic loss. Indirect impacts could result from some parasites, such as ticks, which are also disease vectors. These vector-borne diseases, if diffused to livestock, often result in much more economic loss than the presence of the parasite (Tisdell *et al.,* 1999).

The high incidence of diseases, parasites and mortality can be attributed to poor hygiene and poor housing conditions of animals. Common diseases, such as diarrhoea, are prevalent at the beginning of the rainy season, especially in lambs (Mapiliyao *et al.*, 2012). In livestock production, livestock diseases are basically an economic problem. Diseases can reduce production, productivity, and profitability, because they are associated with treatment cost and aggravate poverty in rural communities (Lamy *et al.,* 2013). Disease is a major issue in many developing countries where veterinary services are scarce or are of poor quality.

2.7.1.3. Labour

Labour plays a critical role in agricultural production, especially in the livestock industry, which is labour intensive. Sheep farming requires a great deal in terms of labour, which entails looking after the sheep in the field, making sure they eat properly, and treating them for any illnesses. The productivity of sheep and goats has been lagging behind in terms of improvement, and this is often attributed to a lack of skilled labour (Gutierrez *et al.,* 1982). Labour in this context can be divided into hired (paid) labour and family labour. Because most of the small-holder farmers face financial constraints, labour is most often provided by the family. Donkor and Owusu (2014) indicated that improvements in the efficiency of human labour resource increase productivity. The day-to-day responsibility of sheep care varies widely depending on the number of animals, the production system (extensive or intensive) and other factors involved in sheep farming. Usually, the young men are tasked with taking care of small or backyard herds (Gutierrez *et al.,* 1982). Studies have shown that labour has a positive correlation with productivity. The more labour is available to a farmer, the higher the productivity and efficiency of that farmer. Studies by Bahta and Hikuepi (2015) and Otieno *et al.* (2012) established a positive relationship between labour and productivity for beef production in Botswana and Kenya respectively.

2.7.1.4. Grazing and Communal Land

Land plays a vital role in agricultural production, particularly in the livestock sector. Livestock in general and sheep farming, in particular, are among the main land users. Pastoral production requires very large expanses of land, and efficiency in its management (Herrero *et al.,* 2013; Nyariki *et al.,* 2009; Ogunkoya, 2014). Since livestock producers depend more on land for their farming, it is expected that land has a very positive effect on livestock production. Livestock production systems occupy approximately 45% of the earth's total surface area (Seré 2009; Ogunkoya, 2014). Approximately 70% of the agricultural land in South Africa is utilised for livestock production (Meissner *et al.,* 2013; Ogunkoya, 2014). Livestock production, especially sheep, depends on land for grazing and the size of the grazing and quality land determines the number of sheep that can be produced. Studies have shown that the size of grazing land has a positive relationship with livestock production. Otieno *et al.* (2012) found a negative correlation between land (grazing land size) and beef production in Kenya. He attributed this to bad or inconsistent land tenure systems in Kenya. The implication is that research on livestock production should not only consider land size and quality of grazing, but also the effects of land tenure systems.

2.7.1.5 Herd Size

Sheep production depends largely on the number of sheep owned by sheep farmers. Sheep output depends on the herd size of farmers. An increase in herd size will significantly increase sheep output (Otieno *et al.,* 2012). Bahta *et al*. (2015) did a metafrontier analysis on beef cattle farms in Botswana and found a positive correlation between cattle herd size and cattle output. Otieno *et al.* (2012) also found a positive correlation between beef herd size and beef output in Kenya, while Bahta and Hikuepi (2015) found a similar result in Bostwana. The findings of all these studies suggest that the larger the herd size, the greater the output of sheep production.

2.7.1.6 Feed

Livestock production as a whole and sheep production in particular depends on feed consumed by animals. Livestock farmers often spend large amounts of money on feed and feed equivalence (feed produced on the farm). Feed for livestock production could be either purchased or produced by the livestock farmers themselves, which includes an element of cost (Otieno *et al.,* 2012). An increase in the amount of money spent on feed and feed equivalence will increase the output of farmers (Otieno *et al.,* 2012). Otieno *et al. (*2012) found a positive correlation between feed cost and beef output in Kenya. They argue that this is the case because, when cattle are fed well, they reproduce easily and grow faster than when they are hungry and sick. Most of the efficiency studies on livestock production found a positive correlation between feed cost and sheep output (Bahta and Hikuepi, 2015; Bahta and Malope, 2014).

2.7.2 Inefficiency Factors

The main interest of this research is enhancing the productivity of smallholder farmers and, for that to be done effectively; inefficiency factors must be determined and explained. The factors that contribute to inefficiency are of interest because the inefficiency effects must be known to determine the level and variability of production. Inefficiency in production can be the result of institutional and socio-economic factors. The following factors were found in literature to influence the level of TE.

2.7.2.1 Institutional Factors

In literature, the institutional factors that influence efficiency of sheep production include land tenure, access to market, access to credit, access to extension services and access to veterinary services.

2.7.2.1.1 Land-tenure Systems

According to IFAD (2010), equitable and secure access to land is important for poor rural households, particularly livestock owners in sub-Saharan Africa, who are dependent on agricultural and livestock production for their livelihoods. Having secure access to land for agricultural and pastoral activities decreases the vulnerability of livestock farmers and increases their opportunities to invest on land for agricultural and livestock production (IFAD, 2010). IFAD (2010) also noted that access to land and land tenure security are very important, and form the basis for all rural and agricultural economies. Land tenure refers to the rules and norms governing how, when and where people access land and other natural resources in a particular country and at a particular time. Empirical studies show that land-tenure systems influence agricultural productivity and efficiency, particularly in Africa. However, Otieno *et al.* (2012) found a negative correlation between land use and productivity, which contradict *a priori* expectation – in this case the insecure land tenure system was the reason for the unexpected outcome. Studies by Iqbal *et al.* (2001) and Oladele *et al.* (2011) found that farmers operating under fixed-rent tenancy were more likely to increase productivity than farmers who owned land. These studies further explain that farmers who pay rent for the use of land tend to use relatively more productive resources, which has the potential of increasing productivity and hence, farm profits.

2.7.2.1.2 Access to Markets and Farm Location

Generally, location is very important to any business venture. Smallholder households characterised mostly by high levels of poverty are often located in the marginal areas, which have poor communication infrastructure, particularly access roads to markets, thereby limiting sheep farmers' capacity to transport sheep to the few available slaughter facilities that are available (Bayer *et al.,* 2001; Mapiliyao *et al.,* 2012). Proximity to markets increases farmers' access to factor inputs, which enable farmers to buy and apply inputs on time and sell their farm products. After overcoming the challenges of production, farmers in inaccessible areas are then faced with the problem of accessing markets to sell their products. A good location makes it easier for farmers to access inputs and extension training from which they can attain information and skills for better crop management and increased productivity (Bagamba *et al.,* 2007). Farmers with poor access to markets have less opportunity to engage in profit-maximising activities than farmers who have access to markets and are located near cities (Aung, 2011). According to Ojo (2003), the location of a farm has a negative correlation with productivity. Ojo (2003) argues that farmers who live in rural areas find it difficult to access markets in urban areas to sell their products, thereby making them inefficient in their production. The bottom line is that the closer a farmer is to the market, the more efficient he/she will be in the production process.

2.7.2.1.3 Indigenous Sheep Breeds

In literature there are three distinct types of sheep and cattle kept by farmers, namely, indigenous breeds, crossbreeds and exotic breeds. Various studies have been done to investigate the effect these types have on productivity. Otieno *et al. (*2012) found that indigenous cattle breeds reduce inefficiency in beef production in Kenya; however, the effect of indigenous cattle breeds on efficiency, though positive, was insignificant. Bahta and Hikuepi (2015) and Bahta *et al.* (2015) found a positive and significant correlation between indigenous cattle breed and efficiency.

Crossbreeding is the most commonly used breeding method in livestock production (Ojo, 2003). It is often practiced by cattle and sheep farmers and its effects on efficiency has been studied. Otieno *et al. (*2012); Bahta and Hikuepi (2015) and Bahta *et al.* (2015) all found a positive relationship between crossbreeding and productivity of cattle production in Botswana and Kenya. They argue that the reason for this finding is that crossbreeding is easier than pure breeding and inbreeding.

2.7.2.1.4 Availability of Extension Services and Information

Smallholder farmers are often limited in their ability to execute certain activities in the production process due to lack of information. Social networking has become vital and it plays an important role, especially for women, who often have less access to formal information channels (Mapiliyao *et al.,* 2012). According to Seidu (2012) there is a wide gap between potential and actual crop yields achieved by smallholder farmers in developing countries, primarily because of poor extension service delivery, institutional and cultural constraints and farmers' long history of traditional practices. Agricultural and livestock extension services are provided in the form of training and information on better farming practices, the adoption of technologies, for example, breeding programmes, feed preparation methods, and using equipment (Otieno *et al.,* 2012). These programmes or training are provided by the government in an effort to educate smallholder farmers on efficient production techniques and to enhance agricultural productivity. Studies in Africa have shown that extension services help to increase productivity and contribute to enhancing the livelihood of the rural poor. Owens *et al.* (2001) concluded that access to agricultural extension services increase farm productivity by 15% in Zimbabwe. The researchers noted that, in Kenya, crop productivity per acre for farmers who received extension services increased by 80%. In Tanzania, farmers who received agricultural training increased their farm productivity by 23% (Owens *et al.,* 2001). Mensah and Brümmer (2016) and Donkor and Owusu, (2014) also found a positive correlation between extension services and productivity. Effective and efficient extension services can therefore play an important role in enhancing agricultural productivity and efficiency among the rural poor in Africa.

2.7.2.1.5 Veterinary Costs and Services

Sheep production depends largely on the health of the animals. Veterinary costs and services are therefore very important to livestock production. Various studies have been done to assess the effect of veterinary costs and services on the output of livestock production (see Bahta *et al.,* 2015; Bahta and Malope 2014; Otieno *et al.,* 2012). Otieno *et al. (*2012) and Bahta *et al.* (2015) argue that, if veterinary costs and services are increased, output of cattle production will increase proportionately. Bahta and Malope (2014) found a positive correlation between veterinary costs and services and beef cattle production in Botswana. This is in line with the expectation that the output of livestock farming depends largely on the health of the livestock and, if more is spent on drugs for the livestock, productivity will be enhanced, since the healthier the livestock, the greater the output of the animal.

2.7.2.1.6 Presence of Farm Manager

Livestock farming is very labour intensive, therefore, a farm manager with suitable managerial skills set is seen as a very important tool in the organising the inputs and general decision-making on the farm. The availability of a manager is, therefore, expected to enhance productivity of the farm, because he/she can enhance co-ordination of farm operations and ensure better utilisation of resources (Otieno *et al*, 2012). On the other hand, the absence of a proper farm manager might lower productivity from the use of farm resources, leading to lower efficiency (Meon and Weill, 2005; Otieno *et al.,* 2012). Ojo (2003); Otieno *et al.* (2012) and Owens *et al. (*2001) all found the presence of a farm manager to have a positive and significant effect on efficiency. This means, therefore, that farmers who hire farm managers are technically efficient in their livestock production.

2.7.2.2 Socio-economic Characteristics

Socio-economic variables, such as age, gender and household size, affect agricultural productivity. In this section, socio-economic characteristics of smallholder livestock farmers will be reviewed.

2.7.2.2.1 Education

Though many argue that education does not play a major role in agricultural productivity, it is, in fact, not true (Ojo, 2003). Considering the increasing use of technology in agriculture, education is essential for agricultural production. Education either increases the farmer's ability to access external sources of information, or enhances his/her ability to acquire information through experience with new technology. Education enables farmers to learn about new farm technologies more efficiently (Baerenklau, 2005). Education is expected to have a positive correlation with agricultural productivity, and many studies have been done to evaluate the effect of education on agricultural productivity. Ojo (2003) found a positive correlation between years of schooling and experience, and agricultural productivity. Schooling and experience gives the farmer knowledge about the adoption of improved technology and techniques of production (Ojo, 2003). Ojo (2003) also argues that education could have a negative correlation with productivity. This is because educated people often turn their attention away from agriculture to management and non-agricultural activities. This view is shared by Mohammed *et al.* (2013), who found education to be a negative influence on TE. Mohammed *et al.* (2013) explained that educated households are less efficient if education increases farmers' returns from non-farm activities, thereby reallocating attention or management from farm to non-farm activities.

2.7.2.2.2 Farm Experience

Farm experience has a role to play in agricultural productivity. Agricultural production is favourable when the farmer has many years of farm experience. Studies have found a positive correlation between farm experience and agricultural productivity. Otieno *et al.* (2012) found a positive correlation between farm experience and agricultural productivity.

The results show that farmers with more years of farming experience are more productive than farmers with fewer years of agricultural production of beef in Kenya. Bahta and Hikuepi (2015) supported this finding by concluding that farmers who had been engaged in beef-cattle production in Botswana for many years had higher agricultural productivity than farmers with fewer years of agricultural production. It is true that farmers with more farm experience know how to respond quickly to changing production circumstances, because they are aware of the environment in which they operate.

2.7.2.2.3 Household Size

African culture is characterised by large and extended families. Most of the households in farming communities in Africa are relatively large. These households provide farmers with family labour for agricultural production. Otieno *et al*. (2012) found family (household) size to have a negative correlation with efficiency. Otieno *et al.* (2012) concluded that large family size reduces the efficiency of beef farmers. Mariano *et al.* (2010) supported the findings of Otieno *et al.* (2012); the former found that large family size tended to increase inefficiency in agricultural productivity in the Philippines. These findings suggest that farmers with larger households tend to allocate most of their resources to the upbringing and education of their children, rather than investing in production. However, a study by Msuya *et al.* (2008) explains that big households are technically more efficient, because they strive to achieve higher output to meet their daily needs. Large families are endowed with the family labour needed for agricultural production.

2.8 Chapter summary

Agricultural productivity growth has attracted intensive research (Coelli *et al.,* 2005). An improvement in productivity is expected to improve the welfare of the rural poor in Africa. Increased efficiency is an important factor of productivity growth, especially when productive resources are scarce and smallholder farmers are living in extreme poverty. Maximising outputs while minimising the use of inputs is a technical problem faced in Africa, especially by smallholder farmers. Efficiency literature identifies a number of efficiency types that could improve productivity, namely, technical, allocative and economic efficiency. These studies focus on TE, since farmers should first aim to produce maximum output while using minimum inputs. When resources are optimally used, TE is achieved, and a farmer can continue to identify optimal input combinations (allocative efficiency). A number of estimation techniques that allows for the estimation of TE are suggested in the literature. The most commonly used techniques are the non-parametric mathematical programming approach, DEA, and the parametric SFA. Both techniques have advantages and disadvantages.

Choosing between DEA and SFA depends on the specific characteristics of the problem. This research proposed using SFA to estimate farmers' production frontier and TE. SFA is able to account for statistical noise (i.e. measurement error and random errors). The SFA model used in this study was specified by Battese and Coelli's (1995) using single-step procedure, which allows for the estimation of a production frontier and the sources of inefficiency in a single step. Information about the sources is a necessary indicator of the aspects of farm characteristics that can be addressed to improve TE.

Although SFA provides very useful information on TE and the sources of inefficiency, it is unable to account for the effect of heterogeneous technologies. Data collected from different production regions require the estimation of separate production frontiers, because of heterogeneous technologies. Comparisons between different regions can only be made if a common production frontier is known. Through metafrontier analysis, a meta-production function can be estimated, which will envelop the estimation of the production frontiers of the heterogeneous technology. The metafrontier is, therefore, a common production frontier that can be used for comparison purposes. The meta-technology gap ratio estimated from the metafrontier is an indication of how well farmers in one locality are doing relative to the common production frontier.

CHAPTER 3: DATA AND CHARACTERISTICS OF THE RESPONDENTS

3.1 Study Area

3.1.1 Geographical Location of the Free State Province

The Free State province is located in the central part of South Africa and is one of nine administrative provinces of South Africa. The Free State province is situated between latitude 26.6° S and 30.7° S and between longitude 24.3° E and 29.8° E. The province has a total land surface area of approximately 129 825 km^2, accounting for an estimated 10.6% of the country's land area (Davis *et al.,* 2006). It is the second-largest province in South Africa alongside Western Cape and shares borders with Gauteng, Mpumalanga, North West, KwaZulu-Natal and the Kingdom of Lesotho. Figure 3.1 shows a map of South Africa indicating the physical location of the Free State and the other eight administrative provinces.

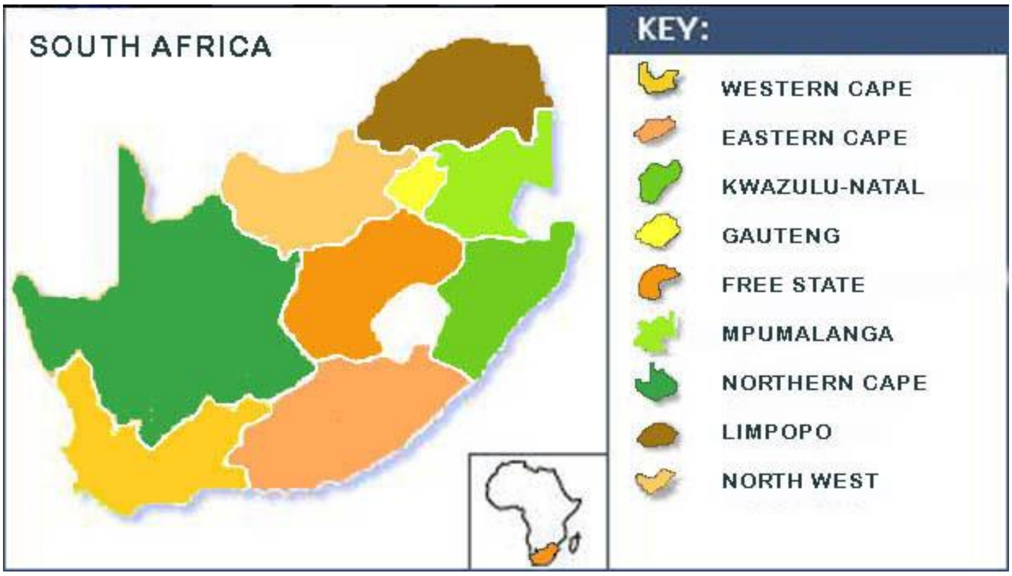


FIGURE 3.1 ADMINISTRATIVE PROVINCES OF SOUTH AFRICA.
SOURCE: GOOGLE MAPS (2016).

The provinces of South Africa, as indicated in Figure 3.1, vary in size. The biggest province is the Northern Cape, covering 30.5% of the total land area, followed by the Free State and Western Cape with 10.6% of the total land area each, and followed by Limpopo with 10.3%. The smallest province is Gauteng, with only 1.4% of the land area.

The Free State is called the granary of South Africa, with agriculture central to its economy, even though mining on the rich goldfields reef is the province's largest employer (South Africa info, 2015). The total population of the Free State is estimated at 2 753 200, which represents 5.2% of the South African population; the Free State is the second-least-populated province in the country (Ogunkoya, 2014; Statistics South Africa, 2013).

The province consists of four district municipalities, making up 19 local municipalities and one metropolitan municipality. In May 2011, Mangaung, comprising Bloemfontein, Botshabelo and Thaba Nchu, became the Free State's newest metropolitan authority, with Bloemfontein as the capital city. Figure 3.2 shows the various district municipalities.

FIGURE 3.2 MAP OF FREE STATE AND ITS DISTRICT MUNICIPALITIES

SOURCE: ADAPTED FROM OGUNKOYA (2014).

Figure 3.2 shows all four district municipalities (Xhariep, Lejweleputswa, Thabo Mofutsanyane and Fezile Dabi districts), and the one metropolitan municipality (Mangaung Metro). The study areas (Thaba Nchu and Botshabelo) are located in the N8 development corridor within Mangaung Metro. Figure 3.3 presents a map of the N8 development corridor.

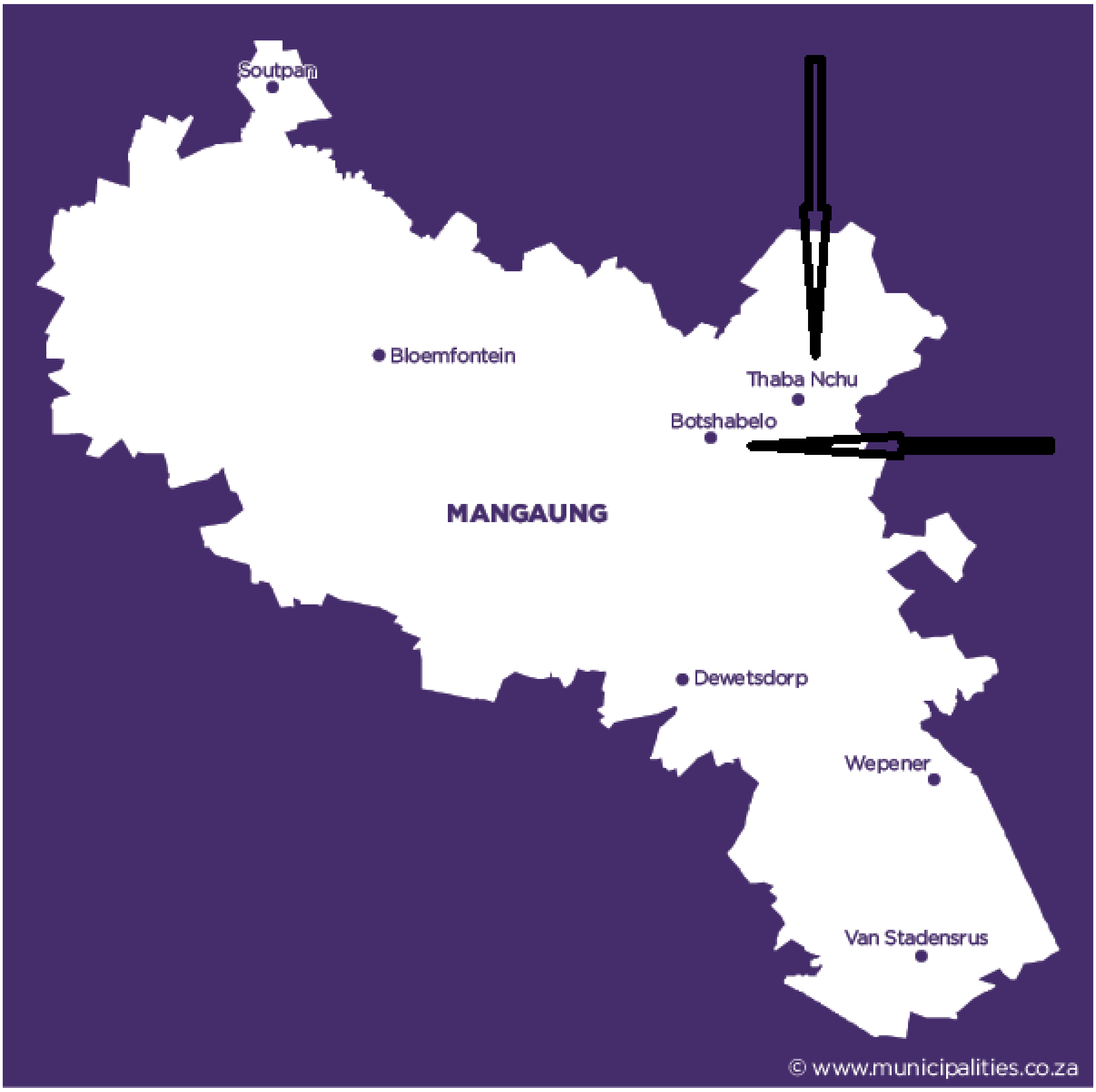


FIGURE 3.3 LOCATION OF STUDY AREAS IN THE N8 DEVELOPMENT CORRIDOR SOURCE: GOOGLE MAPS (2016).

Thaba Nchu is located approximately 60 km east of Bloemfontein and approximately 17 km east of Botshabelo, while Botshabelo is located 45 km east of Bloemfontein in the N8 development corridor. Thaba Nchu covers 36.39 km^2 of the total land area in the N8 development corridor, while the total land area of Botshabelo is 103.98 km^2.

3.2 Climate of the Free State

The Free State province has a continental climate, with very warm to hot summers and cool to cold winters. Some areas in the east of the province often experience snowfalls, especially on the higher ranges, whilst it can be extremely hot in the west during the summer. The climate of the Free State is pleasant, which allows a thriving agricultural industry (Ogunkoya, 2014). The province experiences an annual rainfall between 600mm and 750 mm in the east; it declines slowly to 250 mm in the south-western parts of the province. The winters are sometimes very cold, with heavy frost over most of the province. The average winter temperatures range between 12.5^{o}C and 15^{0}C in the eastern parts of the province and increases to an average range of 17.5°C to 20°C in the west during the summer (Ogunkoya, 2014).

January is the warmest month of the year, with an average temperature of 21.1°C in Botshabelo and an average of 21.5°C in Thaba Nchu, while June is the coldest month, with 6.9°C in Botshabelo, on average. The average annual rainfall of Thaba Nchu is, on average, 629 mm, while in Botshabelo the average annual rainfall is 641 mm. The average annual temperature of Thaba Nchu is 15.2°C, which is higher than that of Botshabelo, which has an average annual temperature of 14.8°C (Climate-Data, 2016).

3.3 Agriculture in the Free State

Agriculture plays a significant role in the economy of South Africa, even though its contribution as a percentage of gross domestic product has decreased over the past four decades. In 2012, agriculture contributed around 2% of the gross domestic product (Statistics SA, 2013).

The main agricultural activities of the Free State include crop production and mixed livestock production. The Free State province is one of the main producers of grain in South Africa. More than 50% of sorghum, almost 50% of sunflower and more than 30% of all wheat, maize, potatoes and groundnuts in South Africa are produced in the fertile western plains and the northern Free State (Maphalla and Salman, 2002). The agricultural producers of the Free State also produce cherries and asparagus. Livestock production is central to agriculture in the province. The Free State is home to large farms that keep cattle for beef and dairy production, sheep and goats and, to a lesser extent, poultry and pigs. The Free State contributes 20% to the number of sheep produced in South Africa, 20% of beef and 40% of goats produced in South Africa (Maphalla and Salman, 2002). Table 3.1 shows the distribution of livestock in all the municipal areas of the Free State.

TABLE 3.1. LIVESTOCK NUMBERS IN THE FREE STATE

District municipality	Number of sheep in the province	Number of cattle in the province	Number of goats in the province
Xhariep	1 960 874	250 443	91 677
Lejweleputswa	250 770	450 339	93 333
Thabo Mofutsanyana	1 096 944	808 984	23 915
Fezile Dabi	1 451 900	671 481	13 134
Mangaung	45 898	52 537	7 170
Total for province	4 806 386	2 233 784	229 229

SOURCE: DAFF (2014).

Xhariep has the highest number of sheep in the Free State, with 1 960 874 sheep, followed by Fezile Dabi, with 1 451 900 sheep. Mangaung has the least number of sheep in the province – in this district more than 60% of the sheep farmers are smallholder farmers (DAFF, 2014).

3.4 Data Collection

Data for this study was collected by means of structured questionnaires written in English. The Department of Agriculture assisted in both district municipalities of the N8 development corridor to obtain permission to conduct the survey among farmers in the area -- permission was obtained from heads of rural households, and herdsmen. Target respondents were smallholder sheep farmers in the N8 development corridor. Data was collected from Thaba Nchu and Botshabelo along the N8 development corridor. These two districts were chosen because of the number of livestock farmers, especially sheep farmers, in the districts and their suitability for livestock production.

The questionnaires were designed to capture relevant input-output data of smallholder sheep farmers. The output data is sheep value in South African currency (rands) while the input data include herd size, size of grazing land, amount of labour (hired and family labour) in man-days, amount spent on veterinary drugs and services in rand and amount spent of feed in rand. Other relevant information on sheep farmers, such as socio-economic and institutional variables, were also captured. The socio-economic variables captured include age, gender, household size and education, while the institutional variables include extension services, veterinary practitioners, access to credit, distance to nearest market and land tenure systems (see questionnaire in Appendix A). A team of five individuals from the area were hired to help interpret and administer the questionnaire in the local language. Interview times and locations were arranged with the farmers beforehand and the process was very friendly and interactive.

3.4.1 Sampling and Size

The survey employed a proportionate stratified random sampling at Thaba Nchu and a simple random sampling approach at Botshabelo. A complete list of all villages in Thaba Nchu was requested and obtained from the Department of Agriculture at Thaba Nchu. Thaba Nchu is divided into three areas, Central, Northern and Southern Thaba Nchu. Central Thaba Nchu consists of 12 villages, while Northern and Southern Thaba Nchu consists of 21 and 12 villages respectively. Villages with the most sheep farmers were identified in the different areas and formed into groups. Only three villages, those with the most sheep famers, were chosen in Central Thaba Nchu and made up the first group (Motlatla, Rooifontein and Seroalo). In Northern Thaba Nchu, the largest area in Thaba Nchu, 15 villages were chosen, forming five groups of three villages each. Villages that were close to each other were joined together to form a group. These villages were Moroto, Mariasdal, Longride, Rathoi, Sediba, Tala, Bofulo, Modutung, Morago, Houtnek, Middledeel, Mothusi, Felloane, Postsane, and Thubusi. Six villages were chosen from Southern Thaba Nchu to form two groups of three villages each. The villages chosen for Southern Thaba Nchu were Gladstone, Woodbridge I, Woodbridge II, Rietfontein, Balaclava, Tweefontein and Yoxford. Seven farmers were chosen from each village in each sub-group, making a total of 21 farmers per sub-group, and therefore a total of 168 farmers were interviewed. Due to incomplete information from some respondents, only 157 responses were eligible (complete) for this study.

A complete list of the villages with sheep farmers could not be obtained from the Department of Agriculture in Botshabelo. Therefore, a simple random sampling technique was used to select sheep farmers at random from two areas known for sheep farming, Bradford Farm and Naledi Commage. Sixty sheep farmers were selected at random and interviewed and all their responses were eligible for the study.

A total of 217 farmers were interviewed for this study, 157 farmers from Thaba Nchu plus 60 farmers in Botshabelo.

3.5 Characteristics of Sheep Farmers

In this section, descriptive statistics of sheep farmers in the N8 development corridor (Thaba Nchu and Botshabelo) will be presented.

3.5.1 Sheep Production

The questionnaire captured the total value of sheep sold (during the last 12 months: January – December 2015) in rand. The value of sheep output was captured in sheep products sold, and will be used as the dependent variable when estimating the production frontier, because sheep output is needed to estimate the production frontier and TE scores of the sheep farmers in the study areas. The questionnaire also captured the total value of sheep purchased in rand (expenditure). A summary of statistics relating to the sheep output produced and sheep purchased is provided in Table 3.2.

TABLE 3.2 SUMMARY DESCRIPTIVE STATISTICS OF SHEEP OUTPUT AND SHEEP PURCHASE IN THE LAST 12 MONTHS (JAN-DEC 2015)

Variables	Thaba Nchu (N=157)		Botshabelo (N=60)		Pooled (N=217)	
	Average (R)	SD	Average (R)	Std.	Average (R)	SD
Sheep output	2 972.39	11 656.28	5 023.52	6 668.59	3 542.15	10 535.81
Sheep purchase	1 419.45	4 988.536	3 034.25	5 099.68	1 865.94	5 059.70

Note: SD = Standard deviation; 1USD = R13.5 (03/10/2016)
SOURCE: FIELD SURVEY (2016)

Sheep output was determined as the product of number of sheep sold in the last 12 months and the price per sheep (sheep output = No. of sheep sold * price per sheep). Sheep farmers sold sheep at different prices. Sheep farmers in Botshabelo obtained a higher sheep output, on average, at R5 023.52, compared to sheep farmers in Thaba Nchu, who obtained, on average, a sheep production output level of R2 972.39. Generally, farmers in Botshabelo obtained higher sheep output for sheep sold over the last 12 months than farmers in Thaba Nchu. The standard deviation (SD) indicates a high variability of sheep output obtained by the sheep producers. The pooled sample shows that farmers in both areas had, on average, an output level of R3 542.15. In terms of expenditure (sheep purchased), farmers in Botshabelo spent more on buying sheep, with an average of R3 034.25 over the last 12 months, while farmers in Thaba Nchu spent, on average, R1 419.45. The average sheep purchased by the pooled sample was R1 865.94, with a standard deviation of R5 059.704. A study by Conradie and Piesse (2015) found sheep farmers in Laingsburg, South Africa, to have a sheep output of R664 on average per year. Sheep farmers in the N8 development corridor have, on average, greater output than sheep farmers in Laingsburg.

3.5.2 Technical Factors

This section is a brief discussion of the technical production factors employed by the sheep farmers in the study areas. The technical factors include grazing land, herd size, sheep lost, breed of sheep, cost of feed, cost of veterinary drugs and services, transport cost, labour and operating expenses. These technical factors are used as the explanatory variables during estimation of the stochastic production frontier. Descriptive statistics for all the above-mentioned variables will be discussed.

3.5.2.1 Grazing Land Size

Grazing land size refers to the total land area used for sheep farming, and was measured in hectares. The average, minimum (Min.), maximum (Max.) and standard deviation (SD) for grazing land size of the sheep producers are summarised in Table 3.3.

TABLE 3.3 GRAZING LAND SIZE FOR SHEEP FARMING

Variable	Min. (ha)	Max. (ha)	Average (ha)	SD
Thaba Nchu (N=157)	15	2 486	353.26	553.819
Botshabelo (N=60)	20	850	425.33	76.429
Pooled (N=217)	15	2 486	373.10	471.753

SOURCE: FIELD SURVEY (2016).

The grazing land per farmer in Botshabelo (425.33 ha), as given in Table 3.3, is on average larger than that in Thaba Nchu (353.26 ha). The majority of the sheep farmers in the pooled sample grazed on 373.10 ha, on average, with a minimum of 15 ha and a maximum of 2 486 ha. Even though the survey data indicates that the sheep farmers in Botshabelo are operating on a more grazing land than in Thaba Nchu, there is a high variability (SD = 553.819) between the sizes of grazing land used by farmers in Thaba Nchu and Botshabelo (SD = 76.429). This means that some farmers in Thaba Nchu graze on larger pieces of land (Max. = 2486 ha) than others (Min. = 15 ha). Conradie and Piesse (2015) found that sheep farmers in Laingsburg grazed on 12.58 hectares of land, on average, with a standard deviation of 4.88. Shomo *et al.* (2015) found sheep farmers in Syria grazed on 6.05 ha. Farmers along the N8 development therefore have relatively larger grazing land.

3.5.2.2 Herd Size

Herd size refers to the total number of sheep and other livestock owned by sheep farmers, measured in numbers. Farmers indicated that they also keep other livestock, either sold or used for other purposes (family pride, cultural activities, household consumption etc.). The average number of sheep and other livestock owned by sheep farmers in the study area is summarised in Table 3.4.

TABLE 3.4 HERD SIZE AND OTHER LIVESTOCK OWNED BY SHEEP FARMERS

Livestock numbers	Thaba Nchu (N=157)		Botshabelo (N=60)		Pooled (N=217)	
	Average	SD	Average	SD	Average	SD
Sheep	24	25	27	27	25	25
Cattle	12	15	8	11	11	14
Goats	1	4	3	9	2	6
Chickens	11	14	7	12	10	14
Pigs	2	12	1	1	2	10
Horses	1	3	1	1	1	2

Note: Figures are rounded to nearest whole number to explain livestock numbers better.
SOURCE: FIELD SURVEY (2016).

Farmers in Botshabelo have, on average, three more sheep (27) than farmers in Thaba Nchu, who have 24 sheep. The pooled sample shows that farmers in the study areas have, on average, 25 sheep on their farms. Regarding other livestock owned by sheep farmers, farmers in Thaba Nchu own more cattle, with an average of 12 animals, which is four more than the eight owned by each Botshabelo farmer. The pooled sample shows that sheep farmers have, on average, 11 cattle on their farms. Farmers in Botshabelo also own on average three goats each, which is two more goats than in farmers in Thaba Nchu own. The Botshabelo farmers have, on average, seven chickens each, which is four less than Thaba Nchu farmers, and one pig which is one less than in Thaba Nchu. Both study areas have on average one horse per farm, although the standard deviation is higher for Thaba Nchu than for Botshabelo.

The number of livestock produced indicates that farmers in both areas produce predominately sheep, since both areas are suitable for sheep and livestock production. A study by Shomo *et al.* (2010) found that farmers in Syria keep more sheep on average than farmers along the N8 development corridor. The study found that farmers in Syria keep 172 sheep on average compared to 25 sheep along the N8 development. This could be because farmers in Syria are large-scale commercial farmers, while farmers along the N8 development corridor are smallholder farmers.

3.5.2.3 Sheep Losses

Information on the number of sheep lost was obtained by asking the farmers how many sheep they had lost in the last 12 months (January-December 2015) due to causes such as diseases and parasites. Sheep losses was measured as a dummy variable with 1 indicating that sheep had been lost and 0 otherwise. The number of sheep lost during the last 12 months (January-December 2015) due to various causes is presented in Table 3.5.

TABLE 3.5 NUMBER OF SHEEP LOST BY FAMERS DURING THE LAST 12 MONTHS (JAN DEC 2015)

Sheep lost	Thaba Nchu (N=157)		Botshabelo (N=60)		Pooled (N=217)	
	Average	SD	Average	SD	Average	SD
Disease and parasite	3	5	4	8	3	6
Drought	2	4	2	3	2	4
Floods	1	1	1	1	1	1
Thunder and lighting	1	1	1	1	1	1
Disputes over pasture	1	1	1	1	1	1
Wild animals	1	2	1	2	1	2
Theft	2	4	3	5	3	5

Note: Figures are rounded to nearest whole number to better explain number sheep lost.
SOURCE: FIELD SURVEY (2016).

Sheep farmers in Botshabelo lost a maximum of 40 sheep in the last 12 months, two more than farmers in Thaba Nchu, who lost of 38 sheep, on average, in the last 12 months. On average, farmers in Botshabelo lost four sheep to diseases and parasites, one more than farmers in Thaba Nchu, who lost three sheep. Farmers in both Thaba Nchu and Botshabelo lost two sheep each, on average, due to drought, and also lost one, on average, each due to flood, thunder and lighting, disputes over pasture, and attacks by wild animals. The variability was the same for farmers in Botshabelo and Thaba Nchu. Furthermore, farmers in Thaba Nchu lost two sheep, on average, due to theft, one less than farmers in Botshabelo, who lost three sheep, on average, to theft. Sheep lost is expected to affect the efficiency of farmers, as it reduces sheep numbers and sheep output. If the numbers of sheep lost due to any of the above causes is minimised, output will increase and TE will be enhanced. A study by Lombard (2015) found that a total of 84 955 sheep are lost yearly due to theft in the Free State province. This study calculated that R144 423 500 is lost annually by livestock farmers in the Free State due to theft. Mdlulwa (2015) found that livestock farmers in the Free State lost R149 000 in production cost in 2010 due to diseases and parasites (Rift Valley fever), R2.5 million in the Northern Cape and R1.8 million in the Eastern Cape.

3.5.2.4 Sheep Breed Types

Farmers were asked to indicate the different sheep breed types kept on their farms. The different breed types were presented to them to choose from. The responses of sheep farmers regarding sheep breed types kept on their farms are presented in Table 3.6.

TABLE 3.6 SHEEP BREED TYPES KEPT ON FARMS BY SHEEP FARMERS

Variables	Indigenous sheep		Crossbreeds		Exotics	
	Count	%	Count	%	Count	%
Thaba Nchu (N=157)	65	41.4	58	36.9	34	21.7
Botshabelo (N=60)	16	26.7	31	51.7	13	21.7
Pooled (N=217)	81	37.3	89	41.0	47	21.7

SOURCE: FIELD SURVEY (2016).

The data collected shows that sheep farmers in Thaba Nchu farm predominantly with indigenous sheep breeds (41.1%), while farmers in Botshabelo farm predominantly with crossbreeds (51.7%). Both areas are less inclined to keep exotic breeds – farmers in both areas indicated that only 21.7% of their animals are exotic breeds. The pooled sample shows that the preferred sheep type is crossbreed, at 41% of the flock size, although 37.3% of the flock consists of indigenous sheep. From the data presented in Table 3.6 it appears that the crossbreed is a popular sheep type, although the number of indigenous sheep is also high. Farmers indicated that they prefer crossbreeds and indigenous sheep, since these breeds are easier to manage and resilient in harsh climates.

3.5.2.5 Breed Preference

Farmers were asked to indicate their sheep-breed preferences for sheep kept on their farms. The different sheep breeds were presented to them to choose from. The responses of the sheep farmers on the different sheep breeds kept on their farms are presented in Table 3.7.

TABLE 3.7 SHEEP BREEDS AND THE PREFERENCES OF FARMERS

Variables	Thaba Nchu (N=157)		Botshabelo (N=60)		Pooled (N=217)	
	Count	%	Count	%	Count	%
Merino	88	56.1	21	35.0	109	50.2
Dorper	3	1.9	1	1.7	4	1.8
Mutton Merino	64	40.8	37	61.7	101	46.5
Dormer	2	1.3	1	1.7	3	1.4

SOURCE: FIELD SURVEY (2016).

The data in Table 3.7 indicates that Merino was the most popular sheep breed among the farmers in Thaba Nchu, with 56.1% (88 farmers) indicating their preference for this breed, while Mutton Merino was the second-most-popular breed (64 farmers showed preference for this breed). Botshabelo showed a preference for the Mutton Merino sheep breed, with 61.7% of the farmers (37 farmers) indicating their preference for the breed. Merino was the second-most-popular sheep breed in Botshabelo, with 35% (21 farmers) indicating their preference for farming with the breed. The pooled data shows that the Merino breed was the preferred breed, with 50.2% of the pooled sample indicating their preference for the breed, followed by Mutton Merino, at 46.5%, Dorper at 1.8%, and Dormer at 1.4%.

3.5.2.6 Grazing Systems

Sheep farming involves various grazing techniques. Sheep farmers are free to choose any grazing technique based on the location of the grazing area, the number of sheep owned and the financial ability of the farmer. The survey considered various grazing systems used by smallholder farmers in the study area, because grazing systems play an important role in sheep production. The questionnaire considered three grazing systems: intensive, extensive and free grazing. Extensive grazing is a system whereby sheep are confined to a particular place, especially during extreme weather conditions, while intensive grazing is a system where the sheep are kept in a fenced area and allowed to graze. Under free grazing farmers leave the sheep to graze without a fence or confinement. The percentages of respondents using the different grazing systems are shown in Figure 3.4.

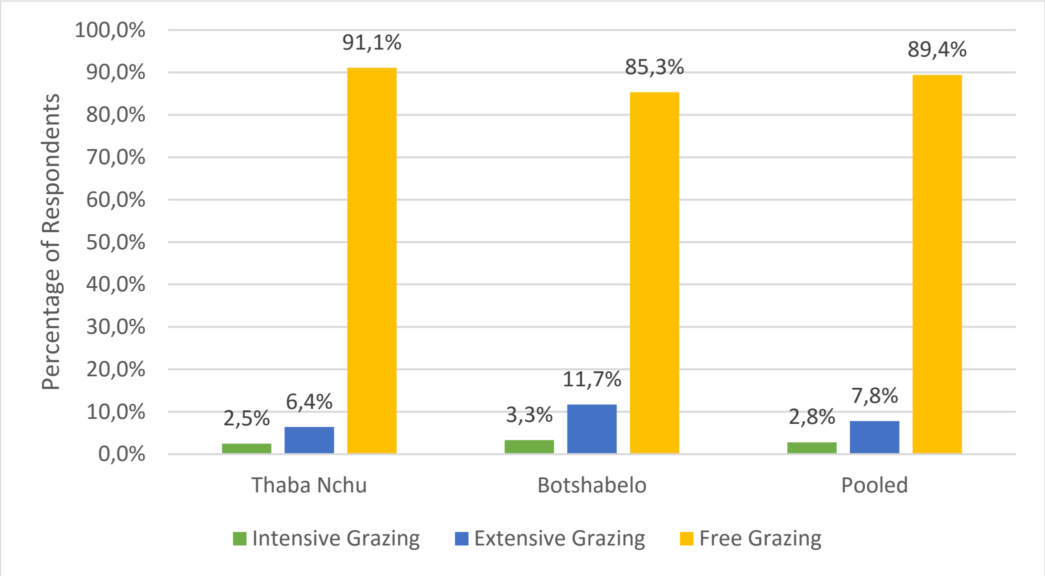


FIGURE 3.4 GRAZING SYSTEMS IN THE STUDY AREAS

SOURCE: FIELD SURVEY (2016).

The results show that 91.1% of sheep farmers in Thaba Nchu practice free grazing, while 2.5% and 6.4% practice intensive and extensive grazing respectively. In Botshabelo, 85.3% of sheep farmers practice free grazing, while 3.3% and 11.7% practice intensive and extensive grazing respectively. The pooled sample shows that 89.4% of sheep farmers in the study areas practice free grazing, while only 2.8% and 7.8% practice intensive and extensive grazing respectively. Farmers in the study area therefore predominantly use free grazing systems. Free grazing is preferred by these farmers because of the cost involved in both intensive and extensive grazing systems. However, due to concerns about the quality of the grazing, most farmers buy or produce extra feed for their livestock.

3.5.2.7 Feed Use by Sheep Farmers

Sheep output depends largely on feed intake by the animals – efficient feed use can increase the productivity of sheep production. During the survey, farmers were asked about the type of feed they use for sheep production, for example, silage, fodder, mineral salt and vitamins. The discussion about feed use focused on the quantity of feed that was used and the cost of the feed per month. A distinction was made between feed produced and feed purchased.

Most sheep farmers in the study area did not use feed at all, while those who did bought most of the feed and produced very little themselves. The quantity of feed used by sheep farmers in the study areas is summarised in Table 3.8 by means of averages and standard deviations.

TABLE 3.8 SUMMARY STATISTICS OF QUANTITY OF FEED USED BY SHEEP FARMERS

District municipality	Quantity of feed purchased per month (kg)		Quantity of feed produced per month (kg)	
	Average	SD	Average	SD
Thaba Nchu (N=157)	148.41	198.29	19.90	71.53
Botshabelo (N=60)	149.48	225.71	6.52	39.03
Pooled (N=217)	148.71	205.70	16.20	64.40

SOURCE: FIELD SURVEY (2016).

The data about quantity of feed used given in Table 3.8 indicates that sheep farmers in Botshabelo and Thaba Nchu purchase, on average, about the same amount of feed. However, the estimated standard deviation estimated for feed purchased for Botshabelo is higher at 225.71 kg, than the 198.29 kg for Thaba Nchu. The data, therefore, indicates that, although the average feed quantity purchased for both areas are the same, the variation in the amount of feed purchased is greater in Botshabelo. The farmers in Thaba Nchu used more feed that they produced, at an average of 19.90 kg per month, while farmers in Botshabelo used only 6.52 kg of produced feed, on average. The pooled sample shows that farmers in the study areas used an average of 148.71 kg of purchased feed per month, and 16.20 kg of produced feed per month, with a standard deviation of 205.702 kg and 64.40 kg respectively.

The survey data shows that the use of feed was low in the study areas. The low use of feed could be due to financial constraints involved in either purchasing or producing feed, so most farmers allow their animals to graze on the field. Table 3.9 provides a summary of how much farmers in the study areas spend on feed per month.

TABLE 3.9 COST OF FEED USE PER MONTH FOR SHEEP PRODUCTION

District municipality	Cost of feed purchased per month (R)		Cost of feed produced per month in (R)	
	Average	SD	Average	SD
Thaba Nchu (N=157)	551.34	755.744	60.51	239.938
Botshabelo (N=60)	540.50	781.938	81.00	268.648
Pooled (N=217)	548.35	761.269	66.18	247.743

SOURCE: FIELD SURVEY (2016).

Farmers in Thaba Nchu spent, on average, R551.34 on purchasing feed for sheep production, while farmers in Botshabelo spent R540.50 on buying feed per month. The pooled sample shows that farmers in the study areas spent, on average, R548.35 on the purchase of feed per month, with a standard deviation of R761.269. On the other hand, farmers in Botshabelo spent on average R81.00 per month producing feed on their farms, while farmers in Thaba Nchu spent only R60.15 per month producing feed on the farm. The pooled sample shows that farmers in the study areas spent R66.18 per month, on average, producing feed on the farm, with a standard deviation of R247.743. Sheep producers in both areas rely heavily on purchased feed for animal production. Although the per-month cost of feed purchased does not seem very high, the cost of feeding sheep in a 12-month (Jan-Dec 2015) period will be in excess of R6 000, which is more than the average profit of the farmers in the study area during the same period.

3.5.2.8 Transport and Operating Costs

Sheep production involve costs, and effective management of the costs involved in sheep production will enhance productivity and sheep output (Mapiliyao *et al.,* 2012). The survey captured and separated two types of cost involved in the day-to-day running of farm operations, namely, transport and operating cost. Transport cost relates to transporting farm inputs and sheep to and from the market, while operating cost involves all other costs involved in sheep production, such as cost of electricity, hire of machinery, fuel and mechanisation. Table 3.10 provides a summary of the amounts farmers in the study areas spent on transport and operations per month.

TABLE 3.10 TRANSPORT AND OPERATING COST PER MONTH IN SHEEP PRODUCTION

District municipality	Transport cost per month (R)		Operating cost per month (R)	
	Average	SD	Average	SD
Thaba Nchu (N=157)	176.75	334.364	417.79	1105.65
Botshabelo (N=60)	136.75	155.11	282.27	148.50
Pooled (N=217)	165.69	296.04	280.32	944.77

SOURCE: FIELD SURVEY (2016).

Farmers in Thaba Nchu spent, on average, R176.75 on transport per month for sheep production, while farmers in Botshabelo spent R136.75 per month. The pooled sample shows that farmers in the study areas spent, on average, R165.69 on transportation per month, with a standard deviation of R296.04. The standard deviation shows that there was high variability regarding the amount farmers spent on transport and operations. On the other hand, farmers in Botshabelo spent, on average, R282.27 on operations on their farms per month, while farmers in Thaba Nchu spent R417.79 per month on operations. The pooled sample shows that farmers in the study areas spent R280.32 per month, on average, on operations, with a standard deviation of R944.77. The standard deviation shows that there was high variability in the amount farmers spent on transport and operations on their farms.

3.5.2.9 Labour

Sheep farming is very labour intensive; it could involve taking sheep to the grazing land, feeding them and vaccinating them. This makes labour an important input for farmers in the study areas. The amount of labour used by sheep farmers in both areas and the percentages of family and hired labour is presented in Table 3.11

TABLE 3.11 QUANTITY OF LABOUR INPUT USED BY THE SHEEP PRODUCERS

District municipality	Observations (man-days)	Average (man-days)	SD	Family labour (man-days)		Hired labour (man-days)	
				Count	%	Count	%
Thaba Nchu	157	7.97	13.42	115	73.2	42	26.8
Botshabelo	60	18.33	20.71	29	48.3	31	51.7
Pooled	217	10.83	16.34	144	66.4	73	33.6

SOURCE: FIELD SURVEY (2016).

Table 3.11 shows that sheep farmers in Botshabelo used more labour (18.33 man-days/month) than farmers in Thaba Nchu, who used 7.97 man-days/month. In the pooled sample, the average amount of labour used by sheep farmers in the study areas was 10.83 man-days/month. The survey also captured information on the quantity of family and hired labour used by the sheep farmers during the last 12 months (January-December 2015). There is a huge variation in the quantity of labour used among the respondents in the two areas. This could be as a result of some farmers operating on larger grazing land than others, which means they require more labour.

Results in Table 3.11 indicate that farmers in Thaba Nchu used more family labour, namely, 73.2%, and only 26.8% of their labour was hired, while Botshabelo used more hired labour, at 51.7%, compared to 48.3% family labour. The pooled sample shows that 66.4% of labour used by farmers in the study area was family labour, compared to 33.6% hired labour. This could be a result of farmers lacking the financial capital to pay for labour. This study is consistent with a study by Shomo *et al.* (2015), who found that small-scale sheep farmers in Syria used more family labour than hired labour. However, Conradie and Piesse (2015) found sheep farmers in Laingsburg, South Africa, used more hired labour than family labour.

3.5.2.10 Veterinary Advisory Services

Farmers were asked if they were the recipients of veterinary advisory services in the last 12 months (January-December 2015). Responses regarding sheep farmers' access to veterinary advisory services in the study areas are shown in Figure 3.5.

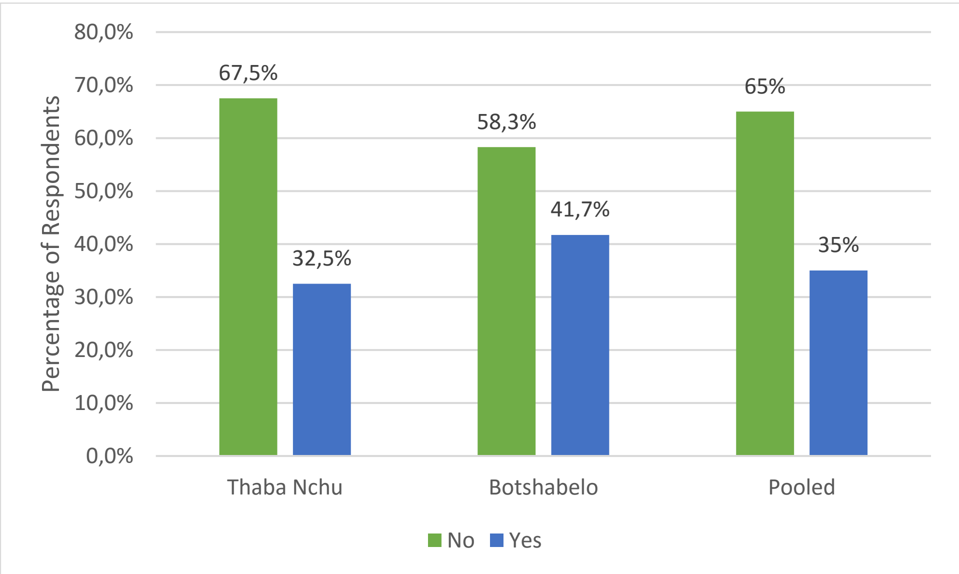


FIGURE 3.5 ACCESS TO VETERINARY ADVISORY SERVICES BY RESPONDENTS

SOURCE: FIELD SURVEY (2016).

Approximately 67.5% of the farmers in Thaba Nchu did not have access to veterinary advisory services, while approximately 32.5% of the farmers had access to veterinary advisory services. In Botshabelo, 58.3% of farmers indicated that they did not have access to veterinary advisory services, while the remaining 41.7% had access to veterinary services. In the pooled sample 65% of the farmers did not receive any veterinary advisory service with respect to their sheep production, while 35% had access to veterinary services. Most farmers consider veterinary advisory services to be expensive and therefore cannot afford to pay for the services. A study by Otieno (2011) found that 58.8% of smallholder cattle farmers, on average, in Kenya had access veterinary advisory more than the sheep farmers along the N8 development corridor.

3.5.2.11 Cost of Veterinary Drugs and Services

Sheep farmers were asked how much they spent, on average, on veterinary drugs and veterinary services per month. The expenditure on veterinary drugs and services was recorded in rand. Descriptive statistics for expenditure on veterinary drugs and services are given in Table 3.12.

TABLE 3.12 EXPENDITURE ON VETERINARY SERVICES AND DRUGS PER MONTH

District municipality	Veterinary drugs		Veterinary services	
	Average (R)	SD	Average (R)	SD
Thaba Nchu (N=157)	861.39	1 170.79	174.83	524.607
Botshabelo (N=60)	670.83	735.16	104.50	247.930
Pooled (N=217)	808.71	1 070.004	155.39	465.348

SOURCE: FIELD SURVEY (2016).

On average, the sheep farmers in Thaba Nchu spent more on veterinary drugs and services per month than farmers in Botshabelo. On average, farmers in Thaba Nchu spent R861.39 per month on veterinary drugs, while farmers in Botshabelo spent R670.83. Furthermore, farmers in Thaba Nchu spent R174.83, on average, on veterinary services, and farmers in Botshabelo spent, on average, R104.50 per month. The pooled sample shows that farmers in the study areas spent, on average, R808.71 per month on veterinary drugs and R155.39 on veterinary services. Veterinary drugs enhance the health of the sheep, which will increase the productivity of the sheep. Spending more money on veterinary drugs could increase sheep output. A study by Otieno (2011) found that smallholder cattle farmers in Kenya spent the equivalent of R5 633.93 per year, on average, on veterinary drugs and services, compared to R18 424.224 spent by farmers in the study area per year.

3.5.3 Socio-economic Characteristics of Sheep Producers

Socio-economic characteristics of the respondents, such as gender, educational level, age, household size and farming experience, will be discussed in this section.

3.5.3.1 Gender

The gender distribution of the sheep farmers in the study areas is shown in Figure 3.6. Data collected shows that the majority of sheep farmers in both Thaba Nchu and Botshabelo were male. The majority of sheep farmers in Thaba Nchu were men (63.1%), while 36.9% of farmers were women. The majority of sheep farmers in Botshabelo were also men (73.3%); women made up 26.7% of the sample. Evaluation of the pooled sample confirmed that the majority of the sheep farmers were male (65.9%). The data collected therefore shows that the majority of sheep farmers in both Thaba Nchu and Botshabelo were male. Related studies have shown that gender has an effect on the TE of farmers. Otieno (2011) found that 72% of smallholder cattle farmers in Kenya were men, and Bahta and Hikuepi (2015) found that 78.3% of smallholder cattle farmers in Botswana were male.

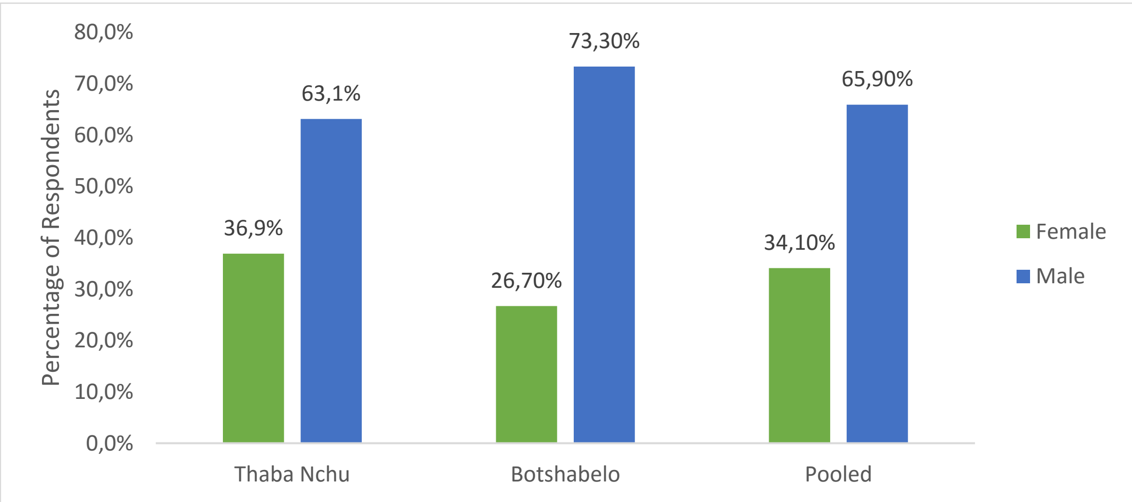
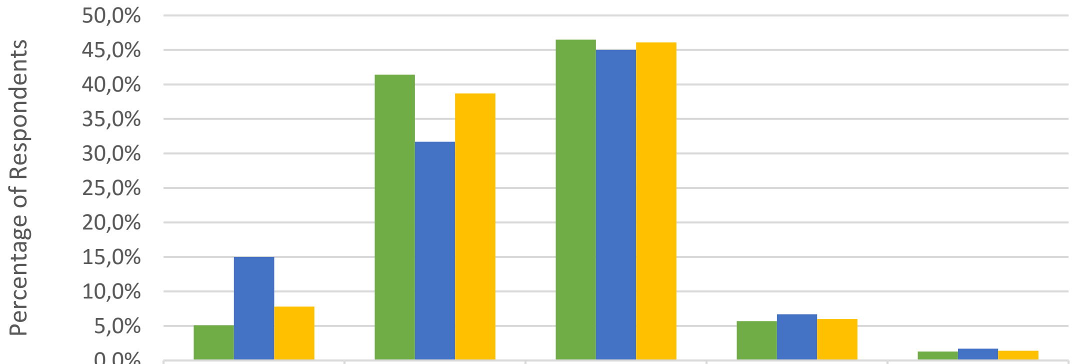


FIGURE 3.6 GENDER OF SHEEP PRODUCERS ACROSS STUDY AREAS

SOURCE: FIELD SURVEY (2016).

3.5.3.2 Educational Level

The educational level of the sheep farmers was categorised into no formal education, primary, secondary, college certificate or diploma, and university degree. College certificate is a professional certificate or diploma lower than a university degree, typically vocational secondary education.



	No Formal Education	Primary Education	Secondary Edcuation	Middle College certifcate or Diploma	University Degree
Thaba Nchu	5,1%	41,4%	46,5%	5,7%	1,3%
Botshabelo	15%	31,7%	45%	6,7%	1,7%
Pooled	7,8%	38,7%	46,1%	6%	1,4%

FIGURE 3.7 EDUCATIONAL LEVEL DISTRIBUTION OF SHEEP FARMERS ACROSS STUDY AREAS

SOURCE: FIELD SURVEY (2016).

Primary education indicates that the respondent has seven years of formal schooling, secondary school is an additional five years, college certificate or diploma is 12 years and university degree is 15 years in total. The frequencies of farmers who had attained these levels of education are provided in Figure 3.7.

The survey results in Figure 3.7 show that 5.1% of sheep farmers in Thaba Nchu had no formal education, 41.4% had completed primary education, 46.5% had obtained secondary education, while 5.7% had a college certificate or diploma and only 1.3% had attained university education. The majority (45%) of sheep farmers in Botshabelo had attained secondary education, followed by primary education (31.7%), while 15% of the farmers had no formal education, 6.7% had college certificates or diplomas and 1.7% had university degrees. Of the 217 sheep farmers in the pooled sample, 46.1% had attained secondary education, while 38.7% had primary education and 7.8% had no formal education, while 6% had attained college certificates or diplomas and 1.4% had completed university education. The survey results indicate that, at the very least, 45% of the farmers in the study area had obtained five years of formal schooling, while an additional 45% had obtained another three years. Education enhances household heads' decisions to adopt and use farm technologies efficiently, which will enhance farm productivity (Otieno, 2011).

3.5.3.3 Age, Household Size and Farming Experience

Descriptive statistics in terms of average, minimum and maximum of the socio-economic characteristics of sheep farmers for age, household size and years farming experience are presented in Table 3.13.

TABLE 3.13 DESCRIPTIVE STATISTICS OF SOCIO-ECONOMIC CHARACTERISTICS OF THE SHEEP FARMERS

Variables	Thaba Nchu (N=157)			Botshabelo (N=60)			Pooled (N=217)		
	Min.	Max.	Average	Min.	Max.	Average	Min	Max	Average
Age	19	94	54	25	82	57	19	94	55
Years of production	1	50	13	1	40	10	1	50	13
Household size	1	13	4	1	10	3	1	13	4

SOURCE: FIELD SURVEY (2016).

Sheep farmers in Botshabelo were older, on average, than farmers in Thaba Nchu. The average age of the farmers was 57 years in Botshabelo, and 54 years in Thaba Nchu. The pooled data shows that the average age of farmers in both district municipalities was 55 years. The minimum age was 19 years and the maximum age 94 years.

The results demonstrate that sheep farmers in Thaba Nchu had more experience (average 13 years) in sheep production than those in the Botshabelo (average 10 years). Table 3.13 also shows that the average time farmers in the pooled sample had engaged in sheep production was 13 years, with a minimum of one year and a maximum 50 years.

On average, Thaba Nchu had a larger household size, with an average of four people, while the average household size for Botshabelo was three people. The average household size of the pooled sample was four people, with a minimum and a maximum of one and 13 people respectively.

The farmers in Botshabelo are therefore, on average, older, have less farming experience and have a smaller household size than sheep farmers from Thaba Nchu. A study by Shomo *et al.* (2015) found that older household heads tend to be more technically efficient regarding sheep production in Syria. The study also argues that larger households are less technically efficient than smaller households, and that farmers with more farm experience are more technically efficient than farmers with less farm experience. Donkor (2015) found that larger households are more efficient than smaller households. However, Bahta and Hikuepi (2015) found that cattle farmers in Botswana with more farm experience were less efficient in cattle production.

3.5.4 Institutional Factors

Institutional variables of the sheep farmers sampled for this study will be described in this section. The institutional factors obtained from the study are extension contact, credit access, distance to nearest market centre and land-tenure systems. These institutional factors provide farmers with technical and financial assistance that enhances their sheep production. A brief discussion of these institutional factors follows, starting with access to extension services.

3.5.4.1 Extension Services

The responses of sheep farmers' access to extension services in the study areas is illustrated in Figure 3.8.

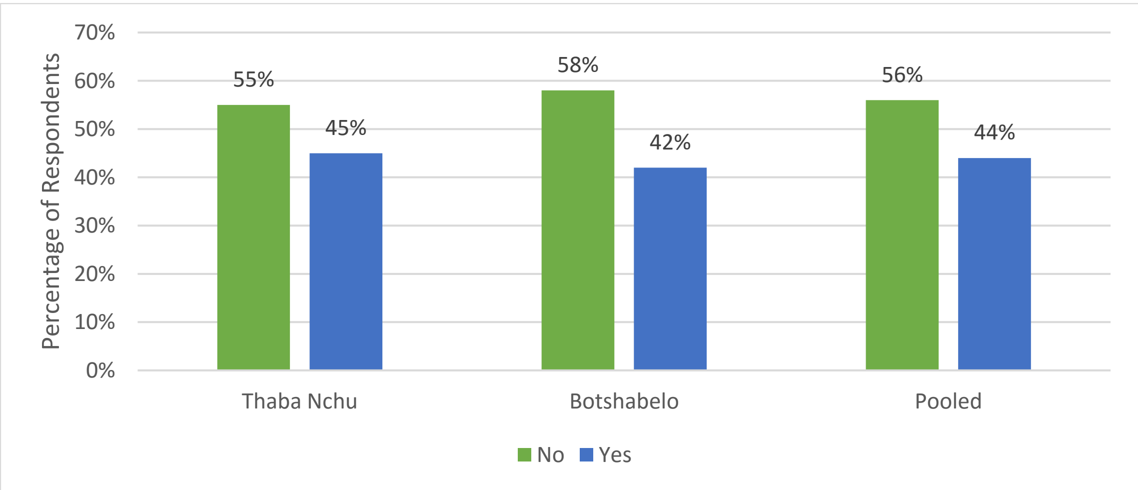


FIGURE 3.8 ACCESS TO EXTENSION SERVICES BY RESPONDENTS ACROSS STUDY AREAS SOURCE: FIELD SURVEY (2016).

The survey results in Figure 3.7 show that 55% of the farmers in Thaba Nchu did not have access to extension service, while 45% of the farmers had access to extension services. In Botshabelo, 58% of farmers did not have access to extension services, while the remaining 42% had access to extension services. Of the pooled sample, 56% of farmers in the study areas did not receive extension service with respect to sheep production, while 44% had access to extension services. The data indicates that more than half of sheep producers in the study area did not have access to extension services. Donkor (2015), in a study on rice production in Ghana, found that 62% of rice farmers had no access to extension services. He concluded that the lack of extension officers is the result of budget constraints by the government, which does not train and hire enough extension officers.

3.5.4.2 Access to Credit

Agricultural finance plays an important role in agricultural production, since farmers need money to acquire farm inputs for their sheep production, and for proper farm management. Sheep production requires, among other inputs, feed, veterinary services and drugs, and all of this requires money. Farmers where asked to indicate whether they had access to credit during the last 12 months (January-December 2015). Figure 3.9 shows farmers' access to credit in the study areas.

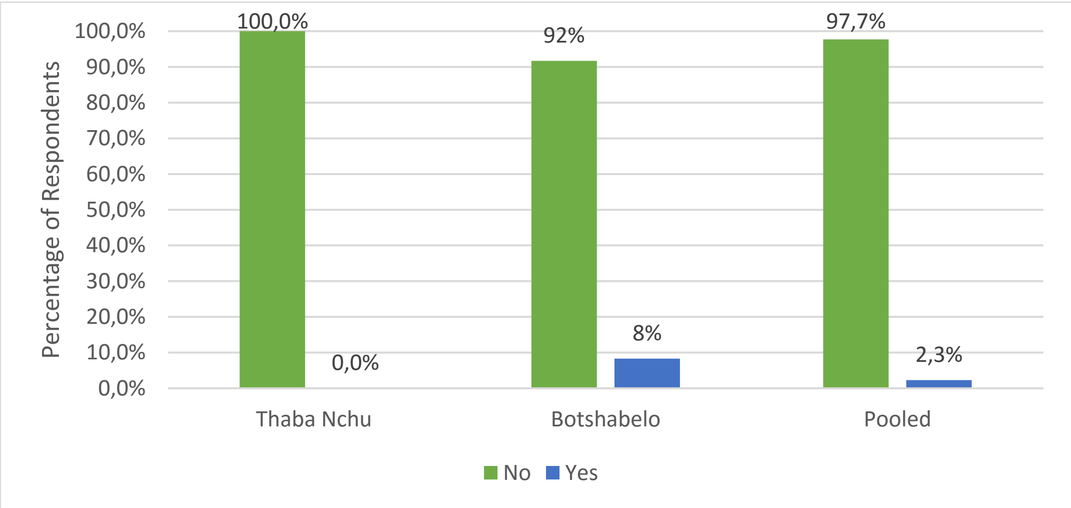


FIGURE 3.9 FARMERS' ACCESS TO CREDIT ACROSS STUDY AREAS

SOURCE: FIELD SURVEY (2016).

Farmers in Thaba Nchu did not have access to credit over the last 12 months (January-December 2015). Sheep farmers indicated they did not apply for loans because most of them did not qualify for loans (lack of collateral). In Botshabelo, 8% of the sheep farmers applied for and obtained credit. However, the farmers who were able to obtain loans from microfinance institutions complained of high interest rates. In Botshabelo 92% of the farmers did not have access to credit and most of them indicated that it was difficult to obtain small loans. In the pooled sample only 2% of the farmers had accessed credit, while the majority

(98%) did not have access to credit. Most smallholder farmers can't afford to pay back loans due to high interest rates, thereby making it difficult for them to get loans. This is consistent with a study by Donkor (2015), who found that 97% of rice farmers in Ghana did not have access to credit.

3.5.4.3 Distance to Market Centre

Distance to a market was measured in kilometres from the farmer's house to the nearest market centre. Results of an investigation into the distance between sheep producers' farms and a market centre are summarised in Table 3.14.

TABLE 3.14 DISTANCE TO NEAREST MARKET CENTRE

District municipality	Observation (km)	Min. (km)	Max. (km)	Average (km)	SD
Thaba Nchu	157	1	50	5.69	8.963
Botshabelo	60	1	35	4.80	6.635
Pooled	217	1	50	5.44	8.379

SOURCE: FIELD SURVEY (2016).

Sheep farmers in Botshabelo travelled shorter distances (on average 4.8 km) to the nearest market centre than farmers in Thaba Nchu (5.69 km). The pooled sample indicates that the sheep farmers were, on average, 5.44 km from the nearest market centre – the minimum was 1 km. Most farmers were able to sell their sheep to their neighbours and other breeders who live in the vicinity, meaning that sellers did not have to travel far to sell their livestock. Longer distances to market centres imply that farmers incur high costs transporting their commodities to the market and transporting farm inputs from the market to their houses or farms. Shomo *et al.* (2015) found that small-scale sheep farmers in Syria where approximately 46.33 km, on average, from the nearest market. The results of this study indicate that distance to market decreases TE.

3.5.4.4 Farm Manager

A farm manager is someone other than the farm owner who manages the day-to-day affairs of the farm. It was hypothesised that smallholders with farm managers would perform better then smallholders who do not have farm managers. The household head was therefore asked to indicate if a farm manager managed farming activities. The distribution of farms in the study areas with farm managers is shown in Figure 3.10.

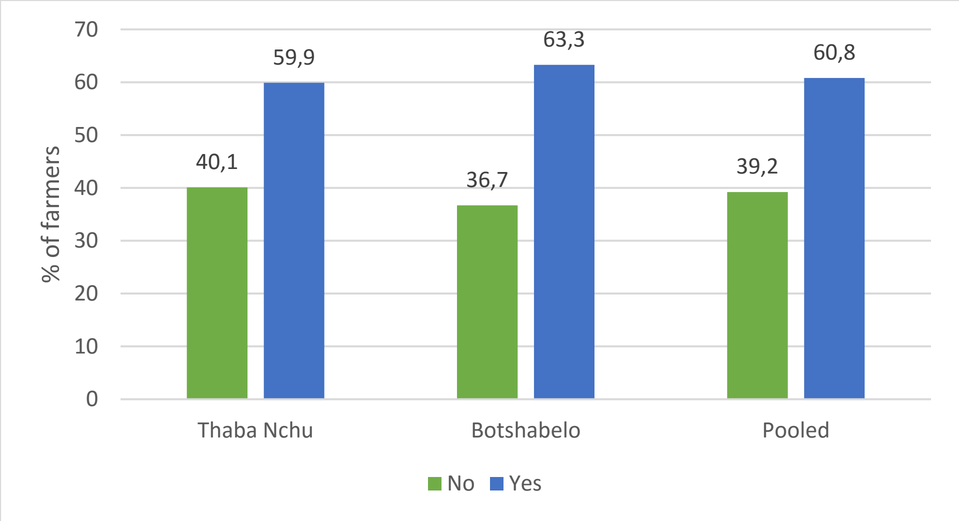


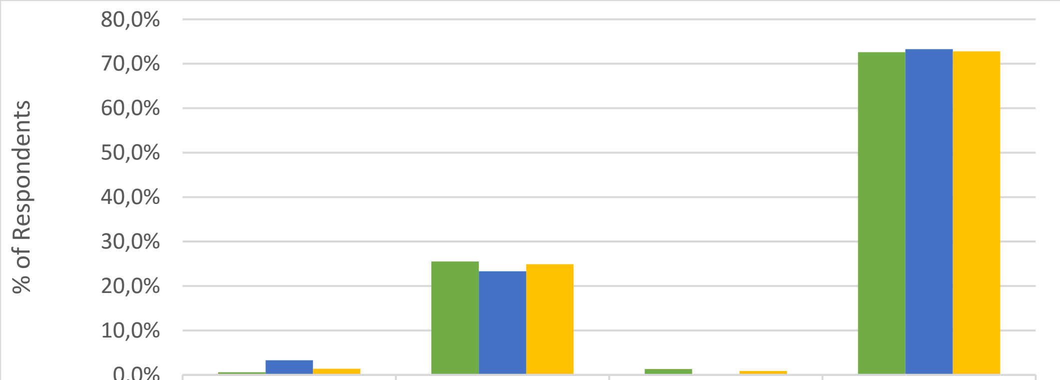
FIGURE 3.10 PROPORTION OF FARMS WITH MANAGERS

SOURCE: FIELD SURVEY (2016)

Data collected shows that the majority of sheep farmers in both Thaba Nchu and Botshabelo have farm managers on their farms. The majority of the sheep farmers in Thaba Nchu said "Yes", they have farm managers (59.9%), while the remaining 40.1% indicated that they do not have farm managers. In Botshabelo, 63.3% said "Yes" to having farm managers on their farms, while 36.7% said "No". The pooled sample shows that the majority of sheep farmers have farm managers (60.8%). It is surprising that the majority of the smallholders indicated that they do make use of farm managers. The expectation was that smallholders would manage farming activities themselves, since it would be costly to have a farm manager. However, a professional farm manager will ensure the effective management of farm resources for efficient sheep production. Otieno *et al.* (2012) found that 22% of cattle farmers in Kenya had farm managers on their farms. Otieno *et al.* (2012) indicated that the presence of a farm manager will increase TE.

3.5.4.5 Land-Tenure System

Farmers were asked to indicate the land tenure system on their grazing land. The responses of sheep farmers' land tenure systems in the study areas are shown in Figure 3.11.



	Individual Owned Land with deed/allotment letter	Individual Owned Land without deed/allotment letter	Communal Land with deed/allotment letter	Communal Land without deed/allotment letter
Thaba Nchu	0,6%	25,5%	1,3%	72,6%
Botshabelo	3,3%	23,3%	0,0%	73,3%
Pooled	1,4%	24,9%	0,9%	72,8%

FIGURE 3.11 LAND TENURE SYSTEMS USED BY SHEEP FARMERS ACROSS THE STUDY AREAS

SOURCE: FIELD SURVEY (2016).

The results in Figure 3.11 indicate that 73.3% of sheep farmers in Botshabelo use communal (community land) land without any deeds or allotment letters, 23.3% own individual lands without deeds/allotment letters, and 3.3% of farmers own individual lands with deeds/allotment letters. In Thaba Nchu, 72.6% of sheep farmers farmed on communal land without deeds/allotment letters, 25.5% owned individual land without deeds/allotment letters, 1.3% grazed on communal land with deeds/allotment letters, and only 0.6% owned individual land with deeds/allotment letters. The results also show that 72.8% of the pooled sample grazed on communal land without deeds/allotment letters, while 24.9% grazed on individual land without deeds/allotment letters, 1.4% grazed on individual land with deeds/allotment letters and 0.9% graze on communal land with deeds/allotment letters. From the above results, it is clear that most sheep farmers graze on communal land, while those who own land and use it for grazing typically do not own the deed for the land. Otieno (2011) found that approximately 90% of the cattle farmers in Kenya own individual land, with title deeds, contrary to farmers in the study area, where 72.8% of farmers farm on communal lands without title deeds.

3.6 Chapter Summary

Agriculture is central to the economy of the Free State. The province is very dry during the summer and really cold and wet during the winter season. The study area is located in Manguang, a municipal metro that was created in 2011.

Farmers in Botshabelo produced more sheep output, on average, than farmers in Thaba Nchu. In terms of resource use, sheep farmers in Botshabelo, on average, grazed on relatively larger areas, used more labour, had more sheep, compared to farmers in Thaba Nchu. The farmers in Thaba Nchu spent on average more on veterinary services and veterinary drugs. The grazing systems in the two areas differ slightly, but the majority of farmers in both areas use identical grazing systems. Farmers in both areas keep the same breed of sheep.

Sheep farming in both areas is dominated by male farmers. Generally, sheep farmers reported low educational levels, though farmers in Thaba Nchu were, on average, slightly more educated than farmers in Botshabelo. The study also reveals that sheep farming in both areas is practised by older farmers, and the farmers in Botshabelo were older than those in Thaba Nchu. Thaba Nchu sheep farmers had more experience in sheep production than those in the Botshabelo area. Even though the household size in the two districts was similar, Thaba Nchu farmers had relatively larger households. Access to extension services was very low in the two districts. However, sheep farmers in Thaba Nchu had more of a comparative advantage in terms of access to extension services than Botshabelo farmers. In terms of proximity to market centres, Botshabelo sheep farmers were closer to market centres than sheep farmers in Thaba Nchu. The majority of the farmers in Thaba Nchu and Botshabelo grazed on communal land without deeds/allotment letters. Access to veterinary services was low for the farmers in the study areas. However, there was higher number of farmers who had access to veterinary services in Botshabelo than in Thaba Nchu.

4.1 Introduction

The purpose of this chapter is to discuss the procedures used to achieve the objectives of the study. The first section focuses on the estimation of the stochastic production frontier used to calculate the TE of sheep production for the two study areas, Thaba Nchu and Botshabelo. During the estimation of the production frontiers, an inefficiency model was estimated using a single estimation procedure. The inefficiency model helps to identify the factors that influence TE of sheep production.

The second section focuses on the estimation of a metafrontier. Since heterogeneous (different) technologies are used in production across the various districts, individual frontiers estimated using SFA will not be sufficient to compare the efficiency levels of sheep farmers in the two study areas. The estimated metafrontier envelops the individual production frontiers to determine a single frontier consisting of the best sheep producers in Thaba Nchu and Botshabelo. Various TGRs and TE scores relative to the metafrontier will be predicted for all the sheep producers in the study areas. The third section identifies and ranks the constraints smallholder sheep farmers in Thaba Nchu and Botshabelo face – this is done by means of Kendall's Coefficient of Concordance.

4.2 The Stochastic Frontier Model

Productivity and efficiency in agricultural production has been studied for quite a while, especially in developing countries. The concept of productivity and efficiency was first initiated by Debreu (1951) and extended by Farrell (1957) using a production frontier. The production frontier used by Farrell (1957) shows the maximum amount of output that could be obtained given a set of inputs with the available technology (Greene, 2003). SFA and DEA can be used to measure or estimate productive efficiency in a single production system (Coelli *et al*., 2005; Greene, 2003).

Studies by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) were crucial in providing a framework for parametric analysis of the way policy variables might influence the production process. They proposed a stochastic frontier production function that separates the error term into technical inefficiency effects and random variations due to statistical noise (Otieno, 2011). By differentiating the effect of stochastic noise from the inefficiency effects, the SFA allows for hypotheses to be tested regarding the production structure and extent of inefficiency, unlike the DEA (Coelli *et al.,* 2005). SFA mainly makes use of the maximum likelihood estimation technique to estimate the frontier function in a given sample (Sarafidis, 2002). Aigner *et al*. (1977) examined the economic application of the SFM by applying the model to United States agricultural data; in its turn, a study by Battese and Corra (1977) applied the SFA technique to the pastoral zone of eastern Australia. A number of studies have been conducted using SFA (see Al-Sharafat, 2013; Chiona *et al.* 2014; Masunda and Chiweshe, 2015; Ojo 2003; Ojo, 2009; Trestini, 2006) thereby expanding on the initial studies of Aigner *et al*. (1977) and Battese and Corra (1977) and providing a comprehensive review of the application of SFM for measuring the effectiveness of agricultural production in developing countries.

The choice of functional form is very important when specifying the model, as it can influence the results of the estimated efficiency (Ogundari *et al*., 2010). Functional forms, like linear models, semi-log models, trans-log and the Cobb-Douglas, have been used in other studies (e.g., Aung, 2011; Ogundari, 2008). However, the Cobb-Douglas production function was chosen for this study because the functional form provides a better fit for the data.

4.2.1 The Stochastic Frontier Model specification

First, the SFA as proposed by Aigner *et al.,* (1977) and Meeusen and van den Broeck, (1977) was used to examine technical efficiencies of the different production systems along the N8 development corridor. Two production systems were identified based on the two study areas used for the analysis. In the second stage, a metafrontier (Battese and Rao, 2002) was used to estimate a frontier that was also used as a production benchmark while accounting for heterogeneous technology in the different regions.

The Cobb-Douglas production function is specified as:

$$InQ_i = \beta_0 + \sum_{k=1}^{9} \beta_k Inx_i + V_i - U_i \qquad i = 1, 2, 3, ...N \quad \text{...} (1)$$

Where Q_i represents sheep output for the i^th^ sheep farm for the each of the study areas. x_i denotes the farm inputs used by the i^{th} sheep farm for each district municipality. β_k denotes the coefficients of the farm inputs for each district municipality while β_0 denotes the constant term. $V_i - U_i$ denotes the total deviation, which is independent of each other. V_i is a symmetric two sided normally distributed random error that accounts for the random effects beyond the farmers' control (e.g. temperature, diseases and parasites, natural hazards, omitted variables, measurement error and other statistical noise) (Coelli *et al*., 2005). The systematic random-error component (V_i) is assumed to be independently and identically distributed with zero mean and variance, $\sigma_v^2(0,\sigma_v^2)$ (Battese and Broca, 1997, Ojo, 2003; Ojo, 2009). U_i denotes the asymmetric non-negative random-error component that measures technical inefficiency. The non-negative variable U_i is assumed to be independently and identically distributed truncations (at zero from below) of the $N(m_i,\sigma_U^2)$ distribution, where $m_i = Z_{ik}\Phi_k.\Phi_k$ is a vector of parameters to be estimated and Z_{ik} is a vector of variables that may influence inefficiency of the sheep farmers (Coelli *et al*., 2005; Greene, 2003; Otieno *et al.,* 2012).

Sigma-squared (σ^2) and gamma (γ) are variance parameters that will also be estimated. The gamma value is used to determine the presence of inefficiency in the production data. For example, a gamma value of 0.7 shows that 70% of the variation in sheep production would be as a result of technical inefficiency (Coelli *et al*., 2005). The gamma value can be used to gauge for the presence of technical inefficiencies in the data.

The sigma squared (σ^2) value is used to determine if the distributional assumption of the inefficiency effect is correctly specified. It follows that (Aigner *et al*., 1977):

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{.......} \quad (2)$$

The variance parameters of the model were also specified as:

$$\gamma = \frac{\sigma_u^2}{\sigma^2} \quad \text{Such that } 0 < \gamma < 1 \quad \text{.......} \quad (3)$$

The Cobb-Douglas SFM specified in Equation (1) shows the TE (TE_i) of the i[th] sheep farm with respect to each district municipality's production frontier can be defined as the ratio of observed output to the expected maximum level from the use of inputs available, given that there is no technical inefficiency in production (Battese and Coelli, 1988). From the above definition, TE_i can be expressed mathematically as (Boshrabadi *et al*., 2008):

$$TE_i = \frac{Q_i}{Q_i^*} = \frac{f(x_{ik};\beta_k)e^{(U_i - V_i)}}{f(x_{ik};\beta_k)e^{(V_i)}} = e^{-U_i} \quad \text{.......} \quad (4)$$

Battese and Coelli (1988) derive the best predicator of TE from Equation (4) and specify it as follows:

$$TE_i = E\left[\exp(-U_i)\right] \quad 0 \leq TE_i \leq 1 \qquad \text{....................(5)}$$

Two SFA functions were estimated, one for each of the study areas of Thaba Nchu and Botshabelo.

4.2.2 Presentation Variables Considered in the Analysis

A total of nine variables were included in the estimation of sheep output produced by the sheep farmers in this study area. The production variables used to estimate the production frontier along with the description of the variables and the expected signs are presented in Table 4.1.

The eight independent variables that were hypothesised to influence sheep output positively in the study areas included communal land, herd size, cost of veterinary services, cost of veterinary drugs, feed cost, labour, transport cost and operating expenses. A unit increase in any of these variables will increase sheep output. However, sheep loss is hypothesised to influence sheep output negatively. A unit increase in sheep loss will decrease sheep output.

TABLE 4.1 PRESENTATION OF FARM INPUTS AND OUTPUT IN THE PRODUCTION FRONTIER

Variable	**Description**	**Expected sign**
Dependent Variable		
Q_i = Sheep output	No. of sheep sold * price per sheep (measured in rand)	
Production Function Variables (Independent)		
X_1 = Size of communal land	Land area for sheep grazing (measured in ha)	+
X_2 = Herd size	Total number of sheep owned	+
X_3 = Cost of veterinary services	Total money spent on veterinary services in rand over the last 12 months	+
X_4= Cost of veterinary drugs	Total money spent on veterinary drugs in rand over the last 12 month	+
X_5 = Feed cost	Total amount spent on feed in rand over the last 12 months (purchased and produced)	+
X_6 = Labour	The quantity of labour used (in man-days)	+
X_7 = Transport cost	Total amount in rand spent on transport over the last 12 months	+
X_8 = Operating expenses	Total cost incurred for sheep production (ruel, electricity, maintenance etc.)	+
X_9 = Sheep losses	Total number of sheep lost over the last 12 months	-

As part of the estimation procedure, the production frontier was estimated, which allowed for efficiency levels for each farm in the study area to be determined. An inefficiency regression that would allow for the identification of factors that would either increase or decrease producers' level of efficiency, was also fitted. The next section will discuss the regression model used to explain producers' efficiency levels.

4.2.3 Technical Inefficiency Model

4.2.3.1 Specification of the Technical Inefficiency Model

It is important to determine the inefficiency factors in sheep production; therefore, the inefficiency model would be useful for determining the factors that will improve the efficiency levels of farmers in the two district municipalities of the N8 development corridor. The inefficiency model that will be used is specified as:

$$U_i = \varphi_0 + \sum_{i=1}^{10} \varphi_k Z_{ik} + \zeta_i \qquad i = 1, 2, 3, \ldots, N \quad \text{.........(6)}$$

Where, U_i represents the technical inefficiency of the i[th] sheep farm in each district munipality. Z_{ik} is a vector of all explanatory variables associated with the inefficiency model. φ_0 represents the constant term and φ_k represents a vector of all the unknown parameters to be estimated, while ζ_i represents the error term.

4.2.3.2 Presentation of Variables in the Technical Inefficiency Model

This step incorporates the estimated efficiency levels into an inefficiency model to determine the factors that will decrease producers' inefficiency, since a decrease in inefficiency will increase efficiency. This study will include 10 explanatory variables in the inefficiency model. The variables used to explain differences in producers' TE, along with the description of the variables and the expected signs, are presented in Table 4.2. The negative signs of the variables in the technical inefficiency model indicate that the associated variables reduce inefficiency in sheep production while positive signs imply that the variables increase inefficiency. Since the model uses inefficiency as the dependent variable, it is expected that variables with a negative sign would increase TE while variables with a positive sign would reduce TE of sheep production along the N8 development corridor.

TABLE 4.2 DESCRIPTION OF THE INEFFICIENCY VARIABLES

Variables	**Description**	**Expected Sign**
Institutional Variables		
Z_1= Extension services	1, if farmer had contact with extension agent and 0 otherwise	-
Z_2= Distance to market	Distance (km) from farm to the nearest market	+
Z_3= Farm manager	1, if farm had a manager and 0 otherwise	-
Z_4= Access to veterinary services	1, if farmer had access to veterinary services and 0 otherwise	-
Z_5= Land-tenure system	1, if farmer uses communal land and 0 otherwise	-
Z_6= Sheep breed	1, if sheep breed is indigenous and 0 otherwise	-
Socio-economic Variables		
Z_7= Educational level of famer	Years of formal education	-
Z_8= Years of farming experience	Number of years of sheep-farming experience	-
Z_9= Household size	Number of people in the household	-
Technological Variables		
Z_{10}= Breeding system	1, if sheep is a crossbreed and 0 otherwise	-

The variables associated with technical inefficiency are categorised into institutional factors (extension services, distance from market, farm manager, veterinary services, land-tenure systems and sheep breed), socio-economic factors (education, farm experience and household size) and technological factors (breeding systems). All the variables in the inefficiency model are expected to decrease inefficiency (negative sign) except for distance from market (positive sign), which is expected to increase inefficiency if the farmers live in peri-urban areas. The next section discusses the estimation of the metafrontier function.

4.3 Metafrontier Model

During the last decade, the metafrontier or stochastic metafrontier, has become the approach that accounts for technological variation of both cross-sectional and panel data

(Otieno, 2011). Battese and Rao (2002), Battese *et al*. (2004) and O'Donnell *et al*. (2008) propose using the stochastic metafrontier model, which can estimate the efficiency of heterogeneous (different) groups based on their distance from a common and identical frontier. Fig 4.1 illustrates the metafrontier production function for the two district municipalities along the N8 development corridor.

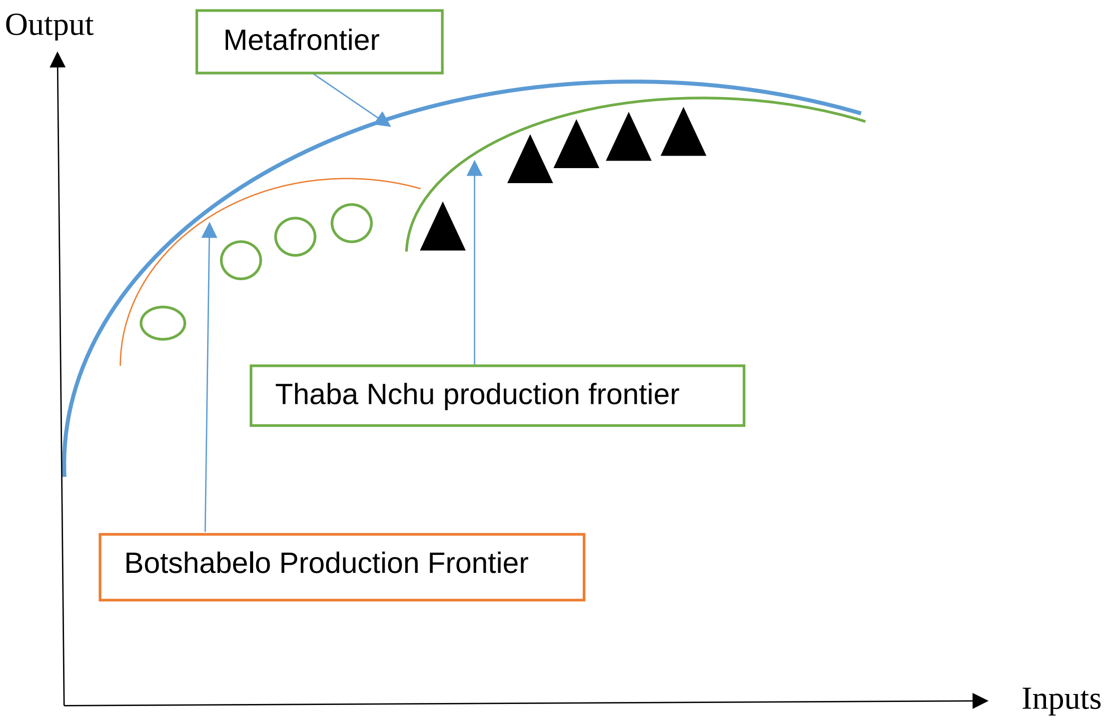


FIGURE 4.1 METAFRONTIER MODEL

SOURCE: ADAPTED FROM MENSAH AND BRUMMER (2016).

The estimation of a metafrontier is necessary since the study area consists of two district municipalities along the N8 development corridor. The assumption is that the two district municipalities do not use the same technology; therefore, measurement errors could occur if the same technology is assumed. The individual production frontiers of Thaba Nchu and Botshabelo indicate the state of technology regarding the transformation of factor inputs into sheep output. The production frontiers for Thaba Nchu and Boshabelo municipalities envelop together, to form the metafrontier function as indicated by the metafrontier line in Figure 4.1. The metafrontier function reflects the state of technology at the regional level or for the sheep industry as a whole. The distance from the individual frontiers to the metafrontier measures the TGR.

4.3.1 Metafrontier Estimation

The stochastic metafrontier model was used to estimate a metafrontier function and TGR as well as TE relative to the metafrontier. The TGR and the TE relative to the metafrontier was used to compare the efficiency of the farmers in the two district municipalities along the N8 development corridor.

To compare different production systems and different technologies used in the different district municipalities along the N8 development corridor, the model in Equation (6) will not be sufficient for comparing the performance of farms in the different groups of farms who does not use the same technology (Otieno *et al.,* 2012). To effectively measure the efficiency and technology gaps of farms producing in different technological environments, Battese and Rao (2002) and Battese et al. (2004) proposed the use of a stochastic metafrontier production function that is considered to be a smooth function that envelops the explained (deterministic) components of the group stochastic frontier functions (e.g. for the different regions in the N8 development corridor). It explains differences between observed outputs and the maximum possible explained output levels in all frontiers.

The metafrontier equation can be specified as:

$$InQ_i^* = \beta_0^* + \sum_{k=1}^{9} \beta_k^* Inx_{ik}^* + V_i - U_i \quad i = 1, 2, 3..., N \quad \text{...(7)}$$

Where Q_i^* denotes the output of sheep farmers while x_{ik}^* denotes all the inputs used. The metafrontier is denoted by the asterisk (*), which indicates that outputs and inputs for two regions of the N8 will be pooled together to estimate the metafrontier. β_0^* denotes the constant term for the metafrontier, while β_k^* denotes the vector of parameters of the metafrontier function such that:

$$x_i\beta^* \geq x_i\beta \quad \text{...(8)}$$

Where β denotes a vector of parameters of the individual district stochastic frontiers. β^* denotes the parameters of the metafrontier function. To satisfy the condition in (7), an optimisation problem can be solved where the sum of total deviations of the metafrontier values can be differentiated from the pooled frontiers values that are minimised as:

$$\min \sum_{i=1}^{n} | \ln f(X_n, \beta^*) - \ln f(X_n, \beta_k) |$$
$$s.t. f(X_n, \beta^*) \geq \ln f(X_n, \beta_k) \qquad \text{...(9)}$$

To solve the problem of linear optimisation, SHAZAM 9 was used to estimate and obtain the parameter (β^*) for the metafrontier using linear programing (Donkor, 2015).

In terms of the metafrontier, the observed output for the n^{th} farm in the k^{th} district municipality (measured by the stochastic frontier) can be expressed as:

$$Q_{nk} = \exp(-Z_{nk}\phi).\frac{f(X_n, \beta_k)}{f(X_n, \beta^*)}.f(X_n, \beta^*) + (v_{nk}) \qquad \text{...(10)}$$

The TGR was estimated to determine the difference between the metafrontier and the individual production frontiers. The TGR estimation will be discussed in the next section.

4.3.2 Estimation of Technology Gap Ratio

The TGR measures the ratio of the output of the production function frontier for each district municipality relative to the potential output that is defined by the metafrontier function, given by the observed inputs (Battese and Rao, 2002; Battese *et al*., 2004; Otieno *et al.,* 2012). The TGR values can range between zero and one (0-1). The TGR is important for explaining the technological gap faced by farmers in the two district municipalities of the N8 when their performances are compared with the regional technology.

The technological gap ratio for the two district municipalities of the N8 can be expressed as:

$$TGR_n = \frac{f(X_n, \beta_k)}{f(X_n, \beta^*)} \qquad \text{..(11)}$$

Where TGR_n is the estimated technology ratio of each municipal district, while $f(X_n, \beta_k)$ denotes the deterministic production frontier for the individual district municipality's frontier and $f(X_n, \beta_k^*)$ represents the metafrontier.

In order to compare the TE of farmers where production frontiers vary among the different district municipalities, is only possible if there is a common point of reference for all the farmers for whom efficiency scores are estimated. TE scores are relative to each district municipality, that is, their production environment and technologies are different. Therefore, using the TE scores as a performance measure to compare between the two district municipalities along the N8 can be very misleading. Taking the metafrontier as a point of reference, the performance of the sheep farmers in the two districts can be compared. The TE scores relative to the metafrontier are considered a more appropriate comparative performance measure. The TE relative to the metafrontier for each district municipality illustrates the efficiency of each district municipality using a similar technology in the district municipality. The TE relative to the metafrontier is the product of the TE relative to the individual frontiers and TGRs. The TE relative to the metafrontier is expressed mathematically as:

$$TE^{*}_{i} = TE_i \times TGR_i \quad \text{.........}(11)$$

Where TE^{*}_{i} is the TE of each district municipality relative to the metafrontier.

4.4 Hypothesis Testing

In order to draw conclusions about the validity of the results, hypothesis testing has to be performed. Hypothesis testing was done to test for the presence of technical inefficiency, non-stochastic effect of the technical inefficiency term, relevance of explanatory variables to explain the variation in technical inefficiency for the two municipal districts along the N8 development corridor, and the appropriateness of the use of the metafrontier. The following hypotheses test shall be performed:

1) $H_0 : \gamma = \varphi_0 = \varphi_1 = ... = \varphi_{12}$ ....(12)

The null hypothesis states that there exist no technical inefficiencies in sheep production along the N8 development corridor. This will be used to determine if technical inefficiencies are present in sheep production along the N8 development corridor and also to determine if there is a need to specify an inefficiency model.

2) $H_0 : \gamma = 0$ ....(13)

Should there not be any technical inefficiencies present in the data, the stochastic production function reduces to a simple OLS (average) production function. The second null hypothesis assumes technical inefficiency effects are non-stochastic. This hypothesis will be used to test for the presence of inefficiency in sheep production data.

3) $H_0 : \varphi_1 = \varphi_2 .... = \varphi_{12} = 0$ .... (14)

The null hypothesis states that the coefficients of all the variables in the inefficiency model do not jointly influence technical inefficiency of sheep production along the N8 development corridor. Should the null hypothesis be rejected, a production function and inefficiency model must be fitted instead of a production function, which includes all the explanatory variables.

4) $H_0 = \gamma_{Pooled} = \gamma_{Thaba-Nchu} = \gamma_{Botshabelo}$ ....(15)

The null hypothesis states that farmers in Thaba Nchu, Botshabelo and the pooled sample are using similar technologies. It is assumed that all the farms in the study areas have the same production frontiers. Accepting the null hypothesis implies that the two districts are homogenous and that a single production function can be fitted to estimate the productivity and efficiency of the two district municipalities. Rejecting the null hypothesis would mean that the two district municipalities are heterogeneous regarding the technology applied and production environment, and two production frontiers should be fitted to estimate productivity and efficiency of the two district municipalities. This allows for the researcher to make comparisons between the two heterogeneous district municipalities using metafrontier estimates.

All hypotheses tests were carried out using the generalised likelihood-ratio test. The test statistics (λ) is defined as (Coelli, 1995):

$$\lambda = -2\left[L(H_0) - L(H_a)\right]$$

Where $L(H_0)$ and $L(H_a)$ are the values of the log likelihood functions for unrestricted (H_0) and the restricted (H_a) models (Coelli, 1995). The test statistics have an approximately asymptotic chi-square or mixed chi-square (X^2) distribution with degrees of freedom equal to the number of parameters specified to be zero in the null hypothesis. The Kodde and Palm chi-square distribution tables were used to obtain the critical values. The estimated test statistics were compared to the Kodde and Palm (1986) critical values at a five percent significance level. The null hypotheses are rejected if the X^2 statistic estimated exceeds the X^2 critical value.

4.5 Kendall's Coefficient of Concordance

First introduced by Kendall and Smith in 1939, Kendall's Coefficient of Concordance (W) measures the agreement among several (*m*) quantitative or semi-quantitative variables that are assessing a set of *n* objects of interest. In the social sciences, the variables are often people, called judges, who assess different subjects or situations. Its application has been used in many areas of research, from social science to biological science, to mathematics and statistics and general scientific studies. Kendall's Coefficient of Concordance test will be used to identify and rank the constraints faced by sheep farmers along the N8 development corridor. This will help the government and other official authorities to know the most pressing needs of the farmers and determine how to approach the needs in the most efficient manner.

4.5.1 Model Specification for Kendall's Coefficient of Concordance

Kendall's Coefficient of Concordance test is used to identify and rank the constraints to sheep production along the N8 development corridor. The test is a nonparametric mathematical technique used to categorise a set of constraints or problems, from the most significant to the least significant, as well as estimate the degree of agreement or concordance among the respondents. The constraints will be assigned ranks, from the most significant to the least significant, using very severe, severe, moderate and not severe as categories. The total ranked score for individual constraints was calculated and the constraint with the smallest score was ranked as the most important constraint, while the constraint with the largest score was ranked as the least important constraint. The total rank score calculated was used to compute the Kendall's Coefficient of Concordance (W), which estimates the degree of agreement between respondents in the ranking. The equation for the Kendall's Coefficient of Concordance, according to Anang *et al. (*2013), is given as:

$$W = \frac{12\left[\sum T^2 - \left(\sum T\right)^2 / n\right]}{nm^2\left(n^2 - 1\right)} \quad \text{.. (16)}$$

Where, W = Kendall's Coefficient of Concordance, T = Sum of ranks for constraints being ranked, m = Total number of respondents (sheep farmers), and n = Total number of constraints being ranked. The Coefficient of Concordance (W) will be tested for significance in terms of the F-distribution. The F-distribution is given by Anang *et al.* (2013):

$$F = \left[(m-1)W/(1-W)\right]$$ ....(17)

The numerator degrees of freedom is given as:

$$(n-1)-(2/m)$$ ....(18)

In the same way the denominator degrees of freedom is given as:

$$m-1\left[(n-1)-2/m\right]$$ ....(19)

4.5.2 Test of Hypothesis

The following null hypothesis was tested:

H_0 : Farmers are not in agreement about the constraints to sheep production in the study areas.

H_1: Farmers are in agreement about the constraints to sheep production in the study areas.

The null hypothesis is rejected if the F-value calculated is greater than the F-critical value, indicating that farmers are in agreement with one another on the ranking of the constraints to sheep production in the study areas.

4.6 Summary of Empirical Application

The estimation of TE in both study areas was done in two steps. The first step was to estimate the production frontier that represents the group frontiers that were used to calculate individual farmers' TE levels. Nine production factors, namely, communal land, herd size, transport cost, cost of veterinary drugs, cost of veterinary services, sheep loss, operating cost, feed cost, and labour were included in a stochastic production model to explain factors influencing sheep output. Using simultaneous equations, an inefficiency model was fitted to determine the factors that affect the farmers' level of TE. Factors included in the estimation of the inefficiency model are extension contact, distance to market, access to veterinary services, communal land, education, household size, crossbreeding method, years of farm experience, farm manager and indigenous sheep. The model was fitted using Frontier 4.1 (Coelli, 1996). Two functions were fitted, one for each production system in the study areas, and the TE scores were predicted based on the SFM fitted for each of the regions.

The second step was to fit a metafrontier model that estimated the efficiency of heterogeneous groups based on their distance from a common and identical frontier. The estimated parameters from the production frontier for the two regions were used, together with the pooled data, to estimate the metafrontier using Shazam 9 (White, 1978), which uses linear programming in metafrontier estimation. Comparative efficiency measures, such as the TGR and TE relative to the metafrontier, were predicted from the metafrontier function of the two regions. The TGR defines the distance between the estimated production frontiers and the metafrontier. The TE relative to the metafrontier is the product of the TE relative to the individual frontiers and TGRs.

Finally, constraints to sheep production were estimated and ranked using SPSS 21 (Nie *et al.,* 1970). The constraints were ranked from the most severe constraint to the less severe constraints using a scale of 1 to 4 (very severe, severe, moderate and not severe).

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Introduction

The main objective of this study is to identify the factors that influence the productivity of sheep production, and thereby enhance the livelihood of sheep producers along the N8 development corridor. The first section of this chapter presents and discusses the results for the production frontiers and TE scores for the individual district municipalities (Thaba Nchu and Botshabelo), along with the results for the hypothesis tests that were performed during the estimation of the production frontiers. The sources of variations in technical inefficiency for the two district municipalities are presented and discussed in the second section. The results of the metafrontier function including the hypothesis tests performed using the metafrontier, the TGR and TE scores relative to the metafrontier are presented and discussed in the third section. Constraints to sheep production are discussed in the fourth section. The chapter will be summarised in the final section.

5.2 Production Parameter Estimates

The production parameter estimates for sheep production in the study areas are presented in this section. The production parameters were estimated using the Cobb-Douglas production function. Firstly, the stochastic production function will be presented without including the inefficiency variables. This will enable a better understanding of the various production inputs used in sheep production and the way they contribute to the overall sheep production output in the study areas. Secondly, the inefficiency model will be presented to show the factors that contribute to the efficiency levels of sheep farmers.

5.2.1 Stochastic Production Frontier

The maximum likelihood estimate for the stochastic production frontiers for Thaba Nchu and Botshabelo and the pooled results along with its statistical test are presented in Table 5.1.

TABLE 5.1 STOCHASTIC FRONTIER PARAMETER ESTIMATES

Variables	Parameters	Thaba Nchu		Botshabelo		Pooled	
		Coeff	SE	Coeff	SE	Coeff	SE
Constant	β_0	6.984***	0.000	-0.643***	0.000	8.056***	0.000
Incommland X_1	β_1	-0.048***	0.009	0.833***	0.001	-0.098**	0.024
Inherdsize X_2	β_2	0.221***	0.000	0.201	0.259	0.465***	0.006
Invertservice X_3	β_3	0.062	0.515	0.300	0.186	0.028	0.757
Invertdrugs X_4	β_4	0.059	0.325	0.082	0.660	0.007	0.913
Infeedcost X_5	β_5	0.127***	0.013	0.026	0.826	0.090*	0.072
Inlabour X_6	β_6	0.024	0.838	0.472	0.119	0.271***	0.007
Intransport X_7	β_7	-0.027	0.712	0.581***	0.001	0.113	0.120
Inoperatingexp X_8	β_8	-0.029	0.679	-0.217	0.284	-0.099	0.168
Insheeploss X_9	β_9	-0.040*	0.064	-0.068**	0.030	-0.642**	0.020
Diagnostic Statistics							
Sigma square	$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.308***	0.000	0.570***	0.000	0.473***	0.000
Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.679***	0.000	0.779***	0.000	0.799***	0.000
Ln (likelihood function)	*LF*	-139.227		-65.754		-224.731	
Number of observations	N	157		60		217	

***1%; **5%; *10%- Statistical significance levels; Coefficients and standard error have been rounded off to three decimal places. In is the logarithm of the variables thus: Incommland = log communal land, Coeff = coefficient of the variables and SE = standard error.
SOURCE: AUTHOR ESTIMATION

The results for Thaba Nchu will be discussed first, followed by the discussion of the Botshabelo results and then the results of the pooled data. The estimated coefficients of the variables in the stochastic production frontier for Thaba Nchu given in Table 5.1.

Table 5.1 indicated the expected positive signs for herd size, veterinary services, veterinary drugs, feed cost and labour and the expected negative signs for sheep loss. The only exception is communal land, transport cost and operating expenses, which have unexpected negative signs. A positive sign for a variable indicates that sheep output is increased by an increase in the variable, while a negative sign indicates a reduction in sheep output as the variable increase.

Communal land is negative and significant at the 1% level. This means that a unit increase in communal land will decrease sheep output by 1%. This result was unexpected, since it was hypothesised that grazing land will have a positive effect on sheep output. The negative effect of communal land size may be due to fact that farmers in Thaba Nchu have relatively small herd sizes. Increasing the land size might increase the cost of managing the increased land size with a relatively small herd size, which will increase cost of production and lower sheep output. This finding is consistent with a study by Masterson (2007), who found an inverse relationship between land size and productivity in Paraguay. He argued that larger land sizes are very capital intensive and will impose additional costs on smallholder farmers, which will eventually reduce their production capabilities.

Herd size is positive and significant in sheep production in Thaba Nchu. This means that an increase in herd size will increase the output of the farmers. Transport cost and operating expenses all represent costs involved in sheep production. An increase in the cost of transport and operating expenses will cause the cost of production to increase, which, if not followed by increase in prices, will lower sheep output. Transport cost and operating expenses are not significant in the estimation of the production frontier, indicating that neither transport cost nor operating expenses contribute significantly to sheep production in Thaba Nchu. Nonetheless, communal land and sheep loss are significant, which means an increase in land size and/or sheep loss will reduce sheep production in Thaba Nchu significantly.

Sheep loss is negative and significant at a 10% level. This means that an increase in sheep loss will significantly reduce sheep output. This result is expected, since sheep loss reduces sheep numbers and subsequently output.

Of the variables that correlate positively with sheep production, herd size and feed cost are the only significant variables, both significant at 1%. This means that an increase in herd size and/or feed cost will lead to an increase in sheep output. This is consistent with Otieno (2011), who also found significant positive correlations between cattle output, cattle herd size and cost of farm inputs. The inputs that are important for sheep production in Thaba Nchu are, therefore, herd size and feed cost. The estimated results in Table 5.1 show that, of the input elasticities for the production frontier for Thaba Nchu (as denoted by the coefficients), herd size had the greatest significant impact on sheep output, followed only by feed cost.

In Botshabelo, communal land size, herd size, veterinary services and drugs, feed cost, transport cost and labour have the expected positive signs. The variables with positive signs imply that they positively affect sheep output when their quantities are increased. The positive sign associated with transport cost may be as a result of the farmers using new markets further away from their farms. Communal land and transport costs are significant at the 1% level, meaning that an increase in either communal land and/or transport cost will increase sheep output.

Herd size, veterinary services and drugs, feed cost and labour are not significant, meaning that they are not significant inputs for sheep production in Botshabelo. However, operating expenses and sheep loss have negative effects on sheep production in Botshabelo. This means that an increase in any of these two variables will reduce sheep output. Operating expenses is not significant, meaning it doesn't play a significant role in sheep production in Botshabelo. Sheep loss, however, is significant at the 5% level, meaning that it is a significant factor in sheep production in Botshabelo. An increase in sheep loss will significantly reduce sheep output, as expected. Of the input elasticities for the production frontier for Botshabelo (as denoted by the coefficients), communal land had the greatest elasticity, followed by labour and transport cost.

The pooled results show that herd size, veterinary service and drugs, feed cost, labour and transport all have positive effects on sheep production in the study areas (Thaba Nchu and Botshabelo). Herd size and labour are significant at 1% level and feed cost is significant at 10% level. This means that an increase in any of these variables will increase sheep production in the pooled data. Veterinary services, drugs and transport cost are positive but not significant. This means that they don't have a significant effect on sheep production in the study areas. Communal land and sheep loss had negative signs, both significant at the 5% level, implying that an increase in any of these variables will reduce sheep output in the area represented by the pooled data. The pooled production frontier shows input elasticities for all the variables (denoted by their coefficients), with herd size having the highest elasticity in the study areas (Thaba Nchu and Botshabelo), followed by labour.

The empirical results for the three sets of data demonstrate that herd size is a critical factor in sheep production in the study areas, since the elasticity of sheep output with respect to herd size was found to be the highest for the two district municipalities along the N8 development corridor. This could be because sheep output depends largely on the number of sheep kept by a farmer in the study areas. The larger the herd size, the larger the sheep output, all things being equal. The findings of the study corroborate what Otieno *et al.* (2012) found, namely, that cattle herd size is positively related to beef output in Kenya. Bahta *et al*. (2015), Bahta and Hikuepi (2015) (in Botswana), and Otieno *et al.* (2012) (in Kenya) found that feed cost and veterinary cost all had a significant influence on beef output.

The estimated sigma-squared values for Thaba Nchu, Botshabelo and the pooled sample are 0.308, 0.570 and 0.473 respectively. These sigma-squared values are all significant at the 1% level, indicating that the one-sided error term dominates the symmetry error and suggests a good fit, and the distributional assumption is specified correctly. The gamma parameter (γ) measures the total variation of output from the frontier that is attributed to technical inefficiency. The gamma values for Thaba Nchu, Botshabelo and the pooled sample are 0.679, 0.779 and 0.799 respectively, and are highly significant at the 1% level, meaning that the total deviation from output is more likely as a result of technical inefficiency than random shocks and measurement errors.

From the empirical results, the gamma value (0.779) for Botshabelo is higher than that of Thaba Nchu, for which the gamma value is 0.679. The pooled sample had the highest gamma value, of 0.799. The gamma value for Botshabelo (0.779) indicated that about 77.9% of the variability in sheep output in Botshabelo is due to technical inefficiency while only 22.1% of the variation is explained by random shock and measurement error. This result indicates that the impact of technical inefficiency in Botshabelo may be relatively high. However, about 67.9% of the variation in sheep output is explained by technical inefficiency in Thaba Nchu while 32.1% of the variation is due to random shocks and statistical noise. The pooled data shows that 79.9% of the variation in sheep output is due to technical inefficiency as shown by the gamma value, while only 20.1% of the variation is due to random shock and statistical noise. Generally, the variation in sheep production for the study areas is primarily a result of technical inefficiency on the part of the sheep farmers, as explained by the gamma value for the pooled sample. The implication is that the average production function, which has no technical inefficiency effects, is not an adequate representation of the data (Battese *et al*., 1996).

5.2.2 Technical Efficiency Ratios

The summary statistics of TE scores among sheep producers in Thaba Nchu and Botshabelo are presented in Table 5.2.

TABLE 5.2 TECHNICAL EFFICIENCY RATIOS

Statistics	Thaba Nchu	Botshabelo	Pooled
Average	0.673	0.657	0.669
Minimum	0.160	0.155	0.155
Maximum	0.904	0.875	0.904
Standard deviation	0.145	0.192	0.159

SOURCE: AUTHOR ESTIMATION

Farmers in Thaba Nchu have minimum and maximum TE scores of 16.0% and 90.4% respectively. On average, farmers in Thaba Nchu had a TE score of 67.3% and a standard deviation of 14.5%. This means, therefore, that sheep farmers in Thaba Nchu have the potential to increase their production by 32.7% by producing at full capacity. Famers in Botshabelo obtained an average efficiency score of 65.7% with a minimum of 15.5%, maximum of 87.5% and a standard deviation of 19.2%. To produce at full capacity, farmers in Botshabelo will have to increase sheep production by 34.3%. From the Table presented, the differences between the two municipal districts, on average, is not large -- the difference is a mere 1.6 percentage point. Farmers in Botshabelo had a higher standard deviation, meaning Botshabelo farmers had more variations in the TE scores than Thaba Nchu farmers.

The pooled data showed an average efficiency score of 66.9%, with a minimum score of 15.5%, maximum score of 90.4% and a standard deviation of 15.9%. This means that the pooled sample has to increase production by 33.1% to produce at full capacity.

From the TE estimates it can be concluded that sheep farmers in the study areas are operating below the production frontier, suggesting that there is scope for sheep farmers in the study areas to improve their efficiency levels to reach the frontier threshold and meet high sheep consumption in South Africa. The reason could be because these farmers are not making maximum use of the technologies available to them. Diagne (2010) argues that lower rates of adoption of agricultural technologies or poor use of it in sub-Saharan Africa can be attributed to lack of various technologies, or the knowledge of how to use it.

Previous studies on the TE of livestock production found similar results to this study. Some studies found livestock producers to have a higher TE, on average, than the TE found by this study, while others found lower TE scores. The average TE scores of Thaba Nchu (67.3%) and Botshabelo (65.7%) are higher than the findings of Bahta *et al.* (2015) and Bahta and Hikuepi (2015), who observed that the average TE of beef cattle producers in South East, Central and Chobe districts of Botswana were 46.3% and 28.1% respectively. Furthermore, Gatti *et al.* (2015) and Nwigwe *et al.* (2015), obtained, on average, relatively higher TE scores of 59.86% for cattle farmers in Argentina and 66% for beef cattle farmers in Nigeria respectively. Villano *et al.* (2008) estimated the TE of wool producers in four districts of Australia and found their average TE to be 81.5%.

The TE levels of the farmers in the two district municipalities differ, though not by much, thereby suggesting that location plays an important role in explaining efficiency. The results indicate that fitting different production frontiers for the two municipal districts is necessary in order to provide specific policy recommendations to improve the performance of the farmers in each region.

Estimates of TE scores are presented in Figure 5.1. The TE scores for Thaba Nchu, Botshabelo and the pooled sample were calculated from the estimates of the stochastic production frontiers. The TE scores are presented as a bar chart and data has been grouped into 9 categories (0.1-0.20; 0.21-0.30, 0.31-0.40, 0.41-0.50, 0.51-60, 0.61-0.70, 0.71-0.80, 0.81-0.90, 0.91-1.00); doing so will give a better understanding of which group the sheep farmers belong to and provide an opportunity to do a more accurate evaluation of the efficiency scores.

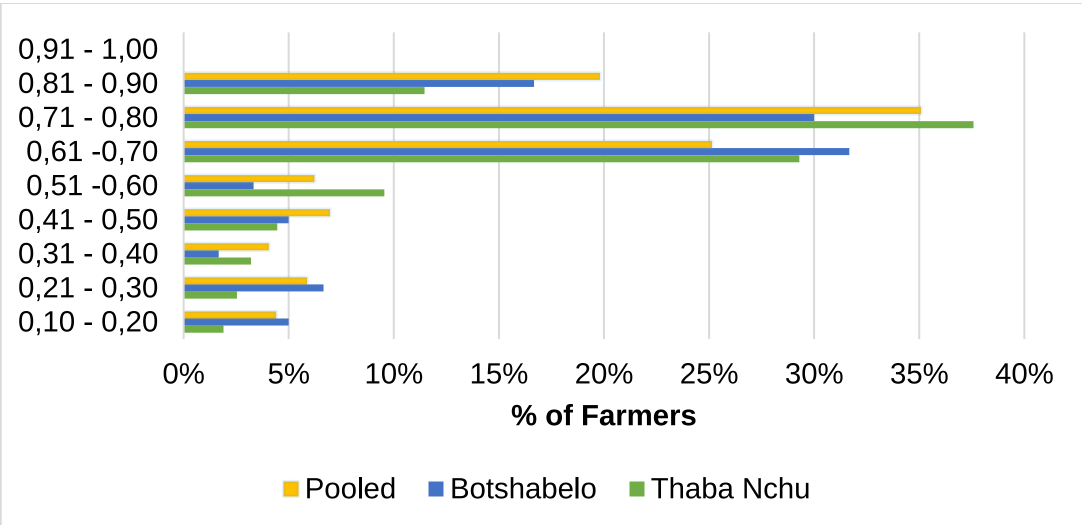


FIGURE 5.1 DISTRIBUTION OF TECHNICAL EFFICIENCY SCORE

SOURCE: AUTHOR ESTIMATION

With respect to the estimated efficiency ratios, the efficiency of farmers in the two districts do not differ much in relation to the lowest and highest estimated TE. About 37.58% of the sample in Thaba Nchu had TE scores between 0.71 and 0.80, while, in Botshabelo, 30% of the sample had TE scores ranging from 0.71 to 0.80. The pooled data shows that 35% of the farmers have TE scores in the range 0.71 to 0.80. These results show that farmers in Thaba Nchu are using farm inputs more efficiently with the technology available to them than famers in Botshabelo, even though the difference is small. Furthermore, 16.67% of farmers in Botshabelo had a TE score ranging from 0.81 to 0.90, compared to 11.46% of the farmers in Thaba Nchu. This means that more farmers in Botshabelo are operating at higher efficiency levels than Thaba Nchu farmers. This study is consistent with the findings of Otieno *et al.* (2012), who found that nomadic farmers were slightly less efficient than ranchers in cattle production in Kenya.

5.2.3 Hypothesis Tests on the Production Structure

Various hypotheses were tested for model adequacy (Table 5.3). A generalised likelihood ratio was used to test for the presence of technical inefficiency and, if there was a need to include the hypothesised explanatory variables in the inefficiency model. The parameters were derived from the frontier estimations. Following Coelli and Battese (1996), the critical value for this distribution was obtained from the statistical table of Kodde and Palm (1986). Table 5.3 presents the result of the hypothesis test performed on the production structure.

TABLE 5.3 RESULTS OF HYPOTHESIS TESTS ON THE PRODUCTION STRUCTURE

Null hypothesis	Location	Test statistic	Degree of freedom	Critical value[a]	Decision
$H_0: \gamma = \varphi_0 = \varphi_1 = ... = \varphi_9$	Thaba Nchu	26.66	9	16.274	Reject H_0
	Botshabelo	35.03	9	16.274	Reject H_0
	Pooled	41.61	9	16.274	Reject H_0
$H_0: \gamma = 0$	Thaba Nchu	23.56	1	2.706	Reject H_0
	Botshabelo	31.74	1	2.706	Reject H_0
	Pooled	17.1	1	2.706	Reject H_0
$H_0: \varphi_1 = \varphi_2 .... = \varphi_{10} = 0$	Thaba Nchu	36.68	10	17.670	Reject H_0
	Botshabelo	66.78	10	17.670	Reject H_0
	Pooled	42.46	10	17.670	Reject H_0

[a]The critical values were obtained from the Kodde and Palm Chi-square table.
SOURCE: AUTHOR ESTIMATION

$H_0: \gamma = \varphi_0 = \varphi_1 = ... = \varphi_9$ tests for the presence of technical inefficiency factors in sheep production in the study areas. H_0 assumes there is no technical inefficiency effects in sheep production in the study areas. If the estimated statistic is greater than the critical values on the Kodde and Palm Chi-square table, H_0 is rejected. Rejecting H_0 means technical inefficiency effects are present in sheep production in the study areas. From Table 5.3, the estimated statistics for Thaba Nchu, Botshabelo and pooled sample are 26.66, 35.03 and 41.61 respectively, while the critical value at 5% is 16.274. This shows that the estimated statistics are greater than the critical values, therefore, H_0 is rejected and the alternative is accepted, namely, that there exist technical inefficiencies in sheep production in the study areas. This means that an inefficiency model will be estimated to determine the factors affecting TE.

Following the discussion above, a second hypothesis was tested. The null hypothesis $H_0 : \gamma = 0$ states that effects of inefficiency factors are not random. This hypothesis was tested by combining the independent variables of the inefficiency model to the stochastic production frontier. H_0 is rejected because the test statistics for Thaba Nchu (23.56), Botshabelo (31.74) and the pooled sample (17.1) are greater than the critical value, 2.706 at 5%. The alternative is therefore accepted, namely, that technical inefficiency effects are random and justify the specification of the stochastic production frontier and the inefficiency model separately.

The third null hypothesis, $H_0 : \varphi_1 = \varphi_2 .... = \varphi_{10} = 0$ states that the coefficients of the variables in the inefficiency model do not jointly influence technical inefficiency of sheep production in the study areas. The null hypothesis is rejected at the 5% level due to the fact that the test statistics for Thaba Nchu (36.68), Botshabelo (66.78) and pooled sample (42.46) are greater than the critical value of 17.670. Rejecting the hypothesis confirms the presence of technical inefficiency and the need to include inefficiency variables in the inefficiency model. Donkor (2015) confirmed the presence of technical inefficiency in rice production in Ghana and, thus, estimated the inefficiency model by testing variables for their effects on TE in rice production

5.3 Determinants of Technical Inefficiency in Sheep Production

The next step was to identify factors that determine the producers' level of TE. The estimates of the determinants of technical inefficiency of sheep in the study areas are presented in Table 5.4. Since the parameters of the inefficiency levels enter the production model as dependent variables, a variable with a negative sign in the inefficiency parameters means the corresponding variable reduces inefficiency or increases efficiency (Otieno, 2011). On the other hand, a positive variable in the inefficiency model is seen to negatively affect or influence efficiency (Coelli *et al*., 2005 and Otieno, 2011).

TABLE 5.4 DETERMINANTS OF TECHNICAL INEFFICIENCY IN SHEEP PRODUCTION IN THABA NCHU AND BOTSHABELO

Variables	Parameters	Thaba Nchu		Botshabelo		Pooled	
		Coeff	SE	Coeff	SE	Coeff	SE
Constant	δ_0	-32.935***	0.000	-10.769**	0.034	-3.899 **	0.005
Indigenous sheep Z_1	δ_1	-2.589**	0.023	-5.521*	0.099	0.781*	0.098
Sheep experience Z_2	δ_2	0.048	0.132	0.458**	0.043	-0.155	0.353
Farm Manager Z_3	δ_3	-0.211	0.810	-1.572	0.215	-9.145	0.648
Cross-breeding method Z_4	δ_4	-1.162	0.458	7.353*	0.075	2.899	0.333
Communal Land Z_5	δ_5	24.151	0.980	1.158	0.345	-3.563*	0.086
Educational Level Z_6	δ_6	-0.619**	0.028	-0.083	0.674	0.109	0.615
Household size Z_7	δ_7	0.007	0.961	-0.028	0.903	0.281	0.540
Extension services Z_8	δ_8	-0.746	0.568	-0.732	0.581	3.149**	0.002
Veterinary services Z_9	δ_9	2.311*	0.093	1.659	0.440	2.723	0.223

Notes: Statistical significance levels: ***1%; **5%; *10%. Coefficients and standard error have been rounded off to three decimal places. Coeff = coefficient of the variables and SE = standard error.
SOURCE: AUTHOR ESTIMATION

The results in Table 5.4 show that indigenous sheep (5%), educational level (5%), and proximity to the market (10%) would significantly increase TE in sheep production in Thaba Nchu. Indigenous sheep increases the TE of sheep production in Thaba Nchu and is significant at the 5% level. The negative coefficient of indigenous sheep implies that farmers who keep indigenous sheep breeds are technically efficient, since these sheep breeds are easy to manage and can cope with extreme weather conditions. The result is consistent with the findings of Bahta and Hikuepi (2015), who observed that indigenous cattle breeds promote TE of cattle production in Botswana. However, Bahta *et al*. (2015) found a positive and significant coefficient of indigenous breed to cattle production. This implies that an increase in indigenous cattle breed will reduce efficiency in cattle production. Furthermore, Otieno *et al.* (2012) found that indigenous breed did not have a significant influence on technical inefficiency of cattle production.

The results also suggest that educational level had positive relation to TE in Thaba Nchu, and is significant at 5%. This implies that the more educated a farmer is, the more efficient the farmer becomes. Most farmers in Thaba Nchu have undergone formal education, though not to high levels. This means that farmers have some level of formal training, which helps them with sheep production. However, Bahta and Hikuepi (2015) and Otieno *et al.* (2012) found that educational level decreases TE of cattle production. Bahta and Hikuepi (2015) explained, further, that the more educated a farmer becomes, the more the farmer engages in activities other than cattle production, thereby reducing the efficiency of the farmer. Mensah and Brummer (2016) also found educational level to reduce TE in mango production in northern Ghana. Donkor and Owusu (2014) found educational level to have no significant effect on the TE of farmers.

Veterinary service in Thaba Nchu shows an unexpected positive sign and is significant at the 10% level. The positive sign of veterinary services implies that TE in sheep production decreases as farmers use more veterinary services. Veterinary services involve regular health checks to ensure animals are healthy and are growing normally. Perhaps farmers are not having their sheep checked regularly, which could lead to loss of sheep due to sheep disease outbreaks, thereby reducing the efficiency of the farmers. This result contradicts Shomo *et al.* (2015), who found that sheep farmers in Syria who received veterinary service experienced an increase in TE.

Distance to the market reduces technical inefficiency of farmers in Thaba Nchu and is significant at the 10% level. The implication of this result is that farmers who are closer to the markets are more likely to be more efficient than those who are further away from the market. This is because farmers who are closer to markets can easily access these markets, sell their sheep and buy farm input more easily than famers who are further away from the markets, who might find it difficult and expensive to reach the market. This result is consistent with studies by Otieno *et al*. (2012), and Donkor and Owusu (2014), who also found distance to market to have a positive relationship with TE.

Farm experience, communal land and household size decrease TE, while farm manager, crossbreeding method and extension services tend to increase TE in sheep production.

However, none of the variables mentioned above is statistically significant and therefore does not result in a significant change in TE. However, Mensah and Brummer (2016) found farm experience to have a positive effect on technical inefficiency in northern Ghana. This means that, as years of farming experience increases, the TE of the farmer reduces.

Factors affecting the technical inefficiency of sheep farmers in Botshabelo are discussed in Section 5.4.4. The results in Table 5.4 show that indigenous sheep breed, distance to the market, farm (sheep) experience, and crossbreeding method have significant effects on technical inefficiency of sheep production in Botshabelo.

The use of indigenous sheep breeds negatively influences technical inefficiency of sheep production in Botshabelo, and is highly significant at the 10% level. This negative effect of indigenous sheep breeds on technical inefficiency shows that, as the number of indigenous sheep breeds increases, the farmers' efficiency levels tends to increase. Thaba Nchu has similar results; indigenous sheep breeds are easy to manage and can cope with extreme weather conditions. The coefficient of farm experience shows an unexpected positive sign for sheep farmers in Botshabelo and is significant at the 5% level. This result indicates that, as years of sheep farming experience increases, the farmers' TE decreases. Farming experience and age are closely linked, since it is assumed that older farmers are more experienced and efficient that younger and inexperienced farmers. This result is a highly unlikely result, as it is expected that, as a farmer gains years of sheep farming experience, the farmer will become more technically efficient. However, a possible explanation for this result could be that farmers with more years of farming experience are not paying much attention to small details. This outcome corroborates the findings of Mensah and Brummer (2016), who found mango producers in northern Ghana to be less efficient as their years of mango production increase. However, Bahta and Hipueki (2015) found a positive relationship between years of cattle farming and TE in Botswana.

The coefficient of crossbreeding method was positive for sheep farmers in Botshabelo, and significant at the 10% level. This indicates that farmers who increase the use of crossbreeding in sheep production experience a decrease in TE. This result is unexpected, because crossbreed sheep are expected to increase efficiency by improving genetic quality of and enhancing adaption to environmental conditions by sheep. However, a possible explanation of this result could be that farmers are crossing the wrong breeds and, as a result, the growth of the crossbreed is affected. This will reduce the productivity of the sheep and the efficiency of the farmer.

The coefficient of distance to market shows an expected negative sign for famers in Botshabelo and is significant at the 10% level, indicating that farmers who are closer to the market tend to be more technically efficient. This result is as expected, since proximity to the market increases farmers' access to factor inputs and income-generating activities at the market.

This finding by this study contradicts the findings of Otieno *et al.* (2012), who found that farmers in peri-urban locations (rural areas) were efficient in cattle production. However, Bagamba *et al*. (2007) and Aye and Mungatana (2012) found that farms located closer to markets are more technically efficient than the farms located further away from markets.

Communal land and veterinary services have positive relationships with technical inefficiency in Botshabelo, but at an insignificant level, while farm manager, educational level, household size and extension services show negative relationships with technical inefficiency. None of the variables are significant and are therefore not considered to be significant contributors to TE in Botshabelo.

The pooled results show that indigenous sheep breed; communal land, extension services and market distance all have significant effects on technical inefficiency in the study areas. The results in Table 5.4 show that indigenous sheep breed have a positive relationship with technical inefficiency in the pooled sample. However, individually, indigenous sheep breed affects technical inefficiency in Thaba Nchu and Botshabelo negatively. A possible explanation could be that farmers in the pooled sample keep fewer indigenous sheep than the other breeds. The results also show that communal land size has a negative relationship with technical inefficiency in the pooled sample. This means that an increase in communal land size will reduce technical inefficiency in the pooled sample. This result is consistent with the findings by Mensah and Brummer (2016), who found a negative relationship between land size and technical inefficiency. However, Otieno *et al.* (2012) found a positive relationship between land size and technical inefficiency and argue that it could be as a result lack of investment in land.

Extension services has a positive coefficient in the pooled sample results, indicating that an increase in extension services will decrease TE in the study areas. This result is highly unexpected, as extension services are expected to equip farmers with better production techniques and market information, among other benefits, which will lead to an increase in TE. However, if extension officers have not been trained properly and lack experience, they can provide farmers with misleading information, which will decrease TE of farmers. Like the individual results for Thaba Nchu and Botshabelo, the pooled sample also has a negative coefficient for market distance. This means that TE increases as farmers move closer to available markets. This finding corroborates the findings of Donkor (2015), who found market distance to be positively related to TE.

As a rule, the coefficients and variable significance differ between the two district municipalities. Therefore, factors that increase or decrease TE in the two districts differ, except for two variables (indigenous sheep and market distance) that are the same for both district municipalities. The conclusion is that specific information about a district is necessary to ensure that farmers receive the correct information on factors that will increase their TE levels.

5.4 Metafrontier Production Function

The second objective of this study was to fit a metafrontier for the N8 development corridor of the Free State province using the estimated stochastic production coefficients of Thaba Nchu and Botshabelo. The estimated parameters of the metafrontier function were obtained by means of the linear programming technique. Table 5.5 presents the estimates of the metafrontier function. The metafrontier function represents the production frontier sheep farmers in the N8 development corridor.

TABLE 5.5 METAFRONTIER PARAMETER ESTIMATES

Variables	Parameters	Coefficients
Constant	β_0	2.179
Incommland X_1	β_1	1.135
Inherdsize X_2	β_2	0.371
Invertservice X_3	β_3	0.547
Invertdrugs X_4	β_4	-0.194
Infeedcost X_5	β_5	-0.788
Inlabour X_6	β_6	0.133
Intransport X_7	β_7	0.260
Inoperatingexp X_8	β_8	0.138
Insheeploss X_9	β_9	-0.469

Note: All the variables were logged before estimation. Incommland means log of communal land.
SOURCE: AUTHOR ESTIMATION

All the coefficients of the variables in the metafrontier estimation have the expected positive effects, except for cost of veterinary drugs, cost of feed and sheep loss, which show negative signs. The positive effects imply that an increase in the farm inputs will increase the sheep output at the district level, and vice versa. The negative effects associated with the coefficients of cost of veterinary drugs and cost of feed in the metafrontier estimation could be that the sheep farmers are using the wrong drugs and not enough feed on their sheep, which will affect the growth of the sheep and output. Sheep loss is expected to reduce sheep output.

The estimation of the metafrontier was validated after a hypothesis test was done. The following discussion will focus on the metafrontier hypothesis test.

5.4.1 Hypothesis Test on the Metafrontier Estimation

The estimation of the metafrontier function was validated with the use of a generalised likelihood ratio test (hypothesis test). Table 5.6 presents of the results of the hypothesis test for the metafrontier estimation.

TABLE 5.6 HYPOTHESIS TEST ON THE METAFRONTIER ESTIMATION

Null hypothesis	Test statistics	Degrees of freedom	Critical value[a]	Decision
$H_0 = \gamma_{Pooled} = \gamma_{Thaba-Nchu} = \gamma_{Botshabelo}$	79.5	3	7.045	Reject H_0

SOURCE: AUTHOR ESTIMATION

The null hypothesis states that farmers in Thaba Nchu, Botshabelo and the pooled sample are using the same technologies and that the production frontiers are the same for the two district municipalities and the pooled sample. The null hypothesis in the case is rejected and the alternative is accepted, since the test statistic (79.50) is greater than the critical value (7.045). All the tests of hypothesis in this study justify specifying different production frontiers for the two district municipalities along the N8 development corridor, since they have different production environments and the technologies they use are heterogeneous.

5.4.2 Technology Gap Ratio

Descriptive statistics of technological gap ratio are presented in Table 5.7. The descriptive statistics include the average, minimum, maximum and the standard deviation.

TABLE 5.7 DESCRIPTIVE STATISTICS FOR TECHNOLOGY GAP RATIO

Statistics	Thaba Nchu	Botshabelo
Average	0.737	0.674
Minimum	0.353	0.199
Maximum	1.000	1.000
Standard deviation	0.144	0.213

SOURCE: AUTHOR ESTIMATION

TGR for Thaba Nchu farmers shows a minimum of 35.3%, a maximum of 100%, and a standard deviation of 14.4%, while Botshabelo farmers have TGR scores of 19.9% minimum, 100% maximum, and a standard deviation of 21.3%. The farmers in Botshabelo had a higher variation in TGR, with a standard deviation of 21.3% compared to farmers in Thaba Nchu, who had a standard deviation of 14.4%. Thaba Nchu farmers had the highest average TGR, namely, 73.7%, suggesting that sheep farmers are able to produce about 73.7% of the potential sheep output using the available regional meta-technology. Farmers in Botshabelo had a lower average TGR of only 67.4% and can only produce 67.4% of the potential sheep output using the regional meta-technology. This implies that Thaba Nchu farmers are producing on a production frontier closer to the metafrontier. The TGR result shows that there are some farmers in Thaba Nchu and Botshabelo who are operating on the metafrontier.

The hypothesis test in Table 5.6 shows that sheep farmers in the N8 development corridor (Thaba Nchu and Botshabelo) use heterogeneous technology and the estimation of the metafrontier further shows that there exists a technology gap between the metafrontier and the regional production frontiers. TGR shows the extent to which the highest output in the district municipalities should increase to achieve the output as given on the metafrontier using the current input set (Donkor, 2015). The TGR scores for both Thaba Nchu and Botshabelo are presented in a bar chart in Figure 5.2 to show the distribution of the TGR scores among sheep farmers in Thaba Nchu and Botshabelo. The bar chart shows that there exists a wide gap between the TGR scores for the two district municipalities.

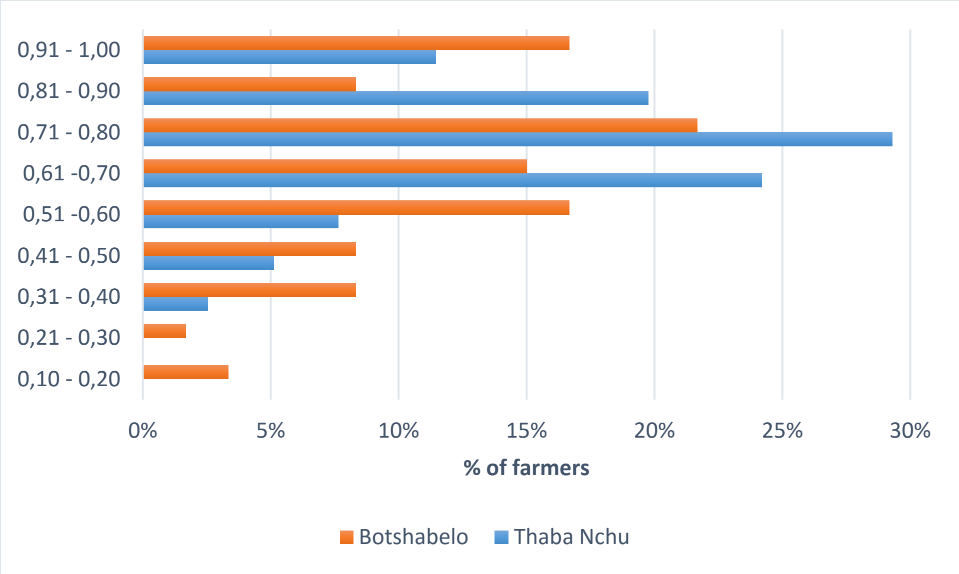


FIGURE 5.2 DISTRIBUTION OF TECHNOLOGICAL GAP RATIO

SOURCE: AUTHOR ESTIMATION

The TGRs illustrated in Figure 5.2 show that about 29.3% of Thaba Nchu sheep farmers have an estimated TGR in the range of 0.71 to 0.80, while 21.67% of the sheep farmers in Botshabelo have a TGR ranging from 0.71 to 0.80. Farmers in Botshabelo had an estimated TGR 16.67% in the range 0.91-1.00 while farmers in Thaba Nchu had only 11.46% in that same range. The results further indicate that almost 50% of the sheep farmers in Botshabelo produce at least 45% of the potential sheep output given the available technology. Generally, Thaba Nchu farmers had a higher TGR than farmers in Botshabelo. The lower TGR for Botshabelo could be explained by lack of managerial skills among farm workers and also by the low quality of purchased and produced feed. The majority of farmers in Thaba Nchu are better off and are operating on a production frontier closer to the metafrontier than farmers from Botshabelo, who are not too far from the metafrontier themselves.

5.4.3 Technical Efficiency Relative to the Metafrontier

It was established earlier that the production environment and the technologies used in sheep production in Thaba Nchu and Botshabelo are different, therefore, the technical efficiencies estimated for the two regions along the N8 development corridor (Thaba Nchu and Botshabelo) are not sufficient for comparisons between the sheep producers in the two district municipalities. Metafrontier is one of the most important measures of TE when dealing with different production environments and heterogeneous technologies. Therefore, the performance of sheep farmers in the two district municipalities can be compared using metafrontier. The TE relative to the metafrontier for each of the district municipalities shows the efficiency level of the farmers in each district municipality using a similar technology in the district municipality. Table 5.8 presents descriptive statistics for TE relative to the metafrontier, using average, minimum, maximum and standard deviation.

TABLE 5.8 DESCRIPTIVE STATISTIC OF TE RELATIVE TO THE METAFRONTIER

Statistics	Thaba Nchu	Botshabelo
Average	0.511	0.442
Minimum	0.081	0.061
Maximum	0.897	0.859
Standard deviation	0.177	0.206

SOURCE: AUTHOR ESTIMATION

As expected, the mean TE estimates for both production system frontiers are consistently higher than TE estimates relative to the metafrontier. This confirms that farmers in the study areas generally have the potential to improve production efficiency with the technologies available to them. The results show that the metafrontier TE scores follow almost the same distribution pattern as the production system frontiers; Botshabelo farmers have a lower mean TE (0.442) with a higher variation (SD = 0.194), while Thaba Nchu farmers have the higher mean TE (0.495) and a lower variation (SD = 0.141). It is important to mention that a relatively higher TGR does not automatically mean a higher TE, given that other non-technology factors in different production environments might affect the ability of farmers to achieve maximum potential output levels (Otieno, 2011).

The distribution of TE scores for each region's production frontier and the TE relative to the metafrontier is presented in a bar chart in Figure 5.3.

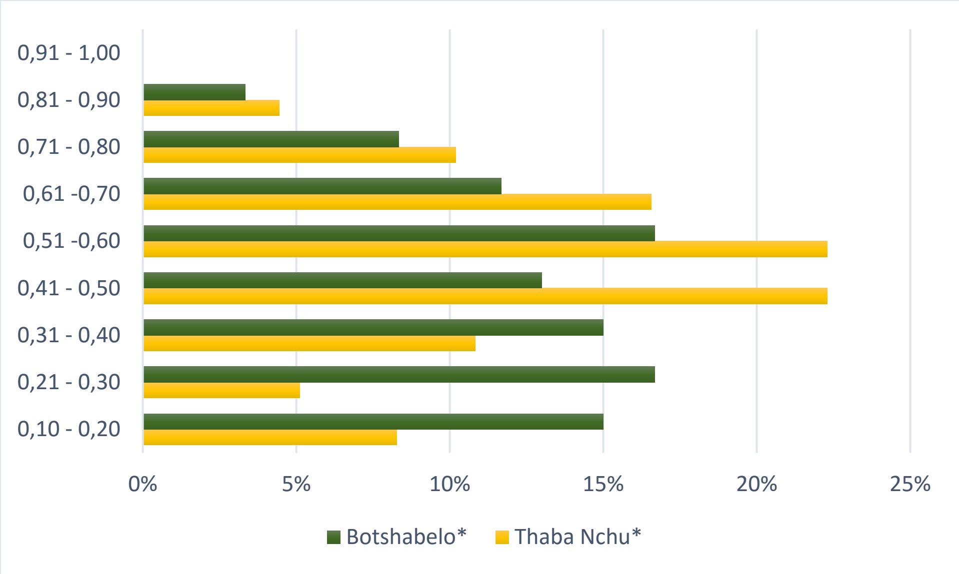


FIGURE 5.3 DISTRIBUTION OF TE RELATIVE TO THE METAFRONTIER

SOURCE: AUTHOR ESTIMATION

Figure 5.3 shows that 10.19% of farmers in Thaba Nchu had TE scores relative to the metafrontier in the range 0.71-0.80. It also shows that only 4.45% had a TE score relative to metafrontier in the range 0.8-91. However, 22.29% of farmers in Thaba Nchu have a TE relative to the metafrontier in the range 0.51-0.60. The situation is slightly different for farmers in Botshabelo. Figure 5.3 shows that 8.33% of farmers had TE scores relative to the metafrontier for the 0.71-0.80. However, only 3.33% had TE scores relative to the metafrontier above 0.81-0.90. It is clear from this discussion that farmers in Thaba Nchu are more efficient, given that they have a higher average TE score, higher TGR score and a higher TE relative to the metafrontier, and are making better use of the available technology than farmers in Botshabelo. This improved efficiency estimated for Thaba Nchu can be attributed to the higher TGR score for Thaba Nchu, thus indicating that some farmers in Thaba Nchu are producing closer to the metafrontier.

5.5 Kendall's Coefficient of Concordance for Ranking Sheep-Production Constraints

The third objective of this study was to estimate and rank the constraints faced by smallholder sheep farmers in Thaba Nchu and Botshabelo using the Kendall's Coefficient of Concordance. The constraints were captured from the most severe to the least severe. Table 5.9 presents the ranking of sheep-production constraints in the N8 development corridor.

TABLE 5.9 KENDALL'S COEFFICIENT OF CONCORDANCE

Production Constraints	Overall rank	Mean ranks (T)	Ranking score of constraints			
			Very severe	Severe	Moderate	Not Severe
Stock theft	1	3.46	176	32	8	1
Lack of capital	2	4.07	158	39	15	5
Diseases and parasites	3	4.46	137	55	24	1
Feed cost	4	5.17	131	45	31	10
Heat stress	5	6.24	67	108	23	19
Limited forage/feed scarcity	6	7.55	35	103	58	21
Water availability	7	8.21	36	63	101	17
Poor road network	8	8.51	36	81	63	38
Professional knowledge	9	8.57	59	25	105	28
Quality of grazing land	10	9.34	21	59	92	45
Transaction cost	11	10.29	11	45	116	45
Marketing constraints	12	11.02	28	33	47	109
Access to grazing land	13	11.07	18	25	79	75
Livestock housing constraint	14	11.96	4	17	96	100
High labour cost	15	12.19	6	20	71	120
High land rent	16	13.91	3	2	19	193

SOURCE: AUTHOR ESTIMATION

Table 5.9 shows the various constraints faced by smallholder farmers in the N8 development corridor. Production constraints refer to all the constraints the farmers face in sheep production. The overall constraints are ranked from the most pressing constraint to the least pressing constraint (ascending from 1 to 16). The mean rank shows the most severe constraint to the least severe constraint. The constraint with the smallest mean rank is the most severe constraint, while the constraint with the highest mean rank is the least severe constraint. The ranking score shows the farmers' responses (number of farmers) to the various constraints.

From the Kendall’s Coefficient of Concordance analysis in Table 5.9, stock theft, lack of capital, diseases and parasites, feed cost and heat stress are the main sheep-production constraints in the study areas (Thaba Nchu and Botshabelo). Market constraints, access to grazing land, housing, high labour cost and high land rent were the least common sheep-production constraints in the study areas. Bahta *et al*. (2016) found that security is a challenge facing all communal farmers, and it is a burning issue for agriculture in South Africa. Anang *et al.* (2013*)* also found lack of capital and high cost of production to be among the severe constraints facing tomato production in Ghana; this study found high land rent and high labour cost to be among the least severe constraints tomato farmers in Ghana face. Lawal *et al.* (2015) found cost of fertiliser, cost of paid labour, cost of transportation and lack of grazing land to be serve constraints faced by farmers in livestock-crop production in Nigeria. A study by Zalkuwi *et al.* (2014) also found high feed cost, lack of credit facilities, cost of vaccination, diseases and parasites and poor pricing to be the main constraints facing sheep farmers in Northern Nigeria.

The constraint with the least (smallest) mean rank was the most serve constraint in the study areas of this study, while the constraint with the highest mean rank was the least serve constraint. Livestock theft was ranked as the most severe constraint by the farmers, followed closely by lack of capital, diseases and parasites, feed cost and heat stress. Farmers also ranked limited forage/feed scarcity, water availability, road network, professional knowledge and quality of grazing land as serve constraints. Marketing and access to grazing land were ranked as moderate constraints, while sheep housing, labour cost and land rent were ranked as constraints that were not severe.

The null hypothesis (H_0) states that farmers were not in agreement with one another over their ranking of the constraints to sheep production. The null hypothesis was rejected at the 5% significance level because the calculated F-value (53.9) was greater than the critical F-value (2.40). Hence, it is concluded that farmers were in agreement on the ranking of the sheep-production constraints in the study areas. The Kendall’s Coefficient of Concordance (*W*) analysis showed that just fewer than 50% (49.9%) of the farmers were in agreement with each other on the ranking of the sheep-production constraints. Table 5.10 shows the summary statistics of the test of hypothesis.

TABLE 5.10 SUMMARY STATISTICS OF TEST OF HYPOTHESIS

Sample	W	Chi-Square	df	F_{cal}	F_{tab}
217	0.499	1625.404	15	53.9	2.40

Note: df = degree of freedom
SOURCE: AUTHOR ESTIMATION

5.6 Chapter Summary

The estimated gamma (γ) is 0.679 for Thaba Nchu, 0.779 for Botshabelo and 0.799 for the pooled sample, indicating that 67.9%, 77.9% and 79.9% of the variation in sheep output respectively is the result of technical inefficiency. The estimated average TEs for Thaba Nchu, Botshabelo and the pooled area are 0.673, 657 and 0.669 respectively, indicating that the farmers can improve their TE by 32.7%, 34.3% and 33.1% respectively to produce at full capacity. The gamma values and the estimated technical efficiencies show that there exists the potential to improve productivity and TE of the sheep farmers in both district municipalities. From the estimated gamma values and the average TE score it can be concluded that the farmers in Thaba Nchu are slightly more technically efficient than the farmers in Botshabelo.

The hypothesis test that was performed using the estimate of metafrontier indicates that a different production frontier exists for the two district municipalities. It is therefore necessary to fit a production frontier for each of the district municipalities. The average TE scores estimated relative to the metafrontier (TE_m) for Thaba Nchu was 0.495, while the average TE_m for Botshabelo was estimated at 0.442. Farmers in Thaba Nchu had higher efficiency scores relative to the metafrontier than farmers in Botshabelo, suggesting that farmers in Thaba Nchu are performing better than farmers in Botshabelo at a district level.

Smallholder sheep farmers are faced with numerous constraints that limit their productive capacity. Livestock theft was identified as the most severe constraint by the farmers, followed by lack of capital, diseases and parasites, feed cost and heat stress.

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Background Information

Sheep production plays a very important role in the South African livestock industry by serving as a source of cash income and contributing to smallholder farmers' livelihood (Brundyna *et al.,* 2005; Mapiliyao *et al.,* 2012). Livestock production has great potential to alleviate household food insecurity and poverty in South Africa. The livestock industry contributes approximately 45% of South Africa's agricultural output and employs approximately 500 000 people nationwide (DAFF, 2012). Land used for agriculture comprises approximately 82.3% of the total land area of South Africa, and approximately 68.6% of the agricultural land in South Africa is used for extensive livestock grazing (DAFF, 2016). Livestock is by far the largest agricultural sub-sector in South Africa, contributing an estimated 25 – 30% of the total agricultural output per year (Blignaut *et al.*, 2014).

In 2012, South Africa's export of sheep products stood at 362 874 kg; the country's import of sheep products for the same period stood at 4 178 493 kg, showing that South Africa is a net importer of sheep (DAFF, 2013). This implies that there is an excess demand for sheep meat in South Africa. Hence, there is the need for sheep farmers to increase their production to meet the excess demand. In order to meet the excess demand, South Africa imports sheep meat from countries such as New Zealand and Australia (DAFF, 2013). This high expenditure on sheep importation has become a great concern to the government of South Africa, because of its negative impact on the nation's economic development. South Africa's importation of sheep and sheep products also exerts pressure on the country's foreign currency reserves. Therefore, the South African government desires to reduce importation of sheep products by promoting domestic sheep production through productivity and efficiency enhancement measures. Enhancing domestic sheep production will reduce South Africa's foreign expenditure on the importation of sheep products. Promotion of domestic sheep production will also enhance the output and income levels of farmers and, eventually, improve their standards of living through the provision of employments for farmers, processors and marketers.

Developing the sheep industry can be a sustainable way of improving food security and livelihoods of smallholder sheep farmers (Mapiliyao *et al.,* 2012l; Miao *et al.,* 2005). Increased productivity and efficiency of lamb and mutton production is key to improving the competitiveness of the sheep meat industry (Montossi *et al.,* 2013).

6.2 Problem Statement

Sheep production in the N8 development corridor is relatively low, with recent data showing that sheep farmers in the Free State in general and along the N8 corridor in particular do not produce enough to meet local demand (DAFF, 2014). The government of South Africa wants to enhance livestock production; however, there is no empirical evidence available on the TE levels of smallholder livestock farmers. The lack of analytical evidence on the efficiency levels of farmers in various sheep production systems in the Free State and N8 development corridor in particular constrains the development of programmes geared to assisting smallholder sheep farmers.

The main objective of this study was to determine the factors that influence the productivity of sheep production in order to enhance the livelihood of smallholder sheep producers in the N8 development corridor. Various production techniques are practiced in the N8 development corridor (Thaba Nchu and Botshabelo) and the production environments of the two areas are not the same. Should the government develop and implement a single development plan for both regions (Thaba Nchu and Botshabelo) along the N8, it might result in a biased outcome. Metafrontier analysis is an appropriate efficiency-measurement technique for dealing with heterogeneous production environments. The metafrontier approach can estimate the efficiency of heterogeneous groups based on their distance from a common and identical frontier. The objective was addressed by first estimating the TEs of the two areas, Thaba Nchu and Botshabelo, using a SFM for each of the district municipalities and then identifying the factors that influence variations in TE in the two districts municipalities. A metafrontier model was estimated to represent a common frontier on which production in the district municipalities could be compared. The meta-technology gap was estimated, which shows the technically efficient producers relative to the metafrontier.

6.3 Study Area and Data Collection

This study was carried out in the N8 development corridor, Free State province. The Free State province is located in the central part of South Africa and is one of the nine administrative provinces of South Africa. The Free State province is situated between latitude 26.6^0 S and 30.7^0 S and between longitude 24.3^0 E and 29.8^0 E. It is the third-largest province in South Africa and shares borders with Gauteng, Mpumalanga, North West, KwaZulu-Natal and the Kingdom of Lesotho.

Data for this study was collected with the use of structured questionnaires written in English. Aided by the Department of Agriculture in both district municipalities of the N8 development corridor, permission to conduct the survey was obtained from the head of rural households and herdsmen. The target respondents were smallholder sheep farmers in the N8 development corridor. Data was collected in both Thaba Nchu and Botshabelo along the N8 development corridor. These two regions were chosen because of the number of livestock farmers, especially sheep farmers, in the district municipalities. The survey employed proportionate stratified random sampling in Thaba Nchu and a simple random sampling approach in Botshabelo. A total of 168 farmers were interviewed in Thaba Nchu and, due to incomplete data recorded by the enumerators, only 157 responses were eligible for this study. In Botshabelo, 60 sheep farmers were selected randomly for interviews and all of their responses were eligible for the study.

6.4 Characteristics of the Respondents

On average, sheep output in Botshabelo was higher than that of Thaba Nchu. In terms of resource use, sheep farmers in Botshabelo grazed on relatively larger areas, used more labour, had, on average, more sheep, and had more sheep compared to farmers in Thaba Nchu. The farmers in Thaba Nchu spent, on average, more on veterinary services and veterinary drugs. The grazing systems in the two areas are slightly different but the majority of farmers in both areas use identical grazing systems. Farmers in the two areas keep the same breed of sheep.

Sheep farming in both areas is dominated by male farmers. Generally, there was a low educational level among the sheep farmers, but farmers in Thaba Nchu were, on average, slightly more educated than farmers in Botshabelo. The study also reveals that sheep farming in both areas is practised by older farmers, but the farmers in Botshabelo were older than those in Thaba Nchu. The Thaba Nchu sheep farmers had more experience in sheep production than those in the Botshabelo area. Even though the household size in both districts was very close, Thaba Nchu farmers had relatively larger households. Access to extension services was very limited in the two districts. However, sheep farmers in Thaba Nchu had a greater comparative advantage in terms of access to extension services than Botshabelo farmers. In terms of proximity to market centres, Botshabelo sheep farmers were closer to market centres than sheep farmers in Thaba Nchu. The majority of the farmers in Thaba Nchu and Botshabelo grazed on communal land without deeds/allotment letters. Access to veterinary services was limited for the farmers in the study areas. However, more farmers who had access to veterinary services in Botshabelo than in Thaba Nchu.

6.5 Empirical Methods

The estimation of TE in the two study areas was done by following two steps. The first step involved estimating the production frontier that represents the group frontiers that were used to calculate individual farmers' TE levels. Nine production factors, namely, communal land, herd size, transport cost, cost of veterinary drugs, cost of veterinary services, sheep loss, operating cost, feed cost, and labour were included in the stochastic production model as factors influencing sheep output. Using simultaneous equations, an inefficiency model was fitted to determine the factors that affect the farmers' level of technical inefficiency. Factors included in the estimation of the inefficiency model include extension contact, distance to market, access to veterinary services, communal land, education, household size, crossbreeding method, years of farm experience, farm manager and indigenous sheep. The model was fitted using Frontier 4.1 (Coelli, 1996). Two functions were fitted, one for each production system in the study areas, and the TE scores were predicted based on the SFM fitted for each of the district municipalities.

The second step was to fit a metafrontier model that estimated the efficiency of heterogeneous groups based on their distance from a common and identical frontier. The estimated parameters from the production frontier for the two regions were used, together with the pooled data, to estimate the metafrontier using Shazam 9 (White, 1978), which uses linear programming in metafrontier estimation. Comparative efficiency measures, such as the TGR and TE relative to the metafrontier, were predicted from the metafrontier function for the two district municipalities. The TGR defines the distance between the estimated production frontiers and the metafrontier. The TE relative to the metafrontier is the product of the TE relative to the individual frontiers and TGRs.

Finally, constraints to sheep production were estimated and ranked using SPSS 21 (Nie *et al.,* 1970). The constraints were ranked from the most severe constraint to the not as severe constraint using a scale of 1 to 4 (very severe, severe, moderate and not severe).

6.6 Results and Discussion

The stochastic production function was estimated, followed by the inefficiency function and the TE scores. Farmers in Thaba Nchu obtained an average TE score of 67.3%, meaning they have a 32.7% potential to increase production at full capacity. Farmers in Botshabelo have a TE score of 65.7%, on average, giving them a 34% potential to increase production. The pooled data shows that farmers in both study areas have an average TE score of 66.9%. This implies that farmers in the study areas have a 33.1% potential to increase production to full capacity. It can be concluded that sheep farmers in the study areas are operating below the production frontiers, suggesting that there is scope for them to improve their efficiency levels and produce at full capacity. Metafrontier was estimated and the TGR and metafrontier TE scores were predicted from the estimations. The production frontier results show the variables that influence sheep production in the study area. The production frontier revealed that herd size and feed cost were the most important inputs for sheep production in Thaba Nchu. This means that an increase in either herd size or feed cost will cause output to increase in Thaba Nchu. Land, labour and transport cost were the most important inputs in Botshabelo. An increase in any of these variables will increase sheep output in Botshabelo. Sheep loss is a negative and significant production input for both Thaba Nchu and Botshabelo, while veterinary service and drugs and operating expenses were not significant for either of the district municipalities. From the pooled results, herd size was the most important input in sheep production in the study areas, which means that sheep output increases as herd size increases. The gamma (γ) value estimated was 0.679 for Thaba Nchu, 0.779 for Botshabelo and 0.799 for the pooled sample, indicating that 67.9%, 77.9% and 79.9% respectively of the total variation in sheep output is due to technical inefficiency. The average TE score estimated for Thaba Nchu is 0.673 (67.3%), that for Botshabelo is 0.657 (65.7%) and the pooled sample is 0.669 (66.9%), indicating that sheep farmers in Thaba Nchu and Botshabelo can improve their TE by 32.7% and 34.3% respectively, and by 33.1% as a group. It can be concluded from the estimated gamma values and TE scores that there is potential for sheep farmers in Thaba Nchu and Botshabelo to increase productivity and efficiency.

Indigenous sheep breed, educational level, veterinary services and market distance were estimated to be significant factors affecting the TE of sheep production in Thaba Nchu. In Botshabelo, indigenous sheep breed, farm experience, crossbreeding method and distance to market were the variables that significantly influence the TE of sheep farmers. Indigenous sheep breed, communal land, extension services and market distance are the variables that significantly influence TE in the pooled data, thus indicating that a change in any of these variables will affect TE in the pooled sample. Thaba Nchu and Botshabelo farmers face different production environments and technologies and, therefore, the factors that affect the TEs of the two district municipalities are slightly different. It is important to have specific information about each district municipality so as make informed decisions about improving the efficiency of sheep production in each district municipality.

A metafrontier function was estimated and a hypothesis test was performed, which indicated that different production frontiers exist for each region in the study area. Fitting a single production frontier for sheep production in the two regions would produce inconclusive results because of the distinct production environment of and technologies used in each district municipality. The TE scores relative to the metafrontier (TEm) was higher, on average, in Thaba Nchu (0.511) than in Botshabelo (0.442). This implies that farmers in Thaba Nchu are performing better, on average, than farmers in Botshabelo at district level.

The constraint analysis (Kendall's Coefficient) indicates that smallholder sheep farmers along the N8 development corridor face numerous production constraints that limit their ability to increase productivity and efficiency. The most pressing constraints to efficient production were identified as stock theft, lack of capital, diseases and parasites, feed cost, heat stress and water availability. These drawbacks (constraints) serve as impediments to sheep production along the N8 development corridor.

The livestock industry in the areas studied can become more competitive and the TE of the farmers can be enhanced by agribusiness incentives. The government needs to adopt discreet policies to create agribusiness incentives that will suppress or reduce the effects of the constraints facing farmers, and ensure an enabling environment for flourishing agribusinesses along the N8 development corridor.

6.7 Conclusions

It can be concluded from the results of the study that farmers in the study area are producing well below the production frontier indicated by the average TE scores obtained. This means that farmers have the potential to increase their productivity and efficiency and produce at full capacity. The gamma values estimated show that a considerable variation in sheep production efficiency in the study areas is caused by technical inefficiencies and, to a lesser extent by statistical noise or random shocks.

The hypothesis test performed from the estimates of the metafrontier model confirms that farmers in Thaba Nchu and Botshabelo are not using the identical technologies for production. This justified the estimation of two separate production frontiers for each study area. The estimation of the metafrontier was justified as it was used to compare the technological differences that exist in the study areas. In conclusion, is it essential to use the correct threshold when comparing the performance of districts. When the correct threshold is not defined properly, it may seem that one district municipality (Thaba Nchu) is performing better another (Botshabelo), which might not be the case. Recommendations will thus be made based on the performance of farmers in each district municipality.

The constraints faced by smallholder farmers in the study areas are numerous, with some constraints being more severe and others less severe. It was, therefore, important to understand the constraints facing these farmers and the way the constraints can be measured, so that useful recommendations can be made to help solve them. Sheep theft, lack of capital, diseases and parasites, heat stress, feed cost, quality of grazing land and water availability were found to be the most severe constraints facing the farmers. Proper measures can be taken to reduce the effects of these constraints on the farmers.

6.8 Recommendations

This section sets out recommendations for policy-makers that might contribute to improving the livelihoods of smallholder sheep farmers in the N8 development corridor. The following recommendations can be made, based on the findings of this study.

The government, through the Department of Agriculture, should organise training workshops and seminars on appropriate management skills to support the decision-making of sheep farmers on the efficient use of farm resources and the coordination of their farm operations. Farmers should be provided with livestock extension training on farm management and keeping proper records of their activities. Extension officers should present demonstration workshops on farms to encourage more experienced farmers to share their farm knowledge with less experienced farmers.

One of the severe constraints facing the farmers was found to be heat stress. To enhance the livelihood opportunities of smallholder farmers and improve their resilience to heat stress, farmers should be encouraged to diversify their farm activities by keeping not only sheep, but also cattle, goats and chickens, and to engage in crop production. These various enterprises should be integrated, rather than farmers depending only on livestock production. Furthermore, policies to promote better use of and proper investment in land, especially in Thaba Nchu, should be encouraged. Farmers should invest on other profit-generating activities on the land.

It is essential to improve the marketing orientation (market identification) among farmers in Thaba Nchu and Botshabelo and to enhance their access to better markets for their livestock in order to improve their productivity. Training smallholder farmers on farm business skills will help them access competitive markets to buy farm inputs and sell their outputs, which will lead to an increase in production. Also, the government should promote smallholder sheep production by encouraging smallholder sheep farmers to consider closing contracts with abattoirs, sheep exporters and processors. If contract farming is not possible for the smallholder farmers, farmers can form collective action groups, through which they can bring their products together for marketing purposes.

Since availability of education has a strong influence on TE in both Thaba Nchu and Botshabelo, government policies and strategies on sheep production should target farmers who have obtained formal education, in particular, and aim to train even those farmers who lack formal education, since farmers with more education are more efficient in sheep production. Future strategies should also be directed at training sheep farmers with no formal education on better and efficient sheep production through extension training. The government should invest in training and equipping more extension agents who could train more smallholder farmers.

As suggested by Bahta *et al.* (2016), the government, through the various Departments of Agriculture, should build new fences and repair damaged ones. This will help secure livestock and reduce incidents of theft. Farmers should also be encouraged to practice intensive and extensive methods of grazing; this will help keep stock safe and reduce the rate of theft.

The government should introduce policies to encourage formal and informal credit providers to develop financing products (capital incentives) that assist smallholder sheep farmers. Smallholder farmers are normally excluded from access to formal credit because they lack collateral. Alternatively, the government, through the Department of Agriculture, can design a programme that offers small loans to smallholder farmers at relatively low interest rates. Farmers should undertake to pay back loans within a certain period. The Department of Agriculture will be able to do follow-ups and check the progress of the farmers at every stage of production. Access to credit will afford smallholder farmers the ability to raise capital to run their farms.

Farmers should be encouraged to invest in long-term water provision and pasture cultivation. This can be done by offering incentives for investment in pasture development. Growing pasture and developing water sources will provide livestock with food and water in the long term.

The government should subsidise the cost of veterinary drugs and services so that farmers can have easier access to these services. This will help them deal with diseases and parasites that affect their sheep. In the long run, farmers should be sensitised on diseases and parasites that affect livestock and techniques of identifying and dealing with these diseases.

6.9 Limitations of the Study and Suggestions for Further Research

Although the research achieved its objectives, there were some unavoidable limitations. Firstly, the target sample size could not be achieved due to financial constraints. Secondly, the respondents speak only the local language, making communication between the researcher (who speaks English) and the respondents difficult. To overcome this language barrier, the researcher obtained the assistance of an interpreter and other individuals who assisted in completing the questionnaires. Efforts were made to ensure uniformity in the researcher's questions and the questions posed by the interviewer (interviewers received training prior to data collection). The researcher acknowledges that there could have been discrepancies in the interpretation of some of the questions, which could impact some of the responses. Thirdly, some questions required farmers to refer to their sheep production records for the last 12 months (January to December 2015). However, some of the farmers did not keep proper records of their sheep production and marketing activities.

Due to financial constraints, only two district municipalities in the Free State were considered in this study. Further research should be done to evaluate technical efficiencies for sheep producers in all the sheep-producing districts in the Free State. This research will help to develop policies necessary to increase the efficiency of sheep production in the Free State.

A study should be done to analyse farmers' preferences for disease-free zones. A study on this topic would provide insights into policies and programmes designed to establish livestock disease-free zones. It is important for farmers to be aware of the various diseases that challenge livestock development and the various diseases control programmes necessary to deal with these challenges.

The results of this study show that an increase in communal land size reduces sheep output in Thaba Nchu. The result is against expectations, as land is a very important factor in sheep production. It is, therefore, necessary for future research to investigate in depth why an increase in land size reduces sheep output.

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APPENDIX: QUESTIONNAIRE

University of the Free State

Department of Agricultural Economics

Sheep Production Survey in the N8 Development Corridor

Respondent

In this survey, households that are involved in sheep production for a period of **ONE YEAR** and above will be eligible for interview. Only **one person** should be interviewed in the selected household. The interviewee, referred to here as "**respondent" must be an individual who normally makes farm decisions** in the household (head of the household). In case the main decision maker is not available, his/her deputy should be interviewed.

Objective of the Survey (the enumerator should explain this part to the respondent)

The **purpose of this survey** is to obtain information on various aspects of sheep production, marketing and production constraints faced by the sheep farmers. Your participation in answering questions on these issues is highly appreciated. Your responses will be analysed together with those from other households in other parts of the N8 development corridor. The results of this survey will be used to inform policy makers on better strategies for improving the Sheep production sector in N8 development corridor in particular and the Free State as a whole.

Confidentiality will be maintained on all information that you provide. The survey will require about thirty minutes. I would like to request your permission to begin the survey now.

Section A: Identification (the enumerator should fill this section through observation in consultation with the researcher)

Name of respondent: …………………..................	Interviewer's Name ………………………...
Region: ……………………………………………	Village ………………………………………
Date of Interview	Questionnaire Number _______

Section B: Respondent's Characteristics and Household Composition

1. Gender: ______ (1 = male, 2 = female)

2. Position in the household (*Tick one option*):

a) Household head_____

b) Spouse_______

c) Son_________

d) Daughter_____

e) Other relative____

f) Farm manager____

g) Other farm employee____

3. Age: ______ years

4. Highest level of formal education completed (*Tick one option*):

a) No formal education____

b) Primary___

c) Secondary___

d) Middle level college certificate or diploma____

e) University degree_____

f) Highest number of years of formal education __________

5. On average, how many people normally reside in this household during a year?

a) Total number of children (18 years and under) _________

b) Total number of adults (over 18 years) ______________

6. What is your marital status? (*Tick one Please*)

   a) Single______

   b) Married _____

   c) Divorced _____

   d) Separated _____

   e) Widowed _____

7. What is your main occupation? (*Tick one please*)

   Farming _________

   Employed ________

   Housewife ________

   Pensioner _________

   Business _______

   No occupation _________

8. What is your main source of Income? (*Tick one please*)

   a) Farming ___________

   b) Employed __________

   c) Pension ____________

   d) Social grant _________

   e) Business ____________

9. For how many years have you practised sheep production? __________ years

10. How many days in a month are you normally available on the farm? ______ days

11. Is there a manager on the farm, besides the household head? _____ (1 = Yes, 2 = No).

Section C: Household Enterprises

12. Which livestock types and numbers did you have on your farm in the past 12 months?

Livestock type	Number	Rank according to importance to you (on a scale of 1 to 7)	Are they kept on the farm	
			Yes	No
Sheep				
Cattle				
Goats				
Chicken				
Pigs				
Horses				
Donkeys				
Others (Specify) ___________________				

13. Which activities does the household **mainly** depend on for livelihood, e.g., for provision of income, food, fees etc.?

Enterprise	Is it your source of livelihood (Tick where appropriate)		If YES, please indicate the proportion of monthly income in an average year, from each enterprise which is a source of livelihood (Tick where appropriate)		
	Yes	No	<25%	50%	>50%
Sheep Production					
Other livestock (Specify)_____________					
Crop Production					
Off farm-Employment					
Others					

14. What are your reasons for keeping sheep?

Reasons	Tick	Rank according to importance (on a scale of 1 to 8)
Wool		
Meat		
Selling live sheep to raise income		
Household consumption		
Savings and Investment		
Manure		
Socio-economic function (e.g lobola)		
Family pride and status		
Others (specify)___________________		

Section D: Sheep Losses

15. Have you had sheep die due to any of the following factors during the last 12 months? If **YES**, please indicate the number.

Cause of loss	Did sheep die from this cause? (Tick where applicable)		If YES, please indicate the number of sheep lost
	Yes	No	
Disease and parasite			
Drought			
Floods			
Thunder/lightning			
Disputes over pasture and water			
Attacks by wild animals			
Theft			

Section E: Sheep Output

16. Please provide information on Sheep production in your farm in the last 12 months.

	Class					
	Ram	Ewe	Lamb	Gimmer	Wither	Total
How many of each do you have						
What is the average age of the animals in the farm (months)						
How many did you purchase in the last 12 months						
What was the average purchase price (Rand)						
How many did you receive from other sources, (e.g., Lobola, gifts)						
How many did you sell in the last 12 months						
What was the average sales price (Rand)						
How many did you use for other purposes e.g., consumption, gifts, Lobola						

Section F: Variable Inputs

17. Please provide information on the inputs used in the Sheep farm in the last 12 months.

Inputs	Average quantity used for all Sheep per month	Total cost (Rand) per month
a) Purchased feeds		
Silage e.g., sunflower, rye, corn (Kilograms)		
Fodder e.g., hay, maize stalk/stover, wheat straw, sugarcane straw, rice straw, grass (Kilograms)		
Other feeds e.g., soya bean meal, urea (Kilograms)		
Mineral salt and vitamins (Kilograms)		
Water (litres)		
b) Feeds produced and used in the farm		
Silage e.g., sunflower, rye, corn (kilograms)		
Fodder e.g., hay, maize stalk/stover, wheat straw, sugarcane straw, rice straw, grass (Kilograms)		
Fertiliser (Kilograms)		
Irrigation water (litres)		
c) Labour		
How many people are employed?		
How many male and female are employed?		
How many days do the employed labourers work per month?		
How much money is each farm employee paid per month?		
How many family members work?		
How many male and female family members work?		
How many days do the family members work per month?		
How much money is each family member paid for working per month?		
d) Cost of veterinary drugs		
e) Cost of veterinary services		
f) Transport cost		
g) Farm mechanization costs		
Fuel (litres)		
Electricity		
Hire of machinery and/or equipment, repairs and maintenance (per month)		
h) Other costs per month, e.g., market services, branding, etc.		

Section G: Fixed Inputs

18. Does the household own any of the following assets on the farm?

Assets	Is it owned in the household?		Number
	Yes	No	
Sheep fence			
Kraal			
Sheep Pen			
Store for farm inputs			
Dip sprayer			
Chaff cutter			
Wheel barrow			
Truck			
Pick-up			
Tractor			
Other (specify)			

Section H: Other farm Inputs and Services

- Land

19. What is the approximate size of your grazing land (excluding homestead)? ______ hectares

20. What is the size of communal grazing land _____________ hectares

21. Which **one** of the following land tenure systems do you have on your farm? (*Tick one option*) Use this for ticking option

i) Individual owned with title deed/allotment letter.............. [ ]

ii) Individual owned without title deed/allotment letter........ [ ]

iii) Communal with title deed/allotment letter ……………... [ ]

iv) Communal without title deed/allotment letter …............. [ ]

v) Mixed/other (specify, e.g., part individually-owned and partially communal)… [ ]

22. Which grazing system do you use? _________ (1= intensive, 2= Extensive, 3= Free Grazing)

- Breed types and breeding method

23. What is the **main** sheep breed kept on your farm? (*Tick one option*)

i) Indigenous sheep ……………. [ ]

ii) Crossbreed …………………... [ ]

iii) Exotic …………………………... [ ]

24. Which breed do you prefer? ___________________

25. Reasons for breed preference?

Reason	Tick	Rank (On a scale of 1 to 8)
Fast growth rate		
Quality of meat		
Quality of wool		
Low feed cost		
Resistance to diseases		
Availability		
Easy to manage and maintain		
Others (specify) ______________________		

26. Which Sheep breeding method is **normally** used in the farm? (*Tick one option*)

a) Pure-breeding ………………… [ ]

b) Inbreeding ……………………. [ ]

c) Crossbreeding ………………... [ ]

- Extension services

27. Did you get any livestock extension services in the last 12 months? ____ (1 = Yes, 2 = No),

28. Who was your **main** provider of livestock extension services in the last 12 months? (*Tick one option*)

a) Government officer ………….. [ ]

b) Private provider e.g., Non-Government Organizations, private companies ………… [ ]

c) Individuals ……………… [ ]

29. How often does the **main** livestock extension service provider visit your farm? (*Tick only one applicable option*)

a) Weekly ……………. [ ]

b) Every two weeks …. [ ]

c) Once a month …….. [ ]

d) Less than once a month [ ]

30. How often would you like the main extension service provider to visit your farm? (*Tick one option*)

a) Weekly ………………….. [ ]

b) Every two weeks ………... [ ]

c) Once a month …………… [ ]

d) Less than once a month …. [ ]

- Veterinary advisory services

31. Did you receive any veterinary advisory services in the last 12 months? _____ (1 = Yes, 2 = No)

32. Where do you normally obtain veterinary advisory services from? (*Tick one option*)

a) Government officers …….. [ ]

b) Private providers e.g., NGOs, private companies or individuals ……… [ ]

- Credit/loan /Cash loan

33. Did any household member try to get a cash loan in the last 12 months? ______ (1 = Yes, 2 = No).

If **YES**, was the loan received? ____ (1 = Yes, 2 = No)

If YES, what was the interest rate paid on the loan? __________

If **NO,** why did not get it? _____________________________________

34. What were the sources of cash loan? (*Tick all that apply)*.

a) Bank ………………………….. [ ]

b) Cooperative society ………... [ ]

c) NGO) ………………………… [ ]

d) Self-help group……………… [ ]

e) Family………………………… [ ]

f) Neighbour…………………….. [ ]

g) Other (specify) ………………. [ ]

Section I: Market Outlets

35. Which one of the following do you normally sell your sheep to? (*Tick one option*)

a) Open market centre …………………………………………………………… [ ]

b) Slaughterhouses/abattoirs …………………………………………………... [ ]

c) Private exporter ……………………………………..…………………….. [ ]

e) Other e.g., neighbour, breeder (specify) …………………………............. [ ]

36. What is the approximate distance from your farm to where you normally sell sheep? _______ Km

37. How would you describe the condition of the road from your farm to where you normally sell sheep? (*Tick one option*)

a) Good, i.e. easily passable most of the time …………………………….. [ ]

b) Poor, i.e., pot holed or muddy or rough most of the time ……………… [ ]

38. Do you normally receive market information on sheep (e.g., on prices of sheep) before you go the market place? _____ (1 = Yes, 2 = No).

39. How frequently do you normally receive the market information? (*Tick one option*)

a) Daily ______

b) Once a week ____

c) Every two weeks ______

d) Once a month _____

e) Less than once a month _____

40. Which channels have been your source to get market information during the last 12 months? (*Please Tick one*)

a) Radio __________

b) TV ____________

c) Farmers Associations _________

d) Social Media __________

e) Other farmers' _________

41. Do you normally sell sheep through prior arrangement (contract agreement)? ___ (1 = Yes, 2 = No),

42. If **YES**, does the contract agreement include the following?

a) Price _______ (1 = Yes, 2 = No)

b) Transportation/delivery _______ (1 = Yes, 2 = No)

c) Other (specify) __________________________

Section J: Constraints to Sheep Production

43. What major constraints do you usually encounter in your sheep flock?

Constraints	Rank (*Tick where appropriate*)			
	Very severe	Severe	Moderate	Not severe
Marketing				
Housing				
Diseases and Parasites				
Feed cost				
Lack of Capital				
Professional knowledge				
Theft				
High land rent				
High labour cost				
Poor Road Network				
Transaction cost				
Limited forage/ feed scarcity				
Water availability				
Access to grazing land				
Heat Stress				
Quality of grazing land				
Others (Specify) ………………………				