UNIVERSITY OF ZULULAND

EFFICIENCIES OF SMALL-SCALE SUGARCANE GROWERS IN THE KING CETSHWAYO DISTRICT MUNICIPALITY OF KWAZULU-NATAL

By

Mushoni Benedict Bulagi
(201640084)

Thesis presented for the Degree of

Doctor of Commerce (Dcom)

In

the Department of Economics

Faculty of Commerce, Administration and Law

University of Zululand

Supervisors

Professor Irrshad Kaseeram &

Professor Dev Tewari

February 2019

DECLARATION

I, **Mushoni Benedict Bulagi**, declare that this thesis is my original work, save for citation and referencing signified otherwise in the text. The thesis has not and will not be presented for the award of any degree at any other university.

Sign ______________________________ Date __________________________________

M.B. Bulagi

CERTIFICATION OF APPROVAL

I declare that this thesis is from the student's own work and citations have been made where other sources of information have been used. The thesis is therefore submitted with my approval.

Sign __________________________ Date ______________________________

Professor I Kaseeram

Sign __________________________ Date ______________________________

Professor D.D Tewari

ACKNOWLEDGEMENTS

This thesis was made possible through the support received from family, friends and colleagues. My heartfelt appreciation and thanks go to my supervisors Professor Kaseraam and Professor Tewari for providing guidance and support throughout my candidature. Through your support and mentorship, I have grown and learned a lot which has provided a formidable foundation for my academic career.

I am indebted to my lovely family for the sacrifice and hardship they have gone through during the course of this thesis. I appreciate their patience, quality time off the thesis and the fire they ignited when the chips were down. My Nyanenge Mosibudi Munyadziwa and Makwarela Bulagi I am grateful to your support, inspiration and love.

My sincere appreciation goes to the extension officers in the Amatikulu and Felixton mills for the guidance and support in the course of data collection and interviews. We shared a common collegial understanding of what drives the production of small–scale sugarcane growers. I owe my gratitude to Dr Nyankomo Marwa from Stellenbosch University, Professor Anim Mugera of the University of Western Australia, and Professor Suren Kulshrestha of the University of Saskatchewan in Canada for their guidance during the proposal stages. My gratitude goes to fellow academics who provided insightful comments during the UKZN research day and Management of Business and Legal Initiatives (MBALI) conference.

I appreciate the support and motivation from the Dean of the Faculty, Professor Greyling, who was once my head of department, all my colleagues (Fortunate, Elisha, Thato, Thami, Nomfundo and Zhou) in the department of economics, and the post-graduate students who assisted in the data collection process.

I have made many friends that work in the field of productivity and efficiency analysis and many thanks to them for the encouragement and support.

I give honour, glory and praise to almighty GOD for his mercy, guidance and endless love.

Singo Rambau!!!! Ndaaa!

DEDICATION

To my daughter, and mother, Makwarela.

ABSTRACT

Low agricultural productivity remains a threat to the existence and sustainability of the small-scale production of crops. Unfavourable climatic conditions such as drought are a concern to the long-term supply of food in the context of a rapidly growing population. The continuous uncertainty surrounding access to credit, extension support and industry regulations exacerbate the dilemma faced by small-scale growers. Therefore, there is a need to develop strategies to promote agricultural efficiency and productivity.

Sugarcane is a traditional crop produced in three provinces in South Africa and it contributes to the livelihoods of many small-scale sugarcane growers operating in the rural set-up. This thesis aimed to evaluate agricultural efficiencies, productivity and efficiency change and identify barriers to technical efficiency of small-scale sugarcane growers in the sugar producing regions of the King Cetshwayo district municipality. This is a grey area as existing studies have given more attention to SFA (Stochastic Frontier Analysis) and ranked constraints faced by small-scale sugarcane growers. The thesis analyses three methodological approaches to addressing the objectives of the thesis. The first objective was to analyse the technical, cost and allocative efficiency of a sample of 300 small cane growers located in the King Cetshwayo district municipality (KCDM) of Northern KwaZulu-Natal. This objective was achieved through estimating agricultural productive efficiency using Data Envelope Analysis (DEA). The second objective was to determine the chemical-input use efficiency, which was determined using the Slack-Based Measure (SBM) approach of the sampled cane growers. The third objective was to employ the Truncated Regression model to identify key socio-economic sources of technical efficiency; this chapter relied on field survey data of 300 sugarcane growers.

The fourth objective measured input-oriented technical, cost and allocative efficiency of 160 small-scale sugarcane growers in the Felixton and Amatikulu regions. The fifth objective investigate the determinants of technical, cost and allocative efficiency in the Felixton and Amatikulu regions. Both objectives used the DEA and Truncated Regression model. The sixth objective decomposed agricultural efficiency change in small-scale sugarcane growers in the Amatikulu region using the Färe Primont Index (FPI) using farm-level data for 38 small-scale growers. Furthermore, the Bayesian Modelling Average technique (BMA) investigated policy-related sources of small-scale sugarcane productivity to investigate determinants of total factor productivity to address objective seven. The last objective was to identify the barriers to technical efficiency using a qualitative approach known as Thematic Analysis (TA) using semi-structured interviews involving fewer than ten participants and Focus Groups (FGs) with extension officers in both Felixton and Amatikulu regions.

The results of the DEA showed that low cost and allocative compared to technical and scale efficiency with distribution of technical efficiency ranging at 60%. The study also reported a higher technical efficiency compared to chemical-use efficiency. The determinants of technical efficiency were education, off-farm income, experience, and extension support and land size. The results of agricultural productive efficiency in the Felixton and Amatikulu regions reported mixed mean scores. The technical scores in both regions were almost equal, but exhibited significant differences in cost and allocative efficiency. Socio-economic factors such as experience, education, and access to credit and employment status of the small-scale sugarcane grower showed a positive relationship with technical, cost and allocative efficiency.

The findings of the FPI approach revealed increased input growth in both input mix and input scale mix efficiency. However, input technical efficiency reported a negative input growth. The sources of TFP were education, sustainability investment, and education of the small-scale grower. The qualitative analysis in chapter seven identified four clear barriers to technical efficiency. Market dynamics were reported as very hard issues to keep up with because they are very tricky. The findings of the qualitative approach also reported the severe distress small-scale sugarcane growers experienced because of drought as one of the environmental challenges faced in the optimisation of technical efficiency. The results also reported technical difficulties because of poor support from extension officers and the slow response of the contractors.

The study recommends agricultural policies targeted at agricultural research and development, educational development, and the adaptation of innovative technologies. Furthermore, there is a need to improve stakeholder involvement and regulation of the sugar industry to promote long-term efficiency and productivity.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ADA	Agribusiness Development Agency
BBBEE	Broad-Based Black Economic Empowerment
BMA	Bayesian Modelling Averaging
CASP	Comprehensive Agricultural Support Programme
CRS	Constant Return to Scale
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Data Envelope Analysis
DMU	Decision Making Unit
DRDLR	Department of Rural Development and Land Reform
ECGs	Emerging Cane Growers
FAF	Financial Aid Fund
FG	Focus Group
FGDs	Focus Group Discussions
FPI	Färe-Primont Index
GDP	Gross Domestic Product
GLS	Generalised Least Square
GT	Grounded Theory
GMM	Generalised Method of Moments
IPA	Interpretive Phenomenological Analysis
LP	Linear Programming
MAFISA	Micro-Agricultural Financial Institutions of South Africa
MPI	Malmquist Productivity Index
PFP	Partial Factor Productivity
PIP	Posterior Inclusion Probabilities
PPS	Production Possibility Set
PTO	Permission to Occupy
RADP	Recapitalisation and Development and Land Reform
R&D	Research and Development
RVP	Recoverable Value Price
SADC	Southern African Development Community
SACGA	South African Cane Growers Association
SASA	South African Sugar Association

SASID	South African Sugar Industry Director
SBM	Slack-Based Measure
SEFA	Small Enterprise Finance Agency
SFA	Stochastic Frontier Analysis
SVM	Sub-Vector Measure
TA	Thematic Analysis
TFP	Total Factor Productivity
VRS	Variable Return to Scale

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

South Africa is the leading cost-competitive producer of high-quality sugarcane in the African continent, followed by Sudan. However, compared to other sugarcane producing countries in the world the industry is ranked fifteenth (SASID, 2017). The South African sugar industry is diverse with highly productive commercial producers and largely inefficient indigent small-scale growers. There are approximately 20 562 small-scale sugarcane growers, out of which 12 994 produced and processed sugarcane in the 2014–2015 season, at the backdrop of dire drought that forced fallowing of plots. These growers accounted for 10.3% of the total crop produced in South Africa. Furthermore, 75% of sugarcane produced by these small-scale sugarcane growers relied on natural rainfall alone to water their crops (SASID, 2017).

Driven by concerns of feeding a rapidly increasing world population and promoting thriving agricultural businesses to stem the tide of urban migration, the focus on the role of small-scale agriculture to create sustainable livelihoods has gained popularity among development specialists globally (Machete, 2004). The Millennium Declaration focuses on a variety of environmental aspects of interest to different fields. In e productive agricultural sector, the pressure associated with higher output may have resulted in degradation of the natural resources. Particular groups focused on agricultural sustainability and food security tend to safeguard their environments against degradation. In the South African context, the National Development Plan as the blueprint for development in agriculture has targeted small-scale farming as a vehicle to create 370 000 improved livelihoods in previously disadvantaged regions (NPC, 2011).

According to Machete (2004) small-scale agriculture in the impoverished rural communities remains a noble contributor to food security, sustainable livelihood and a vehicle for poverty reduction. The natural shocks such as drought and flooding, and other externalities impact directly or indirectly on small-scale agriculture, which raises concerns for long-term food insecurity and production. The 2015–2016 drought episode in South Africa decimated the agricultural sector and posed a serious challenge to the incomes of indigent farmers and the promotion of food security among rural communities. In general, small-scale agriculture operates in dire circumstances and needs government support to produce at optimum levels.

Amidst the mentioned unfavourable conditions, the South African government has shown special interest in small-scale agriculture as a vehicle for rural development, but lack of access to funding, adaptation of innovative machinery and structural land ownership still threaten small-scale agricultural production. The improvement of agricultural productivity, in the face of various negative externalities, is the only effective strategy to address food security in rural communities compared to other solutions. The other strategies include reducing over-dependence on other sectors of the economy as well as alleviating poverty in rural areas through employment creation and improving farm income that results in access to food (Lefophane *et al*., 2013; Aye and Mungatana, 2011). Government support of small-scale agricultural development resulted in policy initiatives that were aimed at land reform, agricultural credit provision, infrastructure development and comprehensive support services to farmers aimed at improving agricultural productivity.

Agricultural productivity and efficiency translate to farm performance techniques focused on ways in which a grower improves profit by minimising usage of inputs while maximising output in the least cost manner. Therefore, knowledge of productive efficiency among small-scale sugarcane growers is consistent with government's development agenda of promoting food security through the encouragement of farming, and improving productivity to address rural poverty. According to Khan *et al*., (2014) there has been a decline of agricultural productivity growth in developing countries, mainly due to under or over utilisation of resources.

During the 2014/2015 and 2015/2016 seasons, there was a decline in sugarcane production in South Africa, mainly in the small-scale sugarcane sector, largely due to drought conditions but also due to lack of vital knowledge, and infrastructural and other input constraints (SASID, 2017). However, globally the demand for sugarcane has been increasing against the backdrop of a production decline especially among small-scale growers, hence, a need to estimate indicators of productive efficiency as key performance management tools for the purposes of fostering improved agricultural production among the mentioned farmers (Tang *et al*., 2015; Henderson, 2015, Ndlovu *et al*., 2014). Additionally, small-scale sugarcane growers need to be aware of both their performance management abilities and of the available innovative technologies used by their peers, to help maximise yields amid challenges and constraints they face in producing sugarcane.

Furthermore, the efficiency of small-scale farmers is important in order to eliminate the productivity gap between large-scale efficient and small-scale inefficient sugarcane growers (Rios and Shively, 2016). The inefficiency of small-scale sugarcane growers may stem from having limited land, labour, capital and farming acumen. It is important for small-scale sugarcane growers to understand how to achieve optimal output given the available input mix and their respective costings, especially since sugarcane farming involves high production costs, thus regular assessment of cost and allocative efficiency of sugarcane production is critical to achieving the desired ends (Murali and Prathap, 2017).

Therefore, benchmarking and estimation of productive efficiency and efficiency growth among small-scale sugarcane growers is of vital importance to mills, growers, extension officers and policymakers as well as other stakeholders involved in the sugar industry. Within this context, it becomes crucial to study the barriers that are faced by small-scale sugarcane growers for it will provide insight into the nature of the decline in production as well as the appropriate measures that may be adopted to improve yields and hence incomes.

Thus, policy-makers and regulators in small-scale sugarcane production should take note of the need to improve productive efficiency and efficiency growth by focusing on socio-economic factors and external factors that constrain the growth of small-scale growers. Understanding policy related determinants of technical efficiency and efficiency growth is imperative to the upliftment of small-scale sugarcane growers. Further, policy implications that may improve efficiency in the small-scale sugar industry are drawn. Investigating the barriers of small-scale sugarcane growers by applying an in-depth qualitative approach has not been examined. Sustainable small-scale sugarcane production is a major worry considering that there has been a decline in cane production in South Africa.

This study aimed to evaluate agricultural efficiencies, productivity and efficiency change and identify barriers to technical efficiency of small-scale sugarcane growers in the sugar producing regions of the King Cetshwayo district municipality. The study used the non-parametric approach to analyse productive efficiency, productivity, and efficiency change, and also applied the qualitative approach to identify the barriers to technical efficiency. The study presents four analytical chapters. The first and second use labour, chemicals, fertilisers, machinery and seeds to represent inputs and sugarcane yield to represent output. Moreover, this chapter uses socio-economic factors to investigate the effect of such dynamics on production. The third uses land, fertiliser, capital and labour to represent inputs and sugarcane yields, while livestock and seed cane were used to represent output. This chapter goes further and applies policy related variables, i.e. education, experience, extension visits, land size and sustainability investment to provide policy direction in small-scale sugarcane production. Lastly, the qualitative approach, using focus group discussion and semi-structured interview identified barriers faced by small-scale sugarcane growers in optimising technical efficiency.

From a review of previous studies that measured productive efficiency and productivity of small-scale sugarcane the study identified the following gaps:

1) Analysis of technical, allocative and cost efficiency and the determinants of technical efficiency using Data Envelope Analysis (DEA). Moreover, the use of input-slack based measure to account for use of chemical input in the production of sugarcane.
2) No study has decomposed productivity and efficiency growth of sugarcane growers using farm data. The decomposition of panel secondary data supplemented with primary data provided finer components of Total Factor Productivity (TFP).

3) The study identified challenges and constraints faced by small-scale growers using a qualitative approach and developed themes, an approach that has not previously been applied.

1.2 Research Objectives, Hypotheses and Questions

The primary objective of this thesis is to evaluate agricultural efficiencies, productivity and efficiency change and identify barriers to technical efficiency of small-scale sugarcane growers in the sugar producing regions of the King Cetshwayo district municipality.

The specific objectives therefore were as follows:

i. To estimate input-oriented technical, cost and allocative efficiency of small-scale sugarcane growers in the King Cetshwayo district of KwaZulu-Natal.

ii. To determine the impact of input-slacks on technical efficiency of small-scale sugarcane growers in the King Cetshwayo district of KwaZulu-Natal.

iii. To identify determinants of technical efficiency of small-scale sugarcane growers in the King Cetshwayo district of KwaZulu-Natal, as well as the determinants of technical, cost and allocative efficiency in Felixton and Amatikulu regions.

iv. To measure input-oriented technical, cost and allocative efficiency in small-scale sugarcane growers in the Felixton and Amatikulu regions.

v. To investigate the determinants of technical, cost and allocative efficiency in the Felixton and Amatikulu regions.

vi. To decompose productivity and efficiency change of small-scale sugarcane growers in the Amatikulu region.

vii. To investigate determinants of total factor productivity growth of small-scale sugarcane growers in the Amatikulu region.

viii. To identify barriers to technical efficiency in small-scale sugarcane growers in the King Cetshwayo district of KwaZulu-Natal.

The study addressed the following research questions using a qualitative approach that was undertaken:

i. What are the barriers to technical and allocative efficiency faced by small- scale growers in the King Cetshwayo district of KwaZulu-Natal?

ii. What strategies have small-scale cane growers adopted in response to drought conditions to improve technical efficiency?

iii. Are government support and intervention programmes effective for technical efficiency?

iv. What is considered to be an appropriate government intervention support programme to improve technical efficiency?

The quantitative aspect of the study tested the following null hypotheses which emerged as the objectives of the study:

i. There is no input-oriented technical, cost and allocative efficiency of small-scale sugarcane growing within the King Cetshwayo district of KwaZulu-Natal.

ii. There is no negative impact of input-slacks on technical efficiency of small-scale sugarcane growing within the King Cetshwayo district of KwaZulu-Natal.

iii. There are no known determinants of technical efficiency of small-scale sugarcane growing within the King Cetshwayo district of KwaZulu-Natal.

iv. There is no input-oriented technical, cost and allocative efficiency of small-scale sugarcane growing within the Felixton and Amatikulu regions.

v. There are no known determinants of technical, cost and allocative efficiency of small-scale sugarcane growing within the King Cetshwayo district of KwaZulu-Natal.

vi. There is no productivity and efficiency change of small-scale sugarcane growers in the Amatikulu region.

vii. There are no known determinants of total factor productivity growth of small-scale sugarcane growers in the Amatikulu region.

1.3 Conceptual Framework of the Thesis

Small-scale sugarcane technological performance and low productivity is still a challenge in developing countries. Small-scale sugarcane growers' efficiency and efficiency growth are influenced by different factors that are a result of internal and external factors in the sugarcane production supply chain. Internal factors are as a result of poor input allocation, slow adaptation of technology, lack of appropriate knowledge, poverty levels and lack of motivation. External factors emanate from different stakeholders that are involved in the sugar industry. The global sugar market issues, socio-economic factors, policy reforms and governance, adverse weather changes, training and extension support as well as food prices are some of the external issues that affect small-scale sugarcane production.

The amalgamation of these factors contributes to both the demand and supply of sugarcane. On the demand side, Recoverable Value Price (RVP) volatility and increased tariffs play a strong role in determining the sugar market as well as the channels for which the processed sugar is destined. Both the RVP volatility and increased tariffs also affect the supply of sugarcane to the mills.

In order to optimise efficiency and productivity, there is need sustain sugarcane production and contribute to agricultural policy reform by analysing biographic factors. Biographic factors such as age, gender, income, education and experience, to mention a few, contribute to the production of sugarcane. Low efficiency and productivity imply low tonnage of sugarcane supply, which leads to food insecurity and poor livelihood for small-scale sugarcane growers. Figure 1.1 presents the relationship between the following three approaches of this thesis.

The first approach relates to the minimisation of production inputs to optimise output It further investigates the determinants of agricultural productive efficiency using socio-economic factors (Mahjoor, 2013; Watto and Muregwa, 2014; Watkins *et al*., 2014; Terin *et al*., 2017). The results drawn from other empirical studies (Thabethe *et al*., 2014; Dlamini *et al*., 2010) which focused on small-scale sugarcane in South Africa and eSwatini that applied parametric approaches also necessitated the need to conduct a study solely focused on a non-parametric approach.

The second approach focused on the long-term production of the small-scale sugarcane grower by decomposing productivity and efficiency change, as motivated by (Fuglie and Rada, 2013; Rahman and Salim, 2013; O'Donnell, 2014; Majiwa *et al*., 2017) using farm-level data. This approach further investigates the sources of TFP growth using policy-related variables. This approach presents key policy issues aimed at improving small-scale sugarcane productivity and also explains the role subsidies, research and development play in the sugar industry in Northern Kwazulu-Natal.

The last approach focused on addressing the constraints and challenges faced by small-scale sugarcane growers and they affect technical efficiency using a qualitative technique. This approach was motivated by the unique nature of the qualitative method in discovering the experiences and understanding of participants in defining their production barriers to technical efficiency. The current study develops a thesis framework to contribute to the knowledge based on these approaches.

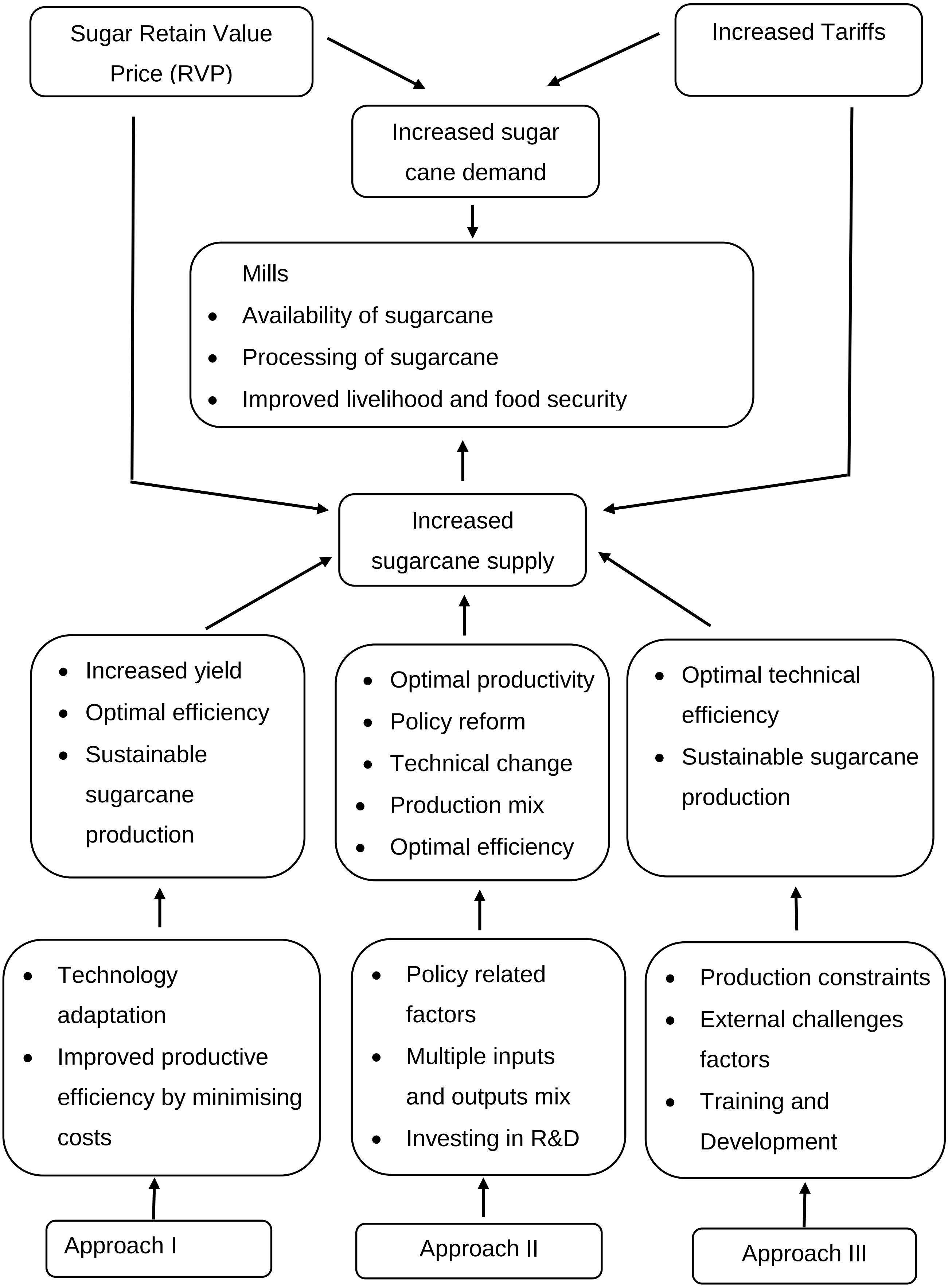

FIGURE 1.1: CONCEPTUAL FRAMEWORK OF THE THESIS

1.4 Contribution of the study

Few scholars that have estimated the productive efficiency of small-scale sugarcane growers in South Africa and its determinants used SFA and the Cobb-Douglas production function. However, the literature is still limited on studies that measure agricultural productive efficiency and its determinants using DEA, particularly focused on small-scale sugarcane growers. The literature also fails to decompose productivity and efficiency change, and how policy-related variables affect total factor productivity.

The first analytical approach of the thesis estimates and investigates technical, cost and allocative efficiency. It further draws input slack from chemical use efficiency and compares it to technical efficiency using DEA, a gap not filled by existing studies. The study also investigates the determinants of productive efficiency by using socio-economic variables, including age, gender, education, off-farm income, experience, land size, extension support, employment status and size of household.

The second analytical approach of the thesis was motivated by low efficiency scores and support from the stakeholders to the small-scale sugarcane growers because growers were experiencing harsh climatic conditions. The multiple farm-level inputs and outputs data were sourced to decompose productivity and efficiency change of small-scale sugarcane growers into finer components, an estimation that has not been explored by existing studies. The study also investigates the sources productivity and draw policy insight using variables.

The last analytical approach draws on the qualitative approach to identify barriers to technical efficiency using TA. This approach was motivated by the need to unearth clear experiences and understanding of internal and external factors that have an influence on technical efficiency. At present, there is limited in-depth understanding of dynamic factors that affect production of small-scale sugarcane growers. In the absence of in-depth knowledge, both growers and extension officers participated in focus group discussions and informal interviews to provide key issues on this subject.

This thesis will contribute to existing studies that have applied different models in South Africa, because it applied a sequential method of analysing the quantitative approaches and use their findings to devise the qualitative approach to find out more about factors that serve as barriers to technical efficiency. This thesis will further provide policy-makers and stakeholders with well-informed insights that will offer clear legislative direction.

1.5 Structure of the thesis

This chapter presented the introduction of the sections, background of the study as well as the research objectives, hypotheses and questions that are going to be answered by the study. Furthermore, the previous section of this chapter has presented the conceptual framework and the contribution of the study. The rest of the thesis proceeds as follows:

Chapter two outlines an overview of sugarcane production in South Africa. This chapter presents the agricultural policies in South Africa, followed by a brief history of sugarcane in KwaZulu-Natal. Sugarcane production trends are discussed in detail and it describes the sugarcane supply chain. It concludes with a presentation of the socio-economic dynamics of the sugar industry.

Chapter three provides a conceptual framework of agricultural efficiency, productivity and barriers to technical efficiency. This chapter reviews the theoretical literature as well as the theoretical model of DEA efficiency followed by a review of empirical studies on agricultural efficiency. This review is important for the first theme of the thesis that estimates technical, cost and allocative efficiency and its determinants in the King Cetshwayo district municipality in chapter four. The chapter also presents a review of the theoretical literature focused on productivity and efficiency change followed by the theoretical model of productivity and efficiency change and, lastly, a review of empirical studies on productivity. This review is critical for the second theme of the thesis that decomposes productivity and efficiency change and the sources of policy-related variables in the Amatikulu region in chapter five. It ends with a conceptualisation of the barriers to technical efficiency and concludes with a summary. The conceptual review of the barriers is important for the qualitative approach that was analysed in chapter six.

Chapter four presents the application of DEA to measure technical, cost and allocative efficiency and determinants of technical efficiency as well as input-slack. It begins with an introduction and proceeds to the methodological and theoretical framework. The study area and the data applied in the estimation are discussed and followed by the empirical results and discussion. The last part of the chapter provides a summary and the conclusion. This chapter makes use of DEA, the input-slack model, and the Truncated regression approach to estimate agricultural productive efficiency and its determinants using cross-sectional data.

Chapter five compares the measurement of technical, cost and allocative efficiency and its determinants in the Felixton and Amatikulu regions. The chapter forms part of theme I of the thesis and starts with an introduction, followed by the methodology empirical results and discussion and later the conclusion as well as clear policy implications. This chapter applies the same methodologies that were applied in chapter four to compare productive efficiency scores and investigate factors that affect efficiency in both Felixton and Amatikulu regions.

Chapter six presents the analysis of productivity and efficiency change of small–scale sugarcane growers in the Amatikulu milling region. This chapter begins with an introduction, followed by the methodological framework. It further elaborates on the study area and the construction of data variables. It presents the empirical results and provides discussion, as well as providing a summary and conclusion. The Färe-Primont Index and the Bayesian Model Averaging were applied to decompose and investigate TFP and its sources.

Chapter seven presents the barriers to technical efficiency of small-scale sugarcane growers in the Amatikulu region. This chapter uses the qualitative approach to develop themes based on small-scale sugarcane growers' experience and understanding. The chapter starts with an introduction, the methodology and the results of the study. It ends with discussion and the conclusion of the study.

CHAPTER TWO

AN OVERVIEW OF SUGARCANE PRODUCTION IN SOUTH AFRICA

This chapter provides an overview of sugarcane production in South Africa. The chapter introduces the South African agricultural sector, and provides an insight into agricultural policies in South Africa, the South African sugar industry, the sugarcane supply chain and the socio-economic dynamics of the sugar industry.

2.1 Introduction

The South African agricultural sector is characterised by a dualistic system comprising both commercial and subsistence farmers. The commercial farmers are mainly established and produce on large portions of land, taking advantage of modern machinery and capital-intensive systems. The commercial farmers are categorised into established and emerging producers. Among the emerging producers are the majority of native African farmers producing on small plots with limited machinery and mainly labour-intensive systems and commonly known as small-scale farmers. The small-scale farming structure is synonymous with low productivity as a result of distortions in land allocation, limited access to inputs, agricultural credit, output market, and provision of infrastructure and services (Makhura, 2001; Binswanger and Deininger, 1993).

The concept of small-scale farmers exists in three spheres as net food buyers, intermediate growers and net food sellers, based on the relationship between land size in hectares and the above three spheres. Net food buyers practise on less than 0.7 hectares, intermediate growers operate between 0.7 and 1.5 hectares, while net food sellers practise on more than 1.5 hectares (Baloyi, 2011). These farmers' contribution to the economy is difficult to measure and thus leads to a lack of vital data necessary to advise and support such farmers which, in turn, affects their ability to expand and grow. The South African agriculture diversification and the involvement of small-scale farmers cover the three main sectors of agriculture, i.e. livestock, horticulture and field crops. The diversity among smallholder farmers across the sectors calls for focused policy interventions targeted at characteristics of a particular group. Small-scale agriculture in South Africa is seen as a vehicle through which the developmental goals of poverty reduction and rural development can be achieved.

The small-scale sector suffers dire consequences emanating from the responsibility to improve rural livelihoods. Challenges related to economic issues create a stumbling block in the acquisition of inputs, adoption of innovative technology and access to capital. Moreover, these challenges, accompanied by harsh climatic conditions, call for intervention from governmental and non-governmental institutions. The history of governmental involvement in South African agriculture has been more favourable to commercial farmers to the neglect of the majority of small-scale farmers. The neglect is evident in land ownership patterns and scope of production.

The history of South African agricultural post the new dispensation also reveals unfavourable land ownership patterns. In 1994, after the apartheid and post-colonial dispossession, the patterns of land ownership showed unequal distribution; the majority of the population in native blacks owned 13% while whites owned 87%. As a consequence, post-apartheid land reform was introduced to redress the injustices of the past. The land reform policy at its slow pace had only transferred 7.95 million hectares (7.5%) from white ownership to the native black population by 2012 (Nkwinti, 2012). As a result, the patterns of land ownership have not changed, while only small numbers of blacks with access to capital acquire land independently without government assistance. A host of small-scale farmers are scattered in former homelands sharing communal lands that cover 17.2 million hectares, with only 14.5 million hectares considered agricultural land (DAFF, 2011). This land is under the custodianship of local kings and chiefs and results in most rural dwellers failing to own land directly and relying mainly on “Permission to Occupy” (PTO) to occupy the land. Although the need for agrarian reform and expanding land ownership to stimulate productivity has been of utmost important post-1994 there is still a lot to be desired.

The natural shocks, including drought, flooding and other externalities impact directly or indirectly on agricultural efficiency and productivity, which raises concerns for long-term food security. The recent occurrence of drought in South Africa has exacerbated the agricultural challenge of poor access to markets and low capital, poverty and has posed a challenge to the promotion of food security and nutrition. Disadvantaged small-scale farmers who were ill-equipped in terms of the latest technology and knowhow and with limited resource found it very hard to produce in times of climatic change. Moreover, small-scale farmers lack access to information and established markets, which hinders their capacity to explore entrepreneurial abilities (Chitja and Morojele, 2014).

The majority of small-scale sugarcane growers have access to small plots of land averaging between 1.5 and 2 hectares. These plots are mainly in tribal areas of KwaZulu-Natal and the holders have the PTO before accessing the plot for farming (Ntshangase, 2016; Le Gal *et al*., 2005). The poor access to land has been seen as a serious drawback for small-scale sugar growers and is associated with the inability to efficiently plant, grow, cut and deliver cane to mills. Faced with these land challenges, the sugar industry has strived to transform the industry by introducing land ownership programmes aimed at improved racial diversity and tonnage produced by those different groups. Although the Emerging Cane Growers (ECGs) programme was rolled out to assist black sugarcane production there is still a need for key policies focused on improving the efficiency and productivity by promoting access to the market, access to land, and social development of small-scale farmers in South Africa.

2.2 Agricultural Policies in South Africa

During the apartheid era, policies aimed at promoting white commercial farmers flourished at the expense of the poor black farmers. The Native Land Act of 1913 pioneered the unequal distribution of land accompanied by the Administration Act of 1927 and many amendments made to these policies in the 60’s managed to control access to land (Vink and Kirsten, 2000). Subsequently, the introduction of these policies resulted in dualistic patterns of land ownership while limiting black farmers from being small-scale farmers with very little economic benefits derived by the fulfilment of subsistence goals. In most communal villages under chieftaincies the adaptation of these policies restricted women small-scale growers to domestic chores because of their cultural social status in a traditional setting.

In an attempt to address inequality, the agricultural sector saw the introduction of numerous land and agrarian policies at the dawn of democracy. The reform introduced the Marketing of Agricultural Product Act of 1996 which focused on access to the agricultural market for small-scale farmers. This act paved the way for vital policies aimed at redressing the injustice of the past and to push small-scale farmers into the capital-oriented and international competitive sector. The Land and Agrarian Reform

Programme and the Comprehensive Agricultural Support Programme (CASP) was in place by 2001 to advance support for black farmers. Overall, there is a belief that the land reform programme has failed to transfer the land to the targeted beneficiaries because of its" willing buyer willing seller" objective. In general, the concept of "willing buyer willing seller" is seen as a voluntary transaction between a seller and a buyer. However, in the South African context, the land owner is perceived as not willing to sell the land while government is not willing to buy land at a higher price charged by the owner. It has been recorded that the South African sugar industry has transferred 21 per cent of land from white to black sugar growers since 1994 SASA (2017). There are parliamentary processes underway to change the relevant section of the constitution to broaden the scope of land reform through expropriation without compensation. Beneficiaries that have acquired land finds it difficult to leverage loans and other support from commercial banks because of lack of income incentives and collateral (Graham and Lyne, 1999; Mbatha and Antrobus, 2012).

With the failure of the land reform programme, the Comprehensive Agricultural Support Programme (CASP) was linked to land reform processes aimed at funding small-scale farmers to overcome the difficulty of leveraging funds. The role of this initiative is still puzzling as a developing strategy for effectively supporting small-scale farmers (Chitja and Morojele, 2014). This is on the back of big budgets channelled through provincial departments with little coordination and administration. Furthermore, with little support, the programme proved difficult to deliver the expected outcomes of improving farming efficiency, sustaining rural development, reducing poverty and inequality in land enterprise ownership, and the creation of wealth in agriculture and rural areas. The Broad-Based Black Economic Empowerment in Agriculture policy of 2003 (Agri-BBBEE) focused on giving procurement preference to emerging small-scale farmers who meet the scorecard points to promote economic participation of native small-scale farmers (NDAFF, 2012). This programme requires native black farmers to partner with commercial farmers in the promotion of economic transformation through skills transfer.

The National Department of Agriculture's Forestry and Fisheries appointed several universities to conduct research focused on different themes. The focus of themes centred on the Zero Hunger Programme with focus on the adaptive measures that small-scale farmers can implement in order for them to access established formal markets. In contrast to this focus, other related challenges like input supply, provision of credit and acquiring information about innovative technologies is still synonymous with poor small-scale farmers. Moreover, the challenges of sending produce timeously to the market, and provision of inputs still remain barriers to the expansion of small-scale farmers into the formal market. The above-mentioned policies and programmes have had limited success in diffusing the dualistic nature of the South African agricultural sector.

Lastly, the sugarcane industry introduced a flagship programme aimed at distribution of land to black growers in the form of the ECGs. The programme resulted in an increase of black-owned sugarcane land from 5% to 22% between 1994 and 2014 (SASA, 2014). The programme paved the way for the transfer of over 74 405 hectares under cane to land reform beneficiaries. For the ECGs to prevail the sugar industry has entered into different partnership agreements with different stakeholders aimed at sourcing grant funding, co-funding arrangements, inputs schemes and loan facilities. The Recapitalisation and Development Programme (RADP) in partnership with the Department of Rural Development and Land Reform (DRDLR) has resulted in the increase of the area under cane production. The KZN Agribusiness Development Agency (ADA) has contributed millions through CASP, while the KZN Department of Agriculture and Rural Development has provided funds aimed at the mechanisation of farms, fertiliser schemes and cane development. The Micro-Agricultural Financial Institutions of South Africa (MAFISA) and the Small Enterprise Finance Agency (SEFA) provide a loan facility for the sugar industry. Despite these partnerships the small-scale sugarcane industry is still operating with challenges that were supposed to be redressed by the latter partnerships.

2.3 The South African sugarcane industry

2.3.1 Background

The South African sugarcane industry is the 15th largest sugar producing industry out of 120 countries worldwide and its contribution overflows to employment, sustainable development and economic growth. Although it proves difficult to measure the outright contribution of the South African sugar industry to the Gross Domestic Product (GDP) the industry generates an annual average estimation of over 12 billion Rand direct income to the economy (SASA, 2016). During favourable seasons the sugar industry produces an average of 2,3 million tons of sugar produced per season, but the recent occurrence of drought has resulted in a decline to 1,6 million tons of sugar for the season-spanning April 2015 to March 2016 (SASID, 2017). The drop was to be expected because the majority (75%) of the harvested sugarcane in South Africa relies on rainfall.

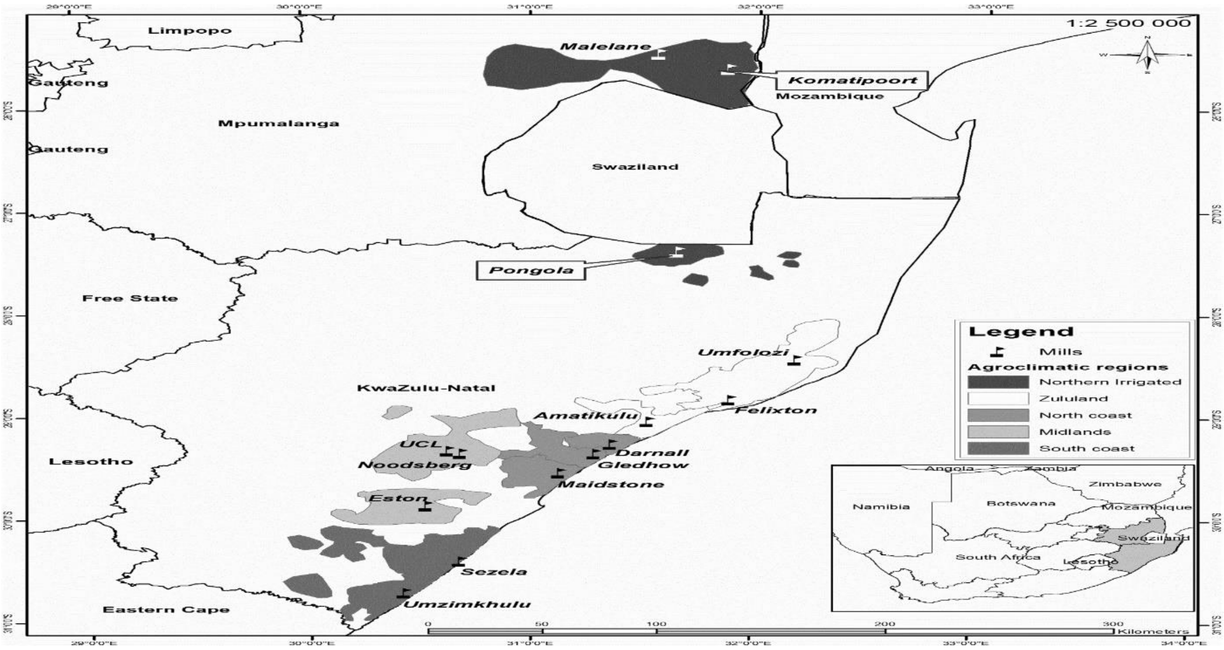

FIGURE 2.1: MAP OF THE SOUTH AFRICAN SUGARCANE INDUSTRY

Source: SASID (2016)

Figure 2.1 presents a map of the sugar industry in South Africa. Production takes place in three provinces and the sugar is processed in 14 mills. The sugarcane production areas vary from the rain feed in KwaZulu-Natal and Eastern cape to the irrigated regions in the Komatipoort, Malelane and Pongola that operate three mills under irrigation. This area is followed by the Midlands region that also operates three mills. The North, the South coast, and Zululand host the remaining mills.

In the context of sugarcane, the term small-scale grower refers to someone who has been an affiliated member of the growers' organisation for a period of more than three years, and who delivers an average of 225 tons or less of recoverable value of cane per season (SASID, 2017). The technologically advanced large-scale sugarcane growers contributed 82%, followed by 10% contributed by small-scale sugarcane growers, while the remaining 8% is accounted for by estates that produce sugarcane (DAFF, 2016).

The South African sugar industry has seen a marginal decline in sugarcane production from the 2010/2011 to 2015/2016 season (SASA, 2017). The decline has seen an influx of imported low priced sugar that is competing with local producers for market share. The RVP payment system was introduced to determine the price of the sugarcane sent to the mill. This system uses the presence of sucrose, non-sucrose and fibre percentages in the sugarcane to determine the price. With this challenging pricing mechanism about 37% of the 2.2 million tons of sugar produced in South Africa in 2015 found export destinations in the Southern African Development Community (SADC) and the rest of the world. The South African sugar industry competes with Brazil, Thailand, Australia and Guatemala in the exportation of raw sugarcane to Europe, Asia, the Far East and the Middle East refineries.

2.3.2 Brief history of sugarcane production in KwaZulu-Natal

The history of Tongaat Hulett as a company that provides extension support and milling for sugarcane in the King Cetshwayo district dates back to 1857 in a town to the north of Durban called Tongaat. Since then, Tongaat Hulett has pioneered the South African sugar industry by supporting development, education and training of different growers. Under the auspices of Tongaat Hulett the Amatikulu sugar mill became operative with a crushing capacity of 7 000 in 1907 and a capacity of 30 tons cane per hour. Its success influenced the establishment of the Felixton sugar mill with a capacity of 35 tons of cane per hour that operated close to the Empangeni mill. In 1930 the sugar industry experienced difficulties in the aftermath of the world depression, severe drought, malaria and infestation of swarms of locust. This unfortunate period resulted in many cane growers abandoning their operations. In the 1960's and 1970's both the Felixton and Empangeni mill were closed and replaced with a bigger new mill in Felixton with a capacity of 400 000 tons of sugar in a season.

2.3.3 Sugarcane Production Trends

Sugarcane thrives in the summer growing season with moist climatic conditions, with a required average rainfall of 1 300 mm per year. Figure 2.2 is a graphical representation of the area planted with sugarcane in hectares per season over the 2002–2015 period. The area planted does not vary much over the years, but an overall gradual declining trend is evident. One notices that between 2002 and 2007 the area planted with sugarcane was over 300 000 hectares. The number of hectares started to decline from 2007 to 2011 and later picked up slightly between 2011 and 2014, but due to drought experienced in 2014 saw a decline in the 2015 production season. Since 2007 the area planted with sugarcane has been ranging between 250 000 to 280 000 hectares.

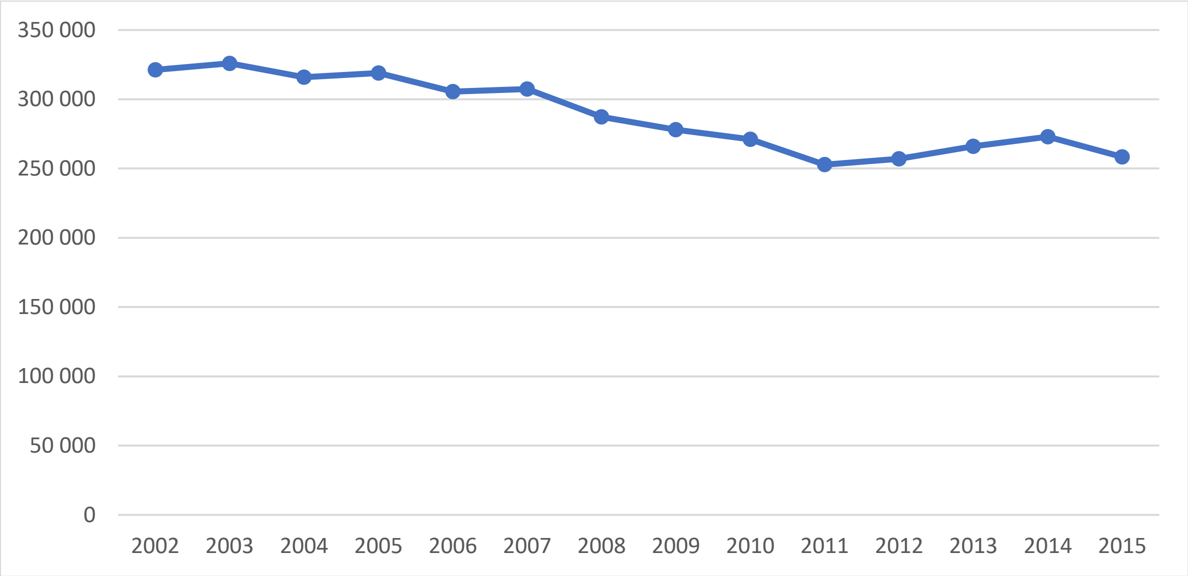

FIGURE 2.2: AREA PLANTED WITH SUGARCANE

Source: DAFF (2017)

Figure 2.3 presents the sugarcane yields and production saleable tons from the year 2002 to 2015 and mirrors Figure 2.2 in every respect. The sugarcane yield and tons sold move in the same direction and do not vary much except for the year 2015 after the drought season. Both the sugarcane yields and saleable tons of sugarcane start with a decline from 2002 to 2004 followed by an increase in 2005 then a period (2006–2009) of sugar yield that was sold at the markets with more constant tons ranging between 2 273 499 and 2 178 450. This period had followed the decline in both variables to reach a tonnage below 2 000 000 until it increased in 2013 and subsequently dropped in 2014 and 2015 because of the drought.

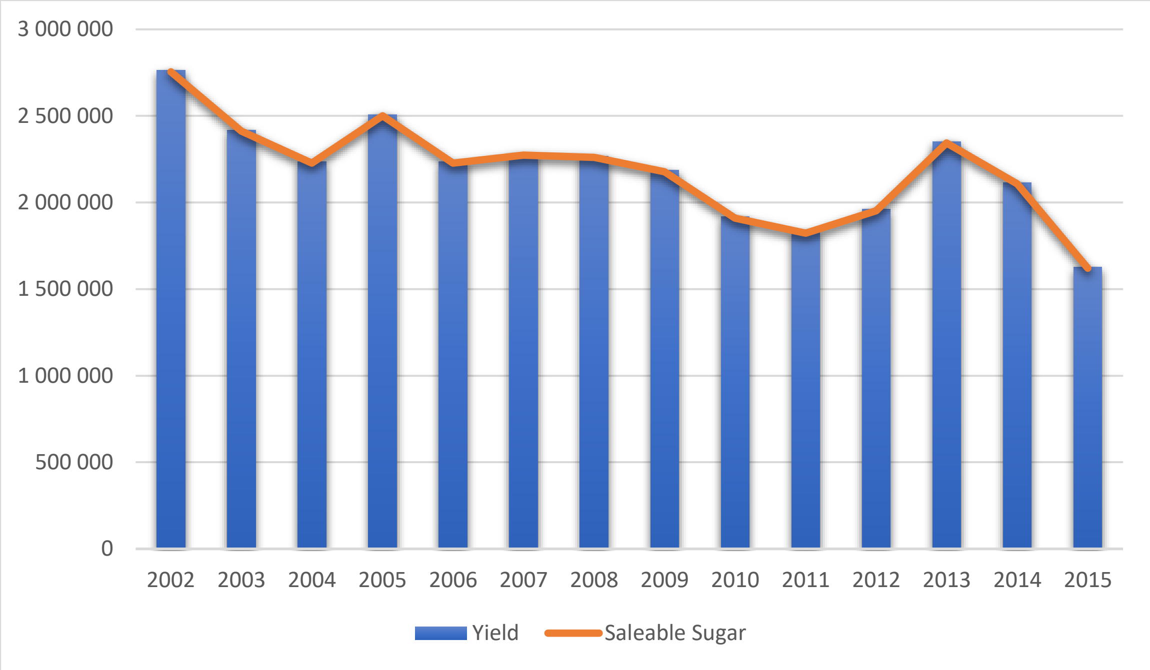

FIGURE 2.3: SUGARCANE YIELDS AND PRODUCTION SALEABLE TONS

Source: DAFF (2017)

Figure 2.4 presents the market destination of South African sugarcane exports to the world in tons. The total tons of sugarcane exported to the African continent surpass those of the other destinations, followed by Asia. The African market reached its maximum exports in the year 2010 with 298 749 tons destined for that market, while minimum exports were experienced recently in 2015 with only 3 528 tons. Asia, the second destination for raw sugar from South Africa, reached its maximum in the 2006 production season with 553 023 tons, which by far still remains the most tons exported in that decade However, it is also regrettable that in the season 2015 no sugarcane was destined for that market. The remaining destinations of Europe and the Americans had very low exports of sugarcane, with no sugarcane destined for those markets from 2013 to 2015.

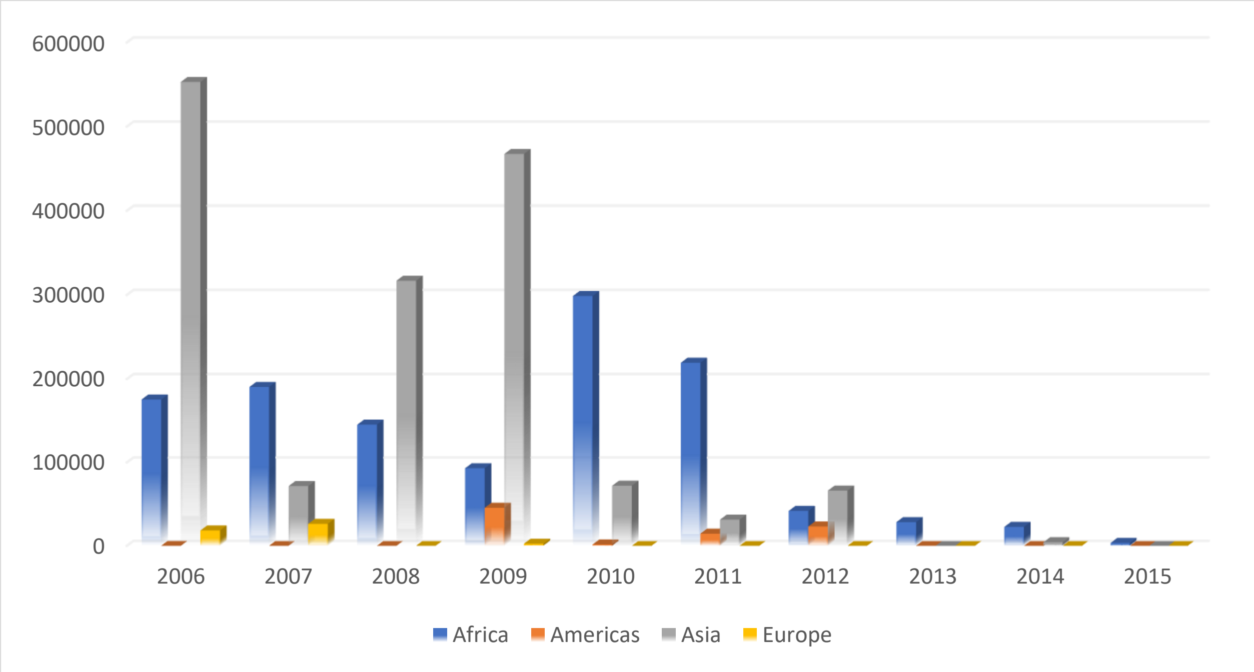

FIGURE 2.4: SOUTH AFRICAN VOLUMES OF SUGARCANE EXPORTS

Source: Quantec (2017)

Against the backdrop of declining exports of sugarcane from South Africa the imports of sugarcane from the world have been increasing. Figure 2.5 presents the import volumes of sugarcane imported from the world to South Africa. The majority of the raw sugar came from the African markets followed by the Americas. There has been an increase in the imports of imports from the African countries starting from the 2012 season and it is not surprising to see that the highest tons imported were in the 2015 season with 206 177. However, the lowest tons imported was 224 tons in the production season of 2009. The Americas were the leading exporters of raw sugar to South Africa between 2006 and 2009; they became the second highest exporter since 2010. However, since 2010 South Africa has been substituting imports from the Americas with those from African countries.

The Americas market over-performed in 2008 with 95 078 tons and underperformed in 2014 with 765 tons. Asia is the last continent that still exports raw sugar to South Africa, but the volume is fairly low, with the highest tons imported from Asia over ten years ago (2007) being 5 616 tons while the lowest was just a ton in 2014. In the year 2015 no sugarcane was imported from Europe or Oceania. Imports from the European market have seen a decline since 2013 after a decade of poor performance. There is little one can say about the Oceanian market that has only imported a ton in the last decade.

Both figures 2.4 and 2.5 provide a clear view of the competition that the South African sugar industry faces. With the RVP being inflation linked it might be cheaper for other countries to send their sugarcane exports to South Africa. If that is the case then policy reform to regulate the inflow of raw sugar can do much for the protection of the of the South African sugar industry.

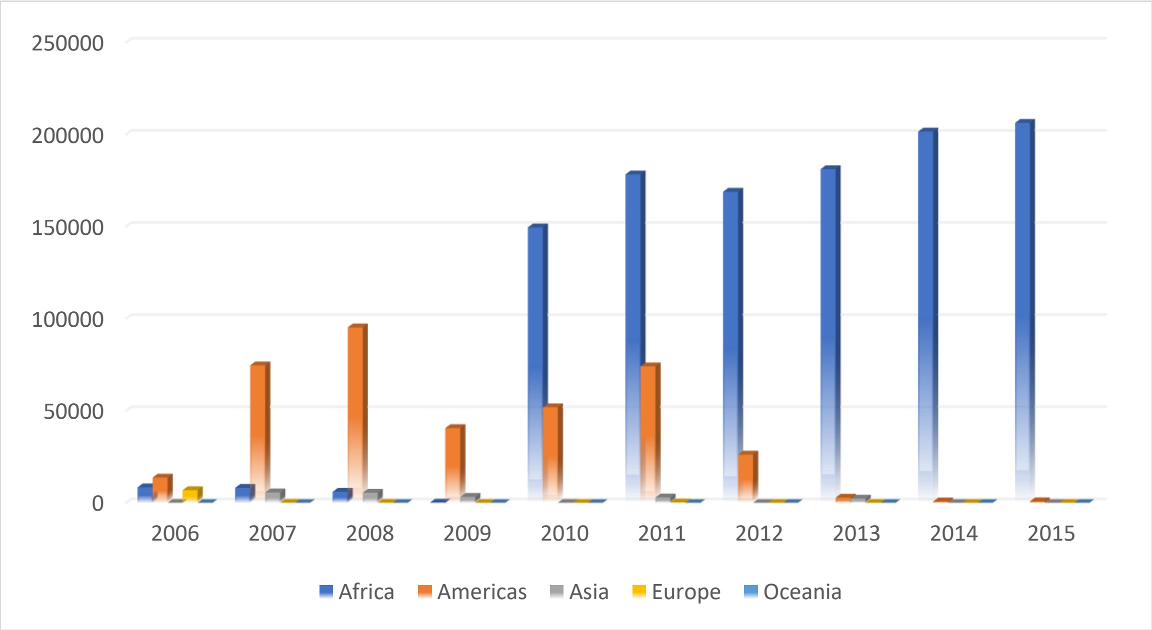

FIGURE 2.5: SOUTH AFRICAN IMPORT VOLUMES OF SUGARCANE FROM THE WORLD

Source: Quantec (2017)

2.4 The sugarcane Supply chain

According to Ntshangase et al., (2016) the sugarcane supply chain is “an inclusive agri-industrial system that aims to grow, harvest, transport and process sugarcane from the field to the mill". Unlike most of the agricultural enterprise supply chain, the sugarcane supply chain is simple and straightforward. The supply chain starts at plot level with the growing of cane and ends at the marketing of retailers. The simple sugar supply chain components developed by Higgins *et al*., (2004) are presented in Figure 2.6.

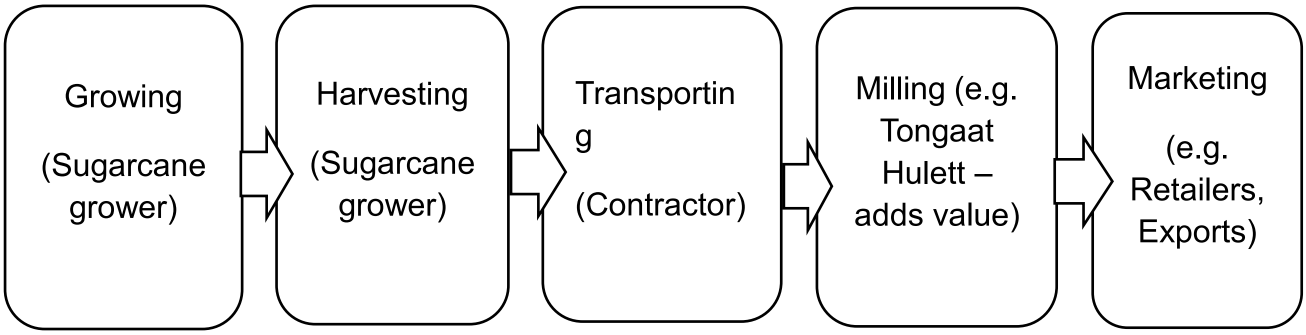

FIGURE 2.6: THE SUPPLY CHAIN COMPONENTS

Source: Higgins et al., 2004

There are a number of processes that take place in each component of the sugarcane supply chain. Higgins *et al*., (2007) as well as Higgins and Muchow, (2003) break down the components into cane growing, harvesting, cane transportation to the mill, mill processing and refining, sugar transportation to the port or market, storage, and retailing to customers. This channel proves that sugarcane growers do not have many marketing possibilities open for their produce since there is no direct link to the customers or secondary market without involving the mills. The over-reliance of the sugarcane growers on the mills exposes them to monopolistic (single buyer controls purchase price) behaviour on the part of the mills.

The sugarcane growers produce, harvest and transport their raw sugar to the mill. In this process hired labour is used to cut burnt or green sugarcane to be transported to the mill by a contractor. This process is mainly mechanised and affords the fastest available approach to stack the sugarcane to loading zones. However, the timeous harvesting and stacking do not guarantee timeous delivery to the mill as many factors such as weather, roads, distance to the mill and the allocated time for the sugarcane grower to cut complicate the delivery process. Failure to timeously deliver the sugarcane to the mill results in the decline in the sucrose per cent of the cane that is the determinant factor in RVP for the sugarcane grower. Upon arrival at the mill, the delivering vehicle is weighed, followed by the offloading of the cane for processing and refinery to generate sugar and molasses (Higgins *et al*., 2007). The processed sugar is sold to domestic and international suppliers for marketing to retailers.

Although this channel seems simple and straightforward there may be few challenges that may impact the desire of the sugarcane grower to minimise production costs to increase the revenue of the farm (Lejars *et al*., 2010). In the 2015–2016 season a total of 1 620 330 tons of sugar was sold to the market at an average RVP of R3 979 22/ton (SASID, 2017). The RVP is influenced by inflation and affects the revenue of the grower when the South African economy is not performing well. The South African Cane Growers Association has called for sugar tariffs to be revised in order to regulate the inflow of cheap subsidised sugar from the world as a last step to improve the domestic sugar prices. To make this a reality, collaborations from different stakeholders is needed to support efficient sugarcane production and limit the inconsistencies in the supply chain. Inconsistencies result in poor planning in respect of harvesting and transportation of cane that impacts on profitability (Le Gal *et al*., 2008).

The most integral part of the supply chain is the cost component incurred for sugar production and other logistics. Therefore, proper ratoon management, resource input allocation and timeous delivery of sugarcane to the mill by contractors are important for profitable production. Profitable sugarcane production is important for rural livelihoods because of its contribution to the rural dwellers. When all stakeholders respond optimally in the production of sugarcane the livelihoods are positively influenced and contribute to a thriving sugar industry that can be self-sustaining.

2.5 The socio-economic dynamics of the sugar industry

Socio-economic factors that affect agricultural enterprises are of the utmost importance as they contribute to policy formulation. Agricultural enterprises in the rural set-up are familiar with difficulties as a result of constraints and challenges faced as a result of underdevelopment of the infrastructure, lack of institutional support and information. Because of its rural location, the sugar industry as part of the agricultural enterprise is seen as a source of curbing poverty, unemployment, inequality and other social ills. The socio-economic impact of the sugar industry on rural dwellers takes both direct and indirect forms. Direct impact is in the form of employment and long-term investment. Indirect impact comes in the form of Broad-Based Black Economic Empowerment (B-BBEE codes). These impacts have an effect on the livelihood of sugarcane growers and contribute to the production of sugar. In South Africa, the sugar industry employs approximately 79 000 people, with an indirect employment figure of 350 000 servicing 29 130 cane growers (SASA, 2018).

Furthermore, the South African sugar industry is a catalyst for rural development since it offers industrial investments and is a labour-intensive sector that attracts many rural dwellers. This is evident from the total of one million people of South Africa's population who derive their livelihood from the sugar industry (SASID, 2017). The recent occurrence of drought has put a damper on the contribution of the industry to the livelihood of small-scale growers. The drought in 2015–2016 resulted in the closure or delayed opening of mills that affected direct and indirect employment, industrial investments and inter-sectoral linkages with other sectors because of lack of availability of sugar.

Because the sugar industry is rural based, the sector prides itself on sustaining communities and building sustainability. Key developmental programmes are focused on funding, training and education, skills development and social enterprise development. The contribution of the sugar industry comes after the work of Maloa (2001) that showed that the industry is the major contributor to the rural economies of Kwazulu-Natal, Mpumalanga and the Eastern Cape, as it provides jobs and indirect benefits in terms of investments. The sugar industry, like other agricultural sectors, is still plagued by inequality in land ownership. In 2015 the South African Sugar Association signed an MoU with the Land Claims Commission, driven by the process of transferring land. Subsequently, the commitment to land reform has resulted in positive developments, with the transfer of 6 364 hectares (SASID, 2017). The ongoing commitment to land reform from the sugar industry and the support of governmental have resulted in the transfer of land from commercial white growers to black growers.

The history of the sugar industry in South Africa outlines key socio-economic factors. SASID (2017) describe the dynamics as follows. In the year 1848, the first crops of sugarcane were planted in KwaZulu-Natal. The sugar industry grew and attracted the sugar market in the Cape and, as a consequence of the rapid growth, it only took thirteen years for the first group of workers that arrived from India to provide their labour. It was in the year 1865 that the first black-owned steam mill was opened, at Amanzimtoti. With sugarcane output growing in the 30 mills that were operating, the Natal Sugar Association was then founded in 1910 to support growers. The production of sugarcane spread to different parts of South Africa and subsequently the South

African Cane Growers Association (SACGA) was founded to deal with the challenges faced by cane growers.

However, there is no clear information about black sugarcane growers' support coming from SACGA. Sokhela (1999) attributed the forefathers of black small-scale growers as the pioneers of sugarcane production in Natal. Because of challenges faced by black sugarcane growers and the non-existence of support from SACGA the Natal and Zululand Black Cane Growers Association was founded in 1936, driven by the need to improve the plight of black cane growers. Later it became known as the KwaZulu Cane Growers Association and joined SACGA in 1981. The South African Cane Growers Association introduced a variety of cane breeds that have adapted to the environment and pest control, and which produce more sucrose. To empower growers and afford them access to these different varieties SASA introduced the Small Growers Financial Aid Fund (FAF) in 1972 to support growers with credit, capital, equipment and basic essentials in order to become viable and efficient farmers.

The FAF was relaunched in 2001 and changed to Umthobo Agricultural Finance. To date, small-scale sugarcane growers are still faced with the same challenges that the FAF aimed to address. In 2008 the provincial government appointed SASA to distribute fertilisers worth R60 million to small-scale growers. However, in the following season, the production of sugarcane dropped to a fifteen-year low (SASID, 2017). In northern KwaZulu-Natal the production of sugarcane and the mills are in the rural areas and have a reputational track record of involvement with local communities and other stakeholders in socio-economic development initiatives that empower local small-scale growers to become sustainable.

The small-scale sugarcane growers benefit from a seed cane subsidy that is paid by Tongaat Hulett that operates from the two mills. The subsidy is enforced by the Memorandum of Understanding. The seed cane subsidy was initiated for sugarcane projects but later adopted to fund individual growers with a minimum of 3 hectares. Moreover, for a grower to be considered, there is need to apply through the extension supervisor. Furthermore, the supervisor gives the permission for part of sugarcane yield to be used as yield seed cane and is also responsible for monitoring and inspection of the seed cane subsidy. Lastly, during the application process, special preference is given to growers who are part of the retention scheme with the mill. If the grower fails to meet the minimum conditions stipulated by the mill the application becomes disqualified. This seed cane subsidy is the sole direct benefit that small-scale growers receive from the mills.

In the King Cetshwayo district there is limited information on the role that government plays in supporting small-scale growers. The need for government to support small-scale growers who fail to benefit from the cane seed subsidy because of owning small plots needs to be considered. Such a contribution will assist the majority of small-scale growers improve their livelihoods which are dependent on the sugar industry. Therefore, there is need to encourage the mills to continue maintaining the relationship with small-scale sugarcane growers and, where appropriate, consider reviewing their subsidy terms and conditions to accommodate a variety of small-scale growers with small plots. Because most of these small-scale growers reside in rural areas, patterns of land ownership are very difficult and disadvantage most growers in terms of mill seed cane benefits. Moreover, sugarcane production for small-scale sugarcane growers is a challenge to growers with small plots. Lastly, institutional challenges also contribute to the problems faced by small-scale growers. Poor and dilapidated infrastructure such as water catchments, roads and bridges all disadvantage small-scale growers.

Therefore the role played by government, mills and other stakeholders may contribute to productive efficiency of small-scale sugarcane growers that operate in rural KwaZulu-Natal. The discussion on the production history, trends and the socio-economic background of the sugarcane industry contributes to the underlying objective of this study. This is due to the need to use the DEA technique and the qualitative approach to address the objectives.

2.6 Chapter summary

This chapter discussed broadly the South African agricultural sector, noting that the small-scale sugarcane industry is located to the agricultural sector. The insight into agricultural policies in South Africa was discussed, focusing on legislation that was aimed to develop small-scale sugarcane growers. The discussion on the South African sugar industry outlined the background and production trends. Lastly, the sugarcane supply chain and the socio-economic dynamics of the sugar industry were outlined.

The following chapter will discuss the conceptual framework of agricultural efficiency, productivity and barriers to technical efficiency.

CHAPTER THREE

CONCEPTUAL FRAMEWORK OF AGRICULTURAL EFFICIENCY, PRODUCTIVITY AND BARRIERS TO TECHNICAL EFFICIENCY

3.0 Introduction

This chapter reviews the literature on agricultural efficiency, productivity and barriers to technical efficiency. Section 3.1 presents a review of agricultural efficiency, and outlines the producer theory and the production efficiency approach. Section 3.2 provides the theoretical model of DEA efficiency. Section 3.3 presents a review of empirical studies on agricultural efficiency; thus, these three sections are with reference to analytical approach one. Section 3.4 provides the conceptual framework for productivity and efficiency change. Section 3.5 presents a theoretical model of productivity and efficiency change. Section 3.6 provides a review of empirical studies on productivity; these three sections are reviews for approach two. Section 3.7 presents a conceptualisation of the barriers to efficiency, to address the last approach. Lastly, section 3.8 provides a summary of the chapter.

3.1 Theoretical Literature Review on agricultural efficiency

3.1.1 Producer Theory

The function of this theory is to separate it from consumer theory, which focuses on the demand behaviour of the consumer. It focuses on the supply aspect of the firm under the notion of market equilibrium to reconcile demand and supply (Levin and Milgrom, 2004). Small-scale growers are described by fixed and exogenously available technologies that transform inputs (labour, chemicals, machinery, capital and land) into output (sugarcane yield). These growers take both inputs and output prices given by the retailers, labour market and RVP from mills to choose a technologically feasible set of inputs and outputs to maximise profit. In their quest as price takers the underlying assumption is what happens to the grower's choice when a price of a particular input changes and what will the implication be for the small-scale sugarcane grower's technology from its choices at various price levels.

Early researchers, e.g. Hicks (1935), Alchian and Kessel (1962) shed useful insights into the production behaviour of firms. Hicks (1935) expressed the view that agricultural firms, as a collective, have the market power to help exploit their production advantage entirely by not bothering to be close to the position of optimum profit rather than by getting close to that point. This was challenged by Alchian and Kessel (1962) in a study which suggests the replacement of the profit maximisation hypothesis with a broader utility maximisation hypothesis, the rationale being to encourage small-scale sugarcane growers to be proficient on the verge of reaching utility. The study went further and explained the outstanding performance of sugarcane growers because they are not regulated in their pursuit of productive efficiency. Competition enhances performance because of its ability to provide profit–generating activities trading off the quiet life advocated by (Hicks 1935; Harold *et al*., 1993).

Suppose that small-scale growers produce sugarcane (single output) with the quantity expressed by q. In order for the small-scale sugarcane grower to minimise the cost of production the problem to solve will be written as follows:

$$\min \mathcal{w} \cdot z$$

$$z \epsilon \mathbb{R}_{+}^{-n}$$

$$\text{s.t } f(z) \geq q$$

To solve this problem the primary assumption is that all input prices are strictly positive: $\mathcal{w} \gg 0$. The primal solution is $z(q, \mathcal{w})$. This solution is the conditional factor demand to indicate that it is conditional on a fixed level of output q. The secondary solution is the optimal value function with the problem as:

$$c(q, \mathcal{w}) = \min \mathcal{w} \cdot z$$

$$\{z : f(z) \geq q\}$$

This solution is called the cost function because it gives the minimum cost at which output q can be produced.

3.1.2 Productive efficiency approach

The focus on productive efficiency was introduced in the early days of Adam Smith but was analytically expanded by the works of (Koopmans, 1951; Debreu, 1951; Farrell, 1957) took the empirical application to the next level and contributed to theoretical significance, while Shepard's work of (Shepard, 1953; Shepard, 1970; Shepard, 1974) models of technology and the distance function contributed immensely to the development of efficiency and productivity. These models contributed to the theory of production function compared to traditional techniques. Furthermore, the distance function models have the ability to characterise all kind of technologies without prior assumptions concerning output aggregation. The Farrell (1957) direct distance function was pioneered as a tool to measure technical efficiency. This approach is central to the decomposition of the productivity and efficiency change that addresses objectives six and seven.

Direct input distance function has the primary role of benchmarking technical efficiency but is not only limited to this since it can be used to construct input quantity and production indexes in a context (Tornqvist, 1936; Caves *et al*., 1982). The DEA, which is the analytical tool applied for empirical analysis in this chapter, falls under the linear programming theory. The work of Charnes and Cooper (1961) contributed extensively in the early stages of the linear programming approach and, to be precise, made it famous through the development of the DEA approach as elaborated in (Charnes *et al*., 1978). In the early millennium, a study (Forsund and Sarafoglou, 2002) which focused on Farrell's seminal paper that introduced the DEA methodology, made an interesting historical reconstruction of the literature. However, Leontief (1941,1953) limited the linear programming analysis to the input-output analysis in the quest to advocate for direct construction of a general equilibrium model. The outstanding work of Shephard (1953,1970,1974), Koopmans (1951,1957) and Afriat (1972) built on it to analyse efficiency based on the microeconomic production programme models to show that inputs and outputs serve as coefficients of activities yielding a piecewise linear frontier technology.

The empirical work of Shepard (1970) and Koopmans (1951) implies the concept of convexity on the available technology, hence the DEA estimator relies on this assumption. Because the DEA envelops data points with linear segments the programming approach reveals the structure of frontier technology while mindful of not imposing a functional form on the available technology. Frontier technology offered ways to compute the distance to the frontier as a way to interpret the efficiency as a maximal-minimal proportionate feasible change in an activity given technology (Daraio and Simar, 2007). This rationale also supported the works of Debreu (1951) and Farrell (1957), but these studies were limited concerning the formulation of the efficiency measurement problem as a linear programming problem.

Derived from the efficiency measurement models for cross-sectional and panel data are the Nonparametric Deterministic Models proposed by (Fare *et al*., 1985; 1994, Fried *et al*., 1993; Charnes *et al*., 1994). These models made developments on the application of the DEA by benchmarking Decision Making Units (DMU's) as well as inputs and output slacks. The Data Envelope Analysis framework is the main nonparametric estimator that is available in the literature on performance management. As proposed by Farrell (1957), and Charnes, Cooper and Rhodes (1978) this linear programming approach assumes free disposability and the convexity of the production set (Daraio and Simar, 2007). The DEA adapts to different returns to scale and can be used to illustrate the concept of input slacks as proposed by Fare *et al*., (1994). The concept of input slacks explains the surplus of input in the DMU in order for it to move to the technical efficient position in the frontier.

3.2 Theoretical model of DEA efficiency

Theoretically, the relationship between farm performance and any socio-economic characteristics is investigated using either a two-stage DEA method or the SFA method which estimate both production frontier and factors influencing inefficiencies simultaneously. The DEA estimator of the production set introduced by Farrell (1957) that operate as the linear programming estimator of Charnes, Cooper and Rhodes (1978) assumes that all small-scale sugarcane growers have access to the same technology for inputs (*x*) into output (*y*):

$$\Psi = \left\{(x, y)\, \epsilon \mathbb{R}_{+}^{p+q} | x \epsilon \mathbb{R}_{+}^{p} \text{ can produce } \; y \epsilon \mathbb{R}_{+}^{p}\right\} \tag{3.1}$$

applying cross-sectional data with each small-scale sugarcane grower's values for inputs and output used in the production process available. The list of p inputs and q

output is defined by means of a set of points, and $\widehat{\Psi}$ is the production set, defined by Eulidean space $\mathbb{R}_{+}^{p+q}$. Therefore, efficiency is measured relative to the boundary of the convex hull of inputs and output as:

$$\widehat{\Psi}_{DEA} = \left\{(x, y)\, \epsilon \mathbb{R}_{+}^{p+q} | y \ \leq \sum_{i=1}^{n} \gamma_i\, y_i\, ; x \ \geq \epsilon \sum_{i=1}^{n} \gamma_i\, x_i, \right.$$
$$\left. \text{for } (\gamma_i, \dots \dots \dots, \gamma_n), \text{s.t.} \ \sum_{i=1}^{n} \gamma_i = 1;\ \gamma_i \ \geq 0, i = 1, \dots., n \right\}$$

(3.2)

where $\overline{\Psi}_{DEA}$ is the smallest free disposal convex set covering all the data and γ_i are the intensity variables that make the process of optimisation. The Variable Return to Scale (VRS) equation (2) can be transformed to Constant Return to Scale (CRS) by dropping the equality constraint, $\sum_{i=1}^{n} \gamma_i = 1$, and Nonincreasing Returns to Scale holds if the inequality constraint is $\sum_{i=1}^{n} \gamma_i \leq 1$. The estimated efficiency DEA scores are characterised by sampling variation because of the deterministic nature of the approach. For a farm operating at level (x_0, y_0) the VRS input-oriented technical efficiency is estimated by decomposing the following linear program:

$$\widehat{\theta}_{DEA}(x_0 y_0) = \min \left\{ \theta | y_0 \ \leq \sum_{i=1}^{n} \gamma_i\, Y_i\, ; \theta x_0 \ \geq \sum_{i=1}^{n} \gamma_i\, X_i, \theta > 0;\ \ \sum_{i=1}^{n} \gamma_i = 1;\ \gamma_i \ \geq 0, i \right.$$
$$\left. = 1, \dots., n \right\}$$

(3.3)

where $\widehat{\theta}_{DEA}(x_0 y_0)$ measures the radial distance between (x_0, y_0) and the level of inputs the unit should reach in order to be on the efficient boundary $\widehat{\Psi}_{DEA}$ with the same level of output, with the same proportion of inputs moving from x_0 to $\widehat{x^{\partial}}(x_0|y_0)$ along the ray θ_{x_0}. Therefore, the projection of x_0 on the efficiency frontier is equal to $\widehat{x^{\partial}}(x_0|y_0)$ = $\widehat{\theta}(x_0, y_0)x_0$. Simar and Wilson (2000) proposed a bootstrapping procedure to eliminate bias efficiency scores. When we assume that all small-scale sugarcane growers are producing the same level of output, different DMUs still fall short of producing the desired unit of y with less input x_1. This process results in a technically efficient DMU exposed to surplus input x_1, and is generally known as input slack, that was expressed by Fare et al., (1994) as follows:

$$\sum_{i=1}^{n} \gamma_i X_i, < x_i^j \widehat{\theta}(x_i y_i) \quad (3.4)$$

Once the efficiency estimates are computed several analyses such as the distribution of efficiency scores and analysis of the best performers can be done. Similarly, if the price of inputs is available the cost minimisation. cost efficiency and allocative efficiency score can be measured based on the small-scale sugarcane growers' success in choosing an optimal set of inputs with a given set of inputs prices.

3.3 Review of empirical studies on agricultural efficiency

3.3.1 Agricultural analysis of efficiency using DEA

In developing countries agricultural productivity growth has been falling (Khan et al, 2014). This decline is attributed to under or over utilisation of resources that may lead to crop diseases, pest, and lack of managerial acumen of the farmer. Studies by (Dawson and Lingard, 1989; Battese and Coelli, 1992; Abedullah and Mushtaq, 2007; Koirala *et al*., 2013) on agricultural productivity and efficiency in developing countries focused mainly on technical efficiency. A handful of studies (Donkoh et al., 2013; Colombi *et al*., 2014; Villano *et al*., 2015; Mishra *et al*., 2015) measured the efficiency of farm production by applying the frontier production function to investigate rice production.

There have been studies in agricultural efficiency in other countries outside of the developing world (Mugera and Nyambane, 2012; Jiang and Sharp, 2014). These studies showed a relationship between productive efficiency and farm characteristics, which include labour, off-farm income, and farm size. Latruffe and Desjeux (2016) investigated how policy changes affected efficiency and productivity in France between 1990 and 2006. Comparison of efficiency showed a significant reduction after the first reforms. Other studies have argued that agricultural subsidies received by farmers change the efficiency of production in a technical way (Minviel and Latruffe, 2014; Rizov *et al*., 2013).

Padilla-Fernandez and Nuthall (2009) applied a non-parametric DEA to determine the inefficiency of farms with the same inputs used by Babalola *et al*., (2010) to produce sugarcane in the Philippines. Results showed that sources of inefficiencies happen to be technical inefficiency rather than scale effect. Mbowa and Nieuwouldt (1998) examined how resources of sugarcane growers are utilised efficiently with different farm sizes in KwaZulu-Natal. The DEA was analysed and showed farm-size efficiency using inputs valued at opportunity cost. The results showed a significant correlation among scale efficiency and farmers' education, training, age and size of farm holdings.

The DEA method of measuring productive efficiency in agriculture focuses on the variable returns to scale approach of a single output and multiple inputs (Hoang Linh, 2012). In a few studies, this technique is bootstrapped to analyse deterministic factors that affect the efficiency and statistic precision of estimators (Fried *et al*., 2008; Hoang Linh, 2012). Accordingly, Olesen and Petersen (2016) expanded the stochastic DEA literature as a measure of relative efficiency by ranking productivity performance through exploring DMU's. This study expanded on the work of Charnes *et al*., (1981) that introduced the use of DMUs to characterise an input-output frontier vector. Comparative studies (Alene and Zelle, 2005; Alene *et al*., 2006; Herrero, 2005) in agriculture that explored the DEA and dual approaches involving parametric and non-parametric measured the efficiency of agricultural production. Toma *et al*., (2015) argued that in agriculture the process of selection of inputs and outputs depends on the input consumption.

However, small-scale farmers can still use inputs in optimal quantities relative to their prices to make up for poor application of the available technologies (Bojnec and Latruffe, 2013b). In a study that applied DEA, farm size and efficiency showed contrasting scores between average larger and smaller farms using a two-stage DEA approach (Rios and Shively, 2016). The geographical location of farms accounts for differences in the scale of operations. In order to achieve efficiency in crop production some adjustment in scale of operation of farms is needed (Abatania *et al*., 2012). Furthermore, prevailing small-sized farming structures tend to be constrained by institutional shortcomings on their land size (Bojnec and Swinnen, 1997). In the sugarcane industry, particularly in the northern region of KwaZulu-Natal, small-scale growers operate on small scattered land.

3.3.2 Empirical analysis of technical, cost and allocative efficiency using Data Envelope Analysis

The measurement of efficiency is accurate compared to that of productivity in the agricultural sector. It provides the performance between input and output in a most recent efficient frontier which is central to addressing objectives one, two, three, four and Five. In agriculture, the problem of specialisation of units is ever-present and is further exacerbated by a large number of possible farm outputs (Atici and Podinovski, 2015). Empirical studies on the efficiency of small-scale farmers in developing countries are focused on both DEA and SFA, with few studies (Serasinghe *et al*., 2003; Alene, 2006; Lihn, 2012, Ayo and Mungatana, 2011) that have applied these two approaches.

Alene, (2006) applied both DEA and SFA in Ethiopia, where mean technical efficiency showed contracting values, with the technical efficiency mean of DEA higher than that of SFA. Likewise, Lihn (2012) applied both these approaches and discovered the influence of education and regional factors on technical efficiency. The output and input sets define production possibility frontiers against which the technical efficiency performance of production activities can be measured. Any production activity that is on the frontier is technically efficient while activities of the frontier are inefficient. Thus, the distance of a production activity from the frontier is a measure of efficiency (Abatania, 2013).

The non-parametric DEA framework has been broadly applied in modelling efficiency in agriculture, microfinance, banking sectors, education, and health sectors, and further used in benchmarking other fields. The concept of measuring efficiency developed by Farrell (1957) has been a pioneering approach for estimating efficiency in agriculture. Among the empirical literature on DEA application there are two broadly used models, namely, Charnes, Cooper and Rhodes, and Banker, Charnes and Cooper. The models are famously known as the CCR-model and the BCC-model and have different ways of treating the return to scale (Charnes *et al*., 1978; Banker *et al*., 1984). In empirical research (Speelman *et al*., 2008; Speelman *et al*., 2009; Dobrowsky, 2013; Lovo, 2010) on the productive efficiency of farms applying the DEA framework there has been little application in the sugarcane industry of this approach in South Africa, with the exception of the study by Mbowa and Nieuwoudt (1998).

Speelman *et al*., (2008) analysed the efficiency of water use and its determinants for small-scale irrigation schemes in North-West Province. Both CRS and VRS specification returns to scale were analysed to measure efficiency. The Tobit regression model showed a significant relationship between farm size, landownership, and irrigation methods and efficiency. Furthermore, Speelman *et al*., (2009) applied DEA to estimate the impacts of water pricing on smallholder irrigators in North West Province. Another study, focusing on corporate farming, applied DEA as one of the models used to determine technical and allocative efficiency of maize farmers in South Africa. The study concluded that farm size is important in determining technical efficiency. There was no important effect of farm size on allocative efficiency (Dobrowsky, 2013). Lovo (2010) decomposed the technical efficiency of farm households in KwaZulu-Natal and revealed that households are liquidity constrained, but that income diversification and access to pension income had a positive impact on overall efficiency.

In other countries, Coelli *et al*., (2002) applied non-parametric DEA to measure the technical and allocative efficiency of rice growers in Bangladesh. The study identified technical inefficiency in labour and fertiliser inputs. A study conducted in East Africa established the extent to which dairy farms operate under variable return to scale to account for technical efficiency applying DEA (Gelan and Muriithi, 2012). In the context of sugarcane, Watto and Mugera (2014) found contrasting technical efficiency scores between tube-well and water buyer growers. Accordingly, in a study conducted in India, Singh (2016) concluded that both technical efficiency and efficiency change showed a positive growth. The efficiency change was arguably due to research development investment in sugar companies. In a different study, using a household sample of 198 using a household sample of 198 in three districts, inefficiencies in sugarcane production affected the technical efficiency of farmers (Murali and Prathap, 2017). An empirical paper presented at a conference by Abatania (2013) that applied DEA, revealed the lack of utilisation of the best available technology by farm households that do not have access to the best technology.

Studies focused on allocative efficiency alone through the application of DEA in developing countries are very limited compared to those on technical efficiency. In the existing literature Laha and Kuri (2011) conducted a study focused on farm households in India. The study concluded that there was a link between allocative efficiency and rural factor market. With limited studies focused on allocative efficiency, there are many researchers (Watto and Mugera, 2014; Coelli *et al*., 2002; Watkins *et al*., 2014) who have applied DEA to shed light on both allocative and technical efficiency across various farming sectors in developing countries. These studies found contracting mean scores with most farmers having high technical efficiency compared to allocative efficiency. Jha *et al*., (2000) showed different results and concluded that there was higher technical and allocative efficiency in India, accompanied by correlation coefficients between farm size and yield per acre.

On the other hand, Mahjoor (2013) focused on the technical, allocative and economic efficiency of farms in Iran. The study applied DEA and found high levels of returns to scale and inefficiencies in socio-economic factors. Application of VRS DEA mean score for technical, allocative and economic efficiency showed very high efficiency scores. Allocative efficiency mean score showed cost production reducing when farmers used the right inputs and output mix relative to input costs and output prices (Lubis *et al*., 2014). According to Watkins *et al*., (2014) most farms have high technical efficiency because of optimum application of inputs to achieve a given output on a very small piece of land, while the very same farms show low allocative and economic efficiencies due to poor combinations of inputs.

Economic efficiency estimation assumes homothetic technologies when benchmarking efficiency using technical and allocative criteria (Aparicio *et al*., 2015). This study found significant differences in the allocative and technical efficiency scores, depending on the approach. In a study conducted in Turkish dairy farms by Terin *et al*., (2017) technical, allocative and economic efficiency scores differed after the application of the CRS DEA approach. Khan *et al*., (2016) applied both the CRS and VRS DEA models to estimate the technical, allocative and economic efficiency of rice farmers in Malaysia. Efficiency mean scores of VRS technologies showed higher performance compared to the CRS technologies using DEA. However, Kelly *et al*., (2012) found that technical, allocative and economics scores applying the VRS DEA model were not fully efficient. The study went further and argued that to increase performance farmers ought to use the least amount of inputs per unit of output and maximise the level of technical and economic efficiency.

3.3.3 Impact of input slack on technical efficiency

In the application of DEA to measure technical efficiency the concept of inputs slack is commonly used to explain the piece-wise linear frontier which runs parallel to the frontier (Coelli *et al*., 2005). The SBM of efficiency has the ability to contain variables that obtained values of zero and negative inputs. The SBM is commonly favoured compared to the additive model because it allows the output values to be "free" and allows the input values to be semi-positive (Cooper *et al*., 2000). Tone (2001) proposed a Slack-Based Measure of efficiency in DEA in order to deal with the input excess and output shortfalls of a particular DMU. This non-radial approach was extended to look at how to deal with zeros and even negative values in the data set for both input and output.

The SBM estimation was compared to Russell (1985), which dealt with input-slacks and gave an efficiency measure score between zero and one. Furthermore, the distinction of the SBM measure of technical efficiency lies on its ability to estimate score that is unit invariant and reference-set dependent (Banker *et al*., 1984; Torgersen *et al*., 1996). According to Ramanathan (2003), input slacks is the difference between the actual and target inputs. In agricultural performance management, input slack is a vital feature for benchmarking enterprises, because a particular input is considered to be optimal when it has zero slacks (Aravindakshan *et al*., 2015). Small-scale sugarcane growers, like other farmers, possibly have difficulties when it comes to the most appropriate input levels for production; empirical evidence observed by (Lliyasi and Mohamed, 2016) in analysing freshwater pond culture in Malaysia revealed input slacks associated with production inputs. The study went further and proposed support for farmers from extension officers concerning input slacks focused on farmers with relatively low technical efficiency to adopt best practice.

3.3.4 Determinants of technical efficiency in agriculture

Empirical studies on efficiency studied determinants influencing efficiency in the agricultural sector (Asadullah and Rahman, 2009; Amos, 2007; Kelly *et al*., 2013). The influence of determinants of technical efficiency was purely on different agricultural practices and commodities. In essence, labour intensive practices tend to draw different determinants compared to modernised practices. Literature on technical efficiency of small-scale sugarcane growers found determinants such as age, education level, access to extension, access to credit, land holding size, ownership of dwelling, family size, gender, market access, as well as access to improved technologies such as fertiliser, agro-chemicals, tractor, and improved seeds to have a positive effect on efficiency (Mokgalabone, 2015).

Traditional studies on determinants of farm efficiency are generally inconclusive on the question of a positive return to education. Consequently, while the first group (Ali and Flinn, 1989; Seyoum *et al*, 1998; Young and Deng, 1999) established the significant role of education in promoting raising farming technical efficiency in Pakistan, China and Ethiopia, the second group (Battese and Coelli, 1995; Llewellyn and Williams, 1996; Asadullah and Rahman, 2009) failed to ascertain the significance of farmers' education on farming efficiency in India and Indonesia. This study used similar variables in its analysis to identify the critical ones affecting both technical and allocative efficiency in sugarcane production by small-scale growers. It is worthwhile to note the determinants of small-scale sugarcane growers and their contribution to production efficiency, because it will inform policy direction and possible strategies that sugarcane growers can adopt. Most studies (Karagiannis *et al*., 2003; Solis *et al*., 2009; Haji, 2007; Speelman *et al*., 2008) found the contracting impact of education to technical efficiency. However, recent literature has shown that education significantly impacts the adoption of technological innovations in agriculture, which leads to efficiency (Kumbhakar *et al*., 2014; Piya *et al*., 2012).

The size of the farm is one of the most researched determinants of agricultural productivity and in particular technical efficiency. The pioneer studies (Sen, 1962; Bhattacharya and Saini, 1972; Bardhan, 1973; Yotopoulos and Lau, 1973; Bhalla, 1977; Carter, 1984) have identified the contrasting relationship between farm size and productivity. According to Barrett (1996), there is a clear relationship between farm size and efficiency. In the agricultural sector, scale efficiency is one key determinant and is parallel to technical efficiency because of the technologies applied in the variable hectares. According to Barrett *et al*., (2010) the negative relationship between farm size and technical efficiency can be curbed by controlling land quality scales. In a contrasting study, Helfand and Levine (2004) discovered a U-shaped relationship between farm size and technical efficiency.

It is also worth noting that small-scale farmers tend to be more technical, allocative and economic efficient (Bravo-Ureta and Pinheiro, 1997). Consequently, there is a positive correlation between higher efficiencies and human capital. The same positive effect also applies for education and extension services on technical efficiency (Watto and Mugera, 2015). Extension service as a stand-alone topic has either a positive or a negative effect on technical efficiency. Ground–breaking research introduced the concept of extension efficiency (Birkhaeuser *et al*., 1991) and this study was later followed by the study of Battese and Coelli, (1992). However, classical studies (Frawley, 1985; Boyle, 1987) showed that exposure to extension support impacts on technical efficiency. In recent years Mango *et al*., (2015) concluded that frequent extension visits impacted technical efficiency positively. In support of the positive literature, Zhou *et al*., (2011) argued for the positive impact of extension services on technical efficiency in China. However, Gebrehiwot (2017) applied the SFA model and concluded that farmers with new extension service support had negative and low technical efficiency scores.

In the context of small-scale sugarcane growers, gender, like other socio-economic factors, stimulates developmental topics to improve efficiency and productivity. In a study conducted in Bangladesh, female labours supplied by family contributed higher cost share compared to their male counterparts, while both male and female education led to significant improvement in technical efficiency (Rahman, 2010). Studies (Booglu and Ceyhan, 2007; Hasnah and Coelli, 2004) draw contrasting results on the influence of gender on decision-making regarding farm inputs and technical efficiency. However, male and female labours operate with different gender gaps in their productivity (Aly and Shields, 2010). The research discussed in this thesis enters a space that seeks to understand whether the gender of the farmer contributes to their technical efficiency. A study conducted by Quisumbing (1996) showed that women are as equally productive as men.

On the other hand, (Udry *et al*., 1995; Udry, 1996; Akresh, 2005; Goldstein and Udry, 2008) found less yield harvested by female farmers compared to male. The shortcoming of these studies is their focus on output without considering their inputs to estimate efficiency. Opposing studies (Masterson, 2007; Quisumbing *et al*., 2014; Swaminathan *et al*., 2012) concluded no yields differences between female and male-headed farm households. Female-headed agricultural enterprises play a significant role in the production of subsistence and sold crops (Mishra *et al*., 2017). This defining study argues for a positive relationship between gender and productive efficiency. Lu (2010) argued the production, processing and marketing as well as value chain of crops produced by women in the agricultural sector. These processes give women direct management in smallholder farming when their husbands have migrated to urban areas. The effect of gender on agricultural productivity shows the descriptive comparison between male and female growers. Improving the productivity of female growers through access to production resources such as on and off-farm income might lead to higher efficiencies. Gender discrimination and differences also extend from average productivity to other on and off-farm resources and capital.

In agricultural production income plays a significant role in the allocation of resources. Farming as a main source of income proved to be not sufficient for most farming households to improve their livelihoods, hence they see a need to seek alternative sources of income (Adelekan and Omotayo, 2017; Babatunde, 2015). In small-scale farming, off-farm income is of importance as a way to compensate for poor performance and also determines decision-making (Poon and Weersink, 2011). In the developing world the availability of off-farm income has resulted in an increase of total income of farm households and contributes to diversity in production and increased income (Xiaobing *et al*., 2007; Chang and Mishra, 2008).

Alternatively, incomes earned from off-farm activities are invested in purchasing of modern inputs and new technology (Abebe, 2014). According to Bojnec and Ferto (2013) the technical efficiency of family farms tends to be higher because of the extra off-farm income. Their study discovered a spill-over effect of income from off-farm activities on farm activities. However, in a different study, Chang and Wen (2011) showed contrasting results; the study argued that a lower score in technical efficiency is not related to off-farm income used in resource allocation. In a more interesting finding, farmers without off-farm wages were found to be technically more efficient than their counterparts (Yue and Sonada, 2012). This may be attributed to the participation of off-farm activities to earn the extra income that limits better knowledge in the application of farm inputs.

On a positive note, studies (Babatunde, 2013; Iheke *et al*., 2013; Pfeiffer *et al*., 2009; Woldehanna, 2002) showed a positive relationship between off-farm income and technical efficiency. All the studies mentioned above applied a parametric analysis to draw conclusions about off-farm income and technical efficiency. The study applied a bootstrapped truncated regression to analyse the relationship between off-farm income and technical efficiency. In the pursuit of off-farm income, growers absent their trade from farming and this results in the lost-labour effect that affects agricultural production (Lopez-Feldman *et al*., 2007; Kilic *et al*., 2009). However, the off-farm activities to earn the income provides an ability to get the availability of credit (Babatunde, 2013). This supported the study conducted by Amare (2005) that stated that off-farm income may have a positive effect on growers' efficiency and purchasing of farm inputs.

As explained in the paragraph above there is a positive effect of credit and participation in on off-farm activities that lead to off-farm income (Beyene, 2008). The question one needs to ask is how access to credit affects efficiency in agricultural production. Traditionally, subsidized credit programmes are popular in the agricultural sector (Taylor *et al*., 1986). Sugarcane growers are not excluded from this practice and enjoy seed subsidies from the mills. This closes the gap in the purchasing of seed as input, but there is a need to break the commercial banks' need to access credit based on the credit barriers due to lack of collateral. Microfinance in rural credit schemes offers alternative ways to promote rural development (Besley, 1994).

In a comparative study of farmers who are bank or non-bank customers, it was argued that bank customers had higher technical efficiency scores compared to their counterparts because they adopt new and improved technology (Laha, 2013). However, expanding access to credit also influences the level at which growers will make their investment decisions, and overall productivity (Shah *et al*., 2012). Although this practice has a positive impact on input and technological adaptation, there is no empirically proven evidence of the effect of expanded access to credit on the efficiency of firms in general, and to be more precise, the agricultural sector. A host of studies

(Battese, 1992; Battesse and Broca, 1997; Liu, 2005; Hazarika and Alwang, 2003) made a significant conclusion on access to credit and firm efficiency.

There is a group of studies (Martey *et al*., 2015; Islam *et al*., 2011; Taylor *et al*., 1986) that estimate the impact of microcredit on on-farm efficiency. These studies produced mixed results, with millennium literature arguing for relaxed credit constraints in order to determine farm efficiency and the rest showing that credit programmes alone do not improve farm efficiency. It is interesting to see that in a developing country such as Ghana credit affects farm efficiency (Donkor and Owusu, 2014). Grower access to credit, like any other socio-economic aspect of farming, has an impact on efficiency. There is little knowledge on this impact on small-scale farmers producing sugarcane, in general, applying a non-parametric technique. According to Taubadel and Saldias (2014) the relationship between credit and technical efficiency is not easy to call, with empirical studies (Hadley *et al*., 2001; Lambert and Bayda, 2005; Davidova and Latruffe, 2007; Ayaz and Hussain, 2011) showing both positive and negative. In order to argue the positive impact of credit on technical efficiency, the theory of credit evaluation is applied and this leads to inefficient sugarcane growers been denied credit (Taubadel and Saldias, 2014).

There is a perception that small-scale sugarcane growers, like other small-scale farmers, are producing through employing inefficient technologies (Dlamini, 2005), thus contributing to low productivity levels, leading to low profitability and hence it becomes very difficult for them to access credit. Improving access to credit is one vital element of raising agricultural production and alleviating poverty (Sharma and Leung, 2000). In a study conducted in the Eastern Cape Province of South Africa access to credit of small-scale growers was found to be significantly influenced by other socioeconomic variables such as gender and age, off-farm income and level of education. This study focused on access to credit on agricultural production and applied a logistic regression (Baiyegunhi and Fraser, 2014). However, Chauke and Anim (2013) applied the same logistic regression to predict access to credit by smallholder irrigation farmers in Limpopo province. Like the later study their contribution was merely focused on access to credit, maybe due to institutional challenges faced by smallholder farmers regarding access to credit.

Smallholder farmers growing different crops had both negative and positive effect of credit on technical efficiency in Swaziland (Masuku *et al*., 2014). However, Duy *et al*., (2012) only focused on rice production and estimated the relationship between access to credit focused on both the informal and formal sources of credit. The study found a positive influence of credit on production efficiency while (Sossou *et al*., 2014) argued a positive allocation of credit to efficiency. Their study was focused on educated farmers and further showed that technical efficiency may be reduced based on the size of household and the gender of the head. To end the debate on access to credit and technical efficiency, Abdallah (2016) witnessed a mere 3.5% increase in technical efficiency of maize farmers when they have access to credit. The above studies applied parametric analysis approaches to measuring technical efficiency.

Labour's relationship to production and technical efficiency in agriculture is one of the important and debatable topics in development circles. One can argue for the need to offer small-scale sugar can labour services in their plots to maximise production and arguably invite family members to lend a hand, while others advocate for off-farm labouring to earn off-farm income that improves technical efficiency, because of access to financial resources that improves adaptation of advanced technologies. Amid this view, a study focused purely on the effect of labour resources on technical efficiency showed contrasting results for the eastern, middle and western regions of China that produced crops and argued that employees migrated to non-agricultural sectors (Yin and Wang, 2017).

Again, in China, and focused on a particular province of Liaoning, Li and Sicular (2014) analysed how the ageing agricultural labour force had an impact on technical efficiency. The study found that the optimal technical efficiency of farmers is reached at an average age of 45 and eventually decreases as the farmer grows older. This implies that most of the rural migrant workers who return to their plots to grow at their retirement age tend to be less technically efficient. In observation emanating from Mochebelele and Winter-Nelson (2000) higher technical efficiency for both non-migrant and migrant farms must be interpreted differently, with rural households supplying labour to other non-family farm businesses (termed off-farm labour) resulting in better resource allocation and consequently higher productivity for these farms. Luis *et al*., (2015) went further and looked at the relationship between male and female labour migrants and technical efficiency in the rice-producing region of the Philippines. The study showed that experience, frequent extension visits, and the type of migrant, are stimulators of technical efficiency while gender accounts for inefficiencies.

Either way, the migration of labour in the agricultural sector has an impact on technical efficiency. Empirical studies (Rozelle *et al*., 1999; Mochebelele and Winter-Nelson, 2000; Goodwin and Mishra, 2004; Chang and Wen, 2011) that focused on labour, either migrant or off-farm labour, drew mixed conclusions. Rozelle *et al*., (1999) found a negative effect between efficiency and labour migration and were supported by Goodwin and Mashra (2004) who found that off-farm labour supply and have an impact on technical efficiency. While Mochebelele and Winter-Nelson (2000) showed that technical efficiency of households with migrants was higher compared to their counterparts without migrants. This was supported by Chang and Wen (2011) in the rice-producing farms of Taiwan operating without off-farm workers.

In the context of agriculture, most labourers are seasonal due to the nature and phases of production while some of them extend to family labour and child labour. Coelli *et al*., (2005), in measuring efficiency and productivity, recommended the number of hours worked as the best indicator for the labour input. The production elasticities of hired labour tend to be positive and not significant while family labour is also positive and statistically significant. This implies that family labour contributes to the increase in output and, subsequently, technical efficiency (Omonona *et al*., 2008). One aspect of labour that stands out in the estimation is the use of aggregated labour, which makes it very challenging to account for seasonal labour and its implication on technical efficiency. Concerning family labour, it can be counted as hired labour to mitigate unfair bias towards poor small-scale growers who cannot afford remunerated labour (Mkhabela, 2005).

Enough said on labour and technical efficiency. Let us now focus on the off-farm employment status of the growers and its effect on technical efficiency. Off-farm employment is linked to both off-farm income and the labour participation rate on sugarcane production and such form of employment provide capital to purchase inputs (Huffman, 1980; Matshe and Young, 2004). The effect of off-farm employment on technical efficiency is very complicated and reduces the available labour for production (Feng, 2008). Empirical evidence points to very low levels of technical efficiency for farmers that participate in off-farm employment (Abdulai and Eberlin, 2001). This negative effect builds on a study conducted by Huffman (1980), which argued that off-farming employment is accompanied by an allocation of time away from farming activities that might hinder technological adaptation and the gathering of technical knowledge to aid technical efficiency.

Accordingly, (Jolliffe, 2004; Fernandez-Cornejo *et al*., 2007; Chang and Wen, 2011) in studies conducted in Ghana and Taiwan respectively reported a total of 74%, 65% and 75% of farm households that participated in off-farm employment. Most studies (Kumbharkar *et al*., 1989; Sherlund *et al*., 2002; Smith, 2002; Chang and Wen, 2011) on off-farm income and technical efficiency applied a stochastic production function. Kumbharkar *et al*., (1989) found a negative relationship between technical efficiency and off-farm employment in the dairy farming industry. This study was supported by the study conducted by Fernandez-Cornejo (1992), interestingly on a different sample, a vegetable farm. However, Goodwin and Mishra (2004) proxied farmers' efficiency by gross cash income and concluded that farm households that have off-farm employment been less efficient on their own plots.

There is a positive effect of off-farm employment on technical efficiency. This can be attributed to non-farm income earned in off-farm activities. Pascaul (2005) and Tesfay *et al*., (2005) showed a positive effect of non-farm employment on technical efficiency. On the other hand, coefficient estimation shows that off-farm work positively and significantly affects technical inefficiency because non-farm labour supply restricts full participation in farming and productive efficiency on one's own farm (Abdulai and Huffman, 2000; Addai and Owusu, 2014). The other positive aspect of off–farm employment comes in the form of off–farm income which has been seen to increase investments on the farm through purchasing of input, investment in labour, and adaptation of innovative technology (Mendol, 2004; Kwon *et al*., 2006; Pfeiffer *et al*., 2009).

3.4 Theoretical Literature Review on productivity and efficiency change

3.4.0 Introduction

3.4.1 Theoretical productivity indices

The underlying concepts for this theory are the Malmquist Index and the Hicks-Moorsteen Index, pioneered by Caves, Christensen, Diewert and Bjurek as motivated by the seminal work of Solow (1957). Each uses the Shepard distance function to measure the radial changes in input and output vectors. The Malmquist is the measure of the shift of the production frontier, while the Hicks-Moorsteen measures the ratio of an output index to an input index. This theory is applicable to any type of firm either aggregated or disaggregated. The firm produces a vector of outputs $y \in \mathbb{R}_{+}^{m}$ using a vector of inputs $x \in \mathbb{R}_{+}^{n}$. To eliminate the nuisance of dealing with null vectors, the function map from production space with the origins of input and output space are expunged: $\mathbb{R}_{+}^{n+m} = \mathbb{R}_{+}^{n}\backslash\{0^{[n]}\} \times \mathbb{R}_{+}^{m}\backslash\{0^{[m]}\} =: \dot{\mathbb{R}}_{+}^{n} \times \dot{\mathbb{R}}_{+}^{m}$.

The set of technologically feasible production vectors is expressed as follows:

$$T = \{\langle x, y\rangle \in \mathbb{R}_{+}^{n+m} |\, x\ can\ produce\ y\}$$

Given the technology T, the output-possibility set for input vector x is

$$P(x,T) = \{\, y \in \mathbb{R}_{+}^{m} |\, \langle x, y\rangle \in T\}$$

and the input-requirement set for output vector y is

$$L(y,T) = \{\, x \in \mathbb{R}_{+}^{n} |\, \langle x, y\rangle \in T\}$$

therefore $\langle x, y\rangle \in T \Leftrightarrow x \in L(y,T) \Leftrightarrow y \in P(x,T)$

The set of technologies, denoted $\mathcal{T}$ is restricted, to satisfy free input disposability ($L(y,T) + \mathbb{R}_{+}^{n} = L(y,T)$ for all $y \in \mathbb{R}_{+}^{m}$) and free output disposability ($P(x,T) = (P(x,T) - \mathbb{R}_{+}^{m}) \cap = \mathbb{R}_{+}^{m}$ for all $x \in \mathbb{R}_{+}^{n}$). As T is closed for all $T \in \mathcal{T}$, so are slices, $L(y,T)$ and $P(x,T)$, for all $\langle x, y\rangle \in \mathbb{R}_{+}^{n+m}$.

The isoquant for output $y \in \dot{\mathbb{R}}_{+}^{m}$ is given by

$$I(y,T) = \{x \in L(y,T) |\, \lambda x \notin L(y)\, \forall\, \lambda < 1\},$$

and the production possibility surface for input $x \in \mathbb{R}_+^n$

$$\Gamma(x,T) = \{y \in L(x,T) |\, \lambda y \notin P(x)\, \forall\, \lambda > 1\},$$

Furthermore, the distance function proposed by Debreu (1951), Malmquist (1953) and Shepard (1953) is the integral part of multiple-output and multiple-input productivity analysis. The input distance function, $D_I: N \times \mathcal{T} \rightarrow \mathbb{R}_{++}$, maps from a subset of production space, N = $\{\langle x,y \rangle \in \mathbb{R}_+^{n+m} \mid L(y,T) \neq \emptyset\}$, and the set of allowable technologies into the positive real line and is defined by

$$D_I(x,y,T) = \max \{\lambda > 0 \dashv |x / \lambda \in L(y,T)\}.$$

The distance function is then independently used to measure technological efficiency. In the case of this study, for a small-scale sugarcane grower to be input inefficient at time t if $D_I(x^t,y^t,T^t) > 1$ and output inefficient if $D_0(x^t,y^t,T^t) < 1$. After the introduction of the restriction of the distance-function domains to feasible production vectors $\langle x\text{^}t, y\text{^}t \rangle \in T\text{^}t, 1/(D_I(x\text{^}t, y\text{^}t, T\text{^}t)) =: E_1(x^t,y^t,T^t)$ and $D_0(x^t,y^t,T^t) =: E_0(x^t,y^t,T^t)$ to each measure the radial distance of the quantity vector from the frontier for technologically feasible production vectors, maps into the [0,1] interval. Moreover, to compare technological comparisons across periods the production possibility is set at the current-period input vector using base-period technology is $P(x^c,T^b)$, and the production possibility set at the base-period input vector using the current-period technology is $P(x^b,T^c)$. The corresponding production possibility surfaces are $\Gamma(x^c,T^b)$ and $\Gamma(x^b,T^c)$.

Suppose

$$P(x^c,T^b) \subset P^c(x^c,T^c) \;\wedge\; \Gamma(x^c,T^b) \cap \Gamma(x^b,T^c) = \emptyset,$$

Therefore, to construct productivity indices the distance function is characterised as a radial distance of an input-quantity vector from the frontier of the technology. After the restrictions on the technology, D_I will be defined as homogenous of degree one and non-decreasing in x , and non-increasing in y for all $\langle x,y,T \rangle \in N \times \mathcal{T}$. Moreover, $x \in L(y,T) \Leftrightarrow D_I(y,x,T) \geq 1$, and $x \in I(y,T) \Leftrightarrow D_I(y,x,T) = 1$, so that, for any $y \in \mathbb{R}_+^m$, $L(y,T)$ is recovered from D_I by

$$L(y,T) = \{x \in \mathbb{R}_+^n \mid D_I(y,x,T) \geq 1\}$$

and $I(y,T)$ is recovered from D_I by

$$I(y,T) = \{x \in \mathbb{R}_+^n \mid D_I(y,x,T) = 1\}$$

On the other hand, the input distance function, $D_o: N \times \mathcal{T} \longrightarrow R_+$, can be defined by

$$D_O(x,y,T) = \min \{\lambda > 0 \mid y/\lambda \in P(x,T)\};$$

With restrictions on the technology $P(x,T), D_O$ is well defined as homogenous of degree one and non-decreasing in y , and non-increasing in x for all $\langle x,y\rangle \in \dot{\mathbb{R}}_+^{n+m}$. Moreover, $y \in P(x,T) \Leftrightarrow D_o(x,y,T) \leq 1,$ so that for any $x \in \dot{\mathbb{R}}_+^n, P(x,T)$ is recovered from by

$$P(x,T) = \{y \in \mathbb{R}_+^m \mid D_o(x,y,T) \leq 1\}$$

and $\Gamma(x)$ is recovered from by

$$\Gamma(x,T) = \{y \in \mathbb{R}_+^m \mid D_o(x,y,T) = 1\},$$

Therefore, the case of the economic unit is unambiguously improved if

$$P(x^b,T^b) \subset P(x^b,T^c) \wedge \Gamma(x^c,T^b) \cap \Gamma(x^b,T^c) = \emptyset.$$

In order to define a multiple-output productivity index, $\Pi : \mathbb{R}_+^{2(n+m)} \longrightarrow \mathbb{R}_{++}$, with image $\Pi(x^b,x^c,y^b,y^c)$ is constructed.

3.4.2 Conceptual framework of productivity and efficiency change

One cannot think of the sole universal definition nor explanation of the concept of productivity. However, in economic circles, the ratio of output to input over a specific time period is commonly used to decompose productivity for a particular firm. Therefore, the efficiency at which scarce resources are utilised is measured by computing productivity, with higher productivity translating to more output with the allocation of less or the same level of input. There are two sub-concepts of productivity in Partial Factor Productivity (PFP) and TFP. The PFP measures the ratio of total output to a single input. This is the main reason why this concept is not fully explored in productivity literature, because productivity cannot be taken to be synonymous with a single input.

Moreover, TFP measures the ratio of output to the aggregate measure of the inputs of all the factors of production and it incorporates the contribution of multiple inputs and estimates of productivity growth. The definition of productivity growth is underlined by the productivity index number formula, and in the case of multiple-output and multiple-input firms TFP show the ratio of an aggregate output to an aggregate input, as proposed by Jorgenson and Griliches (1967) who noted a measure of output growth divided by a measure of input growth as the index numbers used to decompose changes in TFP.

O'Donnell (2008) introduced the concept of mix and TFP efficiency by decomposing the overall productive efficiency of a firm as the observed TFP to the maximum TFP possible by applying available technology. Aggregated quantities of measuring efficiency were defined as output-oriented technical efficiency that are measured by the difference between the observed TFP and the maximum TFP possible when applying existing technology, while fixing output mix and input level; output-oriented scale efficiency is measured by the difference between TFP at a technically efficient point and the maximum TFP based on technology at hand, when fixing input and output mixes but allowing the levels to vary.

While output-oriented mix efficiency is measured by the difference between TFP at technically efficient point by applying the existing technology or enterprise mix and the TFP that is possibly holding the input level fixed by allowing the output level and mix to vary. The residual output-oriented scale efficiency is measured by the difference between TFP at a technically and mix efficient point and the maximum TFP that is possible through altering both input and output with existing technology and residual mix efficiency is measured by the difference between TFP at a technically and scale-efficient point and maximum TFP that is possible through altering input and output mixes with existing technology.

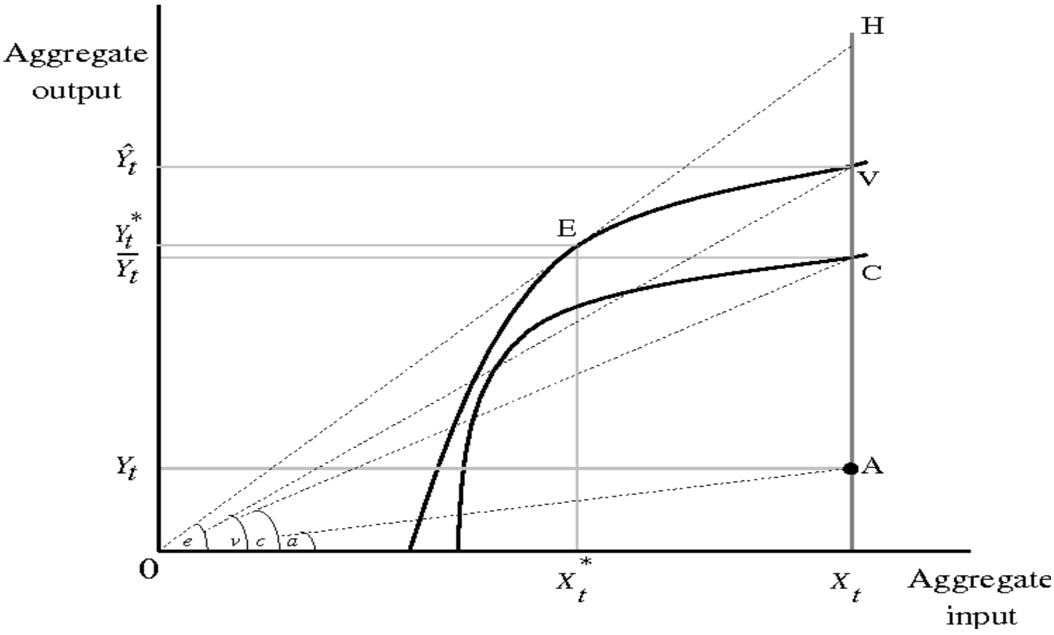

FIGURE 3.1: MEASURES OF EFFICIENCY IN SMALL-SCALE SUGARCANE PRODUCTION

Source: O'Donnell (2010)

The concept of overall productive performance can be shown graphically by the multiple-input multiple-output case in two-dimensional aggregate quantity space. The curve H, because it passes through point E, is a variable return to scale production frontier that envelops all aggregate-output aggregate-input combinations that are technically feasible in period t. Therefore, in aggregate quantity space, the TFP at any point is the slope of the ray from the origin to that point. In figure 3.1 the TFP at point C is $TFP_{it} = Y_{it}/X_{it}$ = slope OC and the TFP at point E is TFP_t^* = slope OE. Henceforth, the measure of TFP efficiency can be expressed as $TFPE_{it} = TFP_{it}/TFP_t^*$ = slope OC/slope OE. The curve passing through point C represents the frontier of a restricted production possibilities set because the input and output vectors in that curve can be written as scalar multiples of X_{it} and Y_{it}. According to O'Donnell (2008), when these mix restrictions are relaxed the firm has access to the expanded production possibilities set bounded by the curve passing through point V and E. Therefore, the figure above illustrates many possible pathways from A to E and also illustrates two of many possible decompositions of TFP efficiency.

3.5 Theoretical model of productivity and efficiency change

The TFP as the ratio of an aggregated output to an aggregated input as defined by O'Donnell (2012b) is the aggregated functions of non-negative, non-decreasing and linearly homogeneous. The properties of these functions are crucial in the construction of a TFP index that satisfies basic axioms from index theory. Suppose $q_{nt} \in \Re_{+}^{J}$ and $x_{nt} \in \Re_{+}^{K}$ denote vectors of output and input quantities for grower n in the period t. As proposed by O'Donnell (2012b), we assume $TFP_{nt} = Q_{nt}/X_{nt}$, and TFP_{nt} denotes the Total Factor Productivity of grower n in period t, while output and input in their aggregated form are represented by Q_{nt} and X_{nt}. Applying this definition, the productivity index that compares the TFP of grower n in period t with the TFP of grower g in period s was:

$$TFP_{gs,nt} = \frac{TFP_{nt}}{TFP_{gs}} = \frac{Q_{nt}/X_{nt}}{Q_{gs}/X_{gs}} = \frac{Q_{nt}/Q_{gs}}{X_{nt}/X_{gs}} = \frac{Q_{gs,nt}}{X_{gs,nt}} \quad (3.5)$$

where $Q_{gs,nt}$ denotes output quantity index and $X_{gs,nt}$ input quantity index. Equation (5) reveals that TFP change can be obtained by dividing an index of output growth by an index of input growth. Suppose Q(q) = $D_O(x_o, q, t_o)$ and $X(x) = D_I(x, q_o, t_o)$ are non-negative, non-decreasing and linearly homogenous the aggregator functions. The Shephard output and input distance functions are represented by $D_O(x_o, q, t_o)$ and $D_I(x, q_o, t_o)$, respectively in period t. Therefore the FPI proposed by O'Donnell (2011, 2014) was as follows:

$$TFP_{gs,nt} = \frac{D_O(x_o, q_{nt}, t_o)}{D_O(x_o, q_{gs}, t_o)} \frac{D_I(x_{gs}, q_o, t_o)}{D_I(x_{nt}, q_o, t_o)} \quad (3.6)$$

As a consequence of O'Donnell (2012b), measures of efficiency were defined as:

Output-oriented technical efficiency, $OTE_{nt} = \frac{Q_{nt}}{Q_{nt}}$, (3.7.a)

Output-oriented scale efficiency, $OSE_{nt} = \frac{\bar{Q}_{nt}/X_{nt}}{\tilde{\bar{Q}}_{nt}/\tilde{X}_{nt}}$, (3.7.b)

Output-oriented mix efficiency, $OME_{nt} = \frac{\bar{Q}_{nt}}{\hat{Q}_{nt}}$, (3.7.c)

Residual output-oriented scale efficiency, $ROSE_{nt} = \frac{\hat{Q}_{nt}/X_{nt}}{Q^{*}_{nt}/\tilde{X}_{nt}}$ and (3.7.d)

Residual mix efficiency, $RME_{nt} = \frac{\tilde{Q}_{nt}/\tilde{X}_{nt}}{Q^*_{nt}/X^*_{nt}}$. (3.7.e)

where, $\bar{Q}_{nt}$ is the maximum aggregate output that is technically feasible to produce a scalar multiple of q_{nt} using x_{nt}; $\hat{Q}_{nt}$ is the maximum possible aggregate output using x_{nt} to produce any output vector; $\tilde{Q}_{nt}$ and $\tilde{X}_{nt}$ denote the aggregate output and input quantities at the point where TFP is maximised subject to the constraint that the output and input vectors are scalar multiples of q_{nt} and x_{nt} respectively; while Q^*_{nt} and X^*_{nt} denote the aggregate output and input quantities at the point of maximum productivity.

We then applied the ratio of the observed TFP to the maximum TFP that is available given the technology in period t. Therefore, TFP efficiency of grower n in period t was decomposed equation (7) where, TFP^*_t denotes the maximum TFP and Q^*_{nt} and X^*_{nt} represent aggregated output and input at the optimum point of TFP.

$$TFPE_{nt} = \frac{TFP_{nt}}{TFP^*_t} = \frac{Q_{nt}/X_{nt}}{Q^*_{nt}/X^*_{nt}} \quad (3.8)$$

However, O'Donnell (2010) showed that equation (3.8) can be applied in many ways to decompose the output-oriented decomposition of TFP efficiency that can be used as a first step of decomposing the output-oriented measure of TFP efficiency. Therefore, following O'Donnell (2012b), equation (3.9) was presented as:

$$TFP_{nt} = TFP_t(\, OTE_{nt} \times OME_{nt} \times ROSE_{nt}\,) = TFP_t(\, OTE_{nt} \times OSE_{nt} \times RME_{nt}) \quad (3.9)$$

where $OTE_{nt}, OME_{nt}, ROSE_{nt}, OSE_{nt}, RME_{nt}$ represent measures of output-oriented pure, mix and residual scale efficiency, output-oriented scale efficiency and residual mix efficiency, respectively.

Therefore, to compare the growers we take the index number that compares the TFP of grower n in period t with the TFP of firm g in period c.The linear measures were presented as:

$$TFP_{gc,nt} = \frac{TFP_{nt}}{TFP_{gc}} = \left(\frac{TFP^*_t}{TFP^*_c}\right) \times \left(\frac{OTE_{nt}}{OTE_{gc}} \times \frac{OME_{nt}}{OME_{gc}} \times \frac{ROSE_{nt}}{ROSE_{gc}}\right) \quad (3.10.a)$$

$$TFP_{gc,nt} = \frac{TFP_{nt}}{TFP_{gc}} = \left(\frac{TFP^*_t}{TFP^*_c}\right) \times \left(\frac{OTE_{nt}}{OTE_{gc}} \times \frac{OSE_{nt}}{OSE_{gc}} \times \frac{RME_{nt}}{RME_{gc}}\right) \quad (3.10.b)$$

The left parenthesis on the right-hand side of the equation (3.10.a and 3.10.b) measures technical change noting that small-scale sugarcane growers will experience technical decline when the parenthesis is less than 1, while the right parenthesis in both equations is different output-oriented measures of relative efficiency such as relative technical efficiency, relative mix-efficiency and relative residual scale efficiency. The other two components are output-oriented relative scale efficiency and relative residual mix efficiency. Therefore, both equation (3.10.a) and (3.10.b) can be expressed as:

$$TFP_{gc,nt} = \frac{TFP_{nt}}{TFP_{gc}} = \left(\frac{TFP_t^*}{TFP_c^*}\right) \left(\frac{OTE_{nt}}{OTE_{gc}}\right) \left(\frac{OSME_{nt}}{OSME_{gc}}\right) \quad (3.10.c)$$

where $OSME_{nt} = OME_{nt} \times ROSE_{nt} \times OSE_{nt} \times RME_{nt}$ is the measure of scale-mix efficiency, which measures the combination of scale and mix efficiency. The output-oriented scale-mix efficiency, $OSME$, measures the increase in TFP between a technically efficient point with the observed scale and input mix to the point of maximum productivity.

3.6 Review of empirical studies on productivity

3.6.1 Agricultural productivity and efficiency change analysis

There has been much empirical work done on the development of the theory and measurement of productivity across all fields introduced by the work of Farrell (1957). Commonly, two frontiers, namely, the stochastic and the non-stochastic production frontier, were introduced by the work of Aigner *et al*., (1977) and Charnes *et al*., (1978), who pioneered the application of both the SFA and DEA methods of measuring productivity. The DEA model uses the best performing DMUs to construct the piecewise frontier, without making any prior assumption of the required technology with the ability to handle multiple inputs and outputs.

Applying the DEA- based model to measure productivity, the work of Fare *et al*., (1994) decomposed the productivity growth into two components i.e. technical change and efficiency change over time. In order to arrive at this point, the Malmquist productivity indexes developed by Caves *et al*., (1982) using an output distance functions were argued to be an appropriate model (Mao and Koo, 1997). Bureau *et al*., (1995) introduced the application of the Malmquist in the agricultural sector to decompose productivity growth with the comparison to other two measures.

Luh *et al*., (2008) applied the Malmquist productivity growth index in the identification of sources for agricultural growth in eight East Asian economies; the focal point of this study was on the interaction between human capital and domestic R&D and with efficiency and technical change results revealing pure efficiency improvement over time period in all East Asian agricultural countries. This study supported the previous studies (Hayani, 1997; Guitierrez and Guitierrez, 2003) that revealed difficulties concerned with the transfer of agricultural technology. Empirical evidence (Pengfei and Bing, 2004) that applied DEA showed the relationship between human capital and productivity, while technical progress was related to productivity growth. The work of Singh (2016) applied the DEA-based Malmquist Productivity Index (MPI) to measure technical change and productivity growth in the Indian sugarcane industry. The study decomposed negative growth in technical change and efficiency as a consequence of technological regress.

On the back of agricultural productivity and efficiency studies, many studies focused mainly on TFP. This measure of firm productivity was carried out by applying the Translog production function and SFA. Chaudhary (2009) applied the Translog production function to decomposed TFP growth for the period 1985–2005 in Pakistan with the focus on the role of technological improvements, human growth and institutional change on achieving economic growth. In the application of SFA, Mandal and Madheswaran (2012) focused on the cement industry of India with the aim of decomposing technological progress, technical efficiency and scale efficiency. The study argued that scale efficiency is the driver of technical efficiency.

In a study that focused on Bangladesh crop agriculture applying SFA covering a period of 1962–1992, Coelli *et al*., (2003) included time variations inefficiency flow and concluded negative technological change until 1973, followed by a declining efficiency until the 1980's. An African study conducted by Conradie *et al*., (2009) with interest in district-level TFP of agriculture, applied a production function framework to measure TFP in the Western Cape. Evidence showed that TFP in some districts was low as a consequence of infrastructure development and the conclusion was that government ought to train small-scale growers to stabilise agricultural productivity. However, certain studies decomposed agricultural productivity without making a prior assumption of the available technology and scales.

Coelli and Rao (2005) applied DEA to compute and decompose output-oriented Malmquist TFP indexes of 93 countries from 1980–2000 focused on agricultural productivity and assumed that the Malmquist is not sufficient to decompose reliable measure for productivity change under the CRS assumption. Since its application by Bjurek (1996) the Hicks-Moorsteen TFP index that encompasses the ratio of a Malmquist output-over a Malmquist input-index has not been applied in the agricultural sector. Briec and Kerstens (2011) interpret that the Hicks-Moorsteen productivity index indicates productivity gain when its index is smaller than unity. The study proceeded to demonstrate that the Hicks-Moorsteen production index has the ability to satisfy determinateness under weak conditions of technology.

Furthermore, the index is feasible based on the fact that all input efficiency measures in the index to meet the condition that the observed output quantities are equal to the period of the technology while all output efficiency measures decomposed assume the condition that the period of the technology is equal to the period of the observed input quantities (Caves *et al*., 1982). There has been empirical literature (Fare *et al*., 1996, O'Dennell, 2012a, Kerstens and Van de Woestyne, 2014, Peyrache, 2014) on the choice between the Malmquist and the Hicks-Moorsteen index, with emphasis on the ability of the Hicks-Moorsteen index to decompose the distance of the production frontier without neglecting scale economies, and the precise direction of the TFP growth. Consequently, O'Donnell (2010) decomposed the Hicks-Moorsteen TFP indexes that is applied under the assumption of any return to scale.

Therefore, as the main focus of this chapter is based on the different scales that exhibit within different small-scale sugarcane growers, the technology applied in their production will be assumed to be VRS, also allowing technical regress in the production possibilities set. The Hicks-Moorsteen TFP, O'Donnell (2014) introduced the Färe-Primont index as a better restrictive assumption concerning statistical noise. Khan *et al*., (2015) proposed the Färe-Primont indexes that can be computed using DEA. This index was merited compared to the Hick-Moorsteen TFP because it provides reliable multi-lateral and multi-temporal comparison. The study was based on Australian broadacre agriculture by estimating distance function and concluded that TFP growth had increased by an average of 1.36%.

3.6.2 Determinants of agricultural productivity and efficiency change

Much interest has been shown in developing the measurement of determinants and sources of agricultural productivity change and efficiency. Scholars have a choice of either applying a non–stochastic production frontier or a stochastic production frontier to investigate determinants of TFP growth. The stochastic production frontier requires prior assumption about the functional form, while the non-stochastic production frontier uses the best performing Decision-Making Units. Coelli *et al*., (2003) applied a stochastic production frontier model to decompose TFP growth for Bangladesh crop agriculture using regional data from 1960–1992. The study showed that agricultural research expenditure and the green revolution influenced TFP change. However, O'Donnell (2014) argued that SFA has a weakness concerning the assumption of how the error term is distributed. Therefore, when multiple inputs and outputs of production technologies are captured, the chosen independent variables correlate with the error term.

Rahman and Salim (2013) applied a non-parametric DEA approach to identify the determinants of TFP change and its components. This study regressed the TFP results generated by the FPI using a Generalised Least Squares (GLS) that is part of the Generalised Method of Moments (GMM) family. As was the case with SFA, O'Donnell (2014) argued that the GMM still had shortcomings concerning the choice of instruments considered and that the finite sample properties of the estimator may be unknown, regardless of its ability to resolve the endogeneity issue. The study conducted by O'Donnell (2014) made use of the Bayesian methods proposed by Fernandez *et al*., (2001) as the best practice in solving the endogeneity challenge and the exact finite sample inferences of the variables. In recent literature, Majiwa (2017) applied the Bayesian modelling average technique to investigate determinants of TFP growth in the African agricultural sector.

Traditional studies focused on the effect of sources and determinants of TFP growth in agricultural regions, countries and at farm-level. Accordingly, Rosegrant and Evenson (1992) showed that the main sources and determinants of productivity growth have been both public and private research without neglecting the value of extension support. This influence of Research and Development (R&D) expenditure has received more attention in the agricultural productivity literature (see Mullen, 2007). A study by Rahman and Salim (2013) showed that R&D expenditure influenced TFP change, technical change, technical efficiency and scale efficiency. This study supported the work of Coelli *et al*., (2003) that also reported a positive contribution of R&D investment on TFP change and technical change. Lastly, in a study that focused on agricultural productivity in the African context, Majiwa (2017) revealed that agricultural R&D expenditure has a positive relationship with TFP growth. These findings were in line with Fuglie and Rada (2013) and Alene (2010) who also revealed a positive effect of R&D on agricultural TFP growth in African agricultural TFP growth estimation.

Chang *et al*., (1994) in China attributed TFP growth to investment in both physical and human capital. This study showed that agricultural productivity promotes labour productivity. The study conducted by Alene (2010) went further and showed a positive relationship between TFP growth and literacy as expressed by mean years of schooling. Kumbhakar *et al*., (2014) and Piya *et al*., (2012) argued that education impacts the adoption of technological innovations in agriculture, which leads to efficiency. In developing countries, the quality of education has remained so low that the number of years of schooling does not guarantee human capital (Pritchett, 2001). Evidence from (Rahman and Salim, 2013; Coelli *et al*., 2002; Deb, 1995) showed mixed results on the influence of education on TFP change and efficiency in Bangladesh. These studies were in line with the negative influence of education on efficiency. Bamidele *et al*., (2008) show that in Nigeria the enhancement of farmers' access to education influenced agricultural TFP.

In addition to determinants of TFP growth, studies have been conducted on the size of land, which would affect the small-scale growers' TFP growth. Rahman and Salim (2013) revealed that average farm size had a dominant influence on TFP growth, together with scale-efficiency and technical-efficiency. But, in the case of Kenya, increased land size resulted in reduced TFP growth (Majiwa, 2017). The empirical literature on TFP growth at farm level has focused more on variables that have an effect on policy reforms in developing countries like South Africa. Socio–economic variables such as age, size of household and the experience of farmers have an effect on efficiency (Gebrehiwot, 2017; Msangi, 2017). The argument is how these variables can affect TFP growth in small-scale sugarcane production and how can their effect affect policy issues.

3.6.3 Previous studies: agricultural productivity and efficiency change

The empirical literature on productivity and efficiency has been increasing over a period of time and has been applied in different sectors. The first group of studies focused on the economic theory of production with firms exhibiting the constant return to scale, see (Jorgenson and Griliches, 1967; Nadiri, 1970; Good *et al*., 1996). Jorgenson and Griliches (1967) estimated the growth rate of output, input and total factor productivity by eliminating errors associated with estimation of inputs and prices of those particular inputs. This study showed a significant change in growth of output after the elimination of aggregated errors, with movements along a production function exhibiting at 96.7%, based on the observation of the 1945–1965 period. There have been attempts that resulted in the isolation of pure residual by attributing the growth of productivity to change in the quality of inputs after consideration of their aggregation bias (Nadiri, 1970). Accordingly, Khan *et al*., (2015) showed that the above studies solve multiple outputs and multiple inputs firms by forming aggregates of market prices.

The second group of studies (Thirtle and Bottomley, 1992; Thirtle *et al*., 1993; Thirtle *et al*., 2005; Jin *et al*., 2010; Brigatte and Teixeira, 2010; Kannan, 2011) focused on a particular country or group of countries. These studies covered the agricultural productivity literature with the focus on South Africa, the United Kingdom, Western Australia, China, Brazil and India. Studies (Thirtle *et al*., 1993; Poonyth *et al*., 2001; Thirtle *et al*., 2005; Liebenberg *et al*., 2010) conducted in South Africa focused on commercial farming. These studies have decomposed productivity by estimating multifactor productivity as an approximation of TFP at district, regional and national levels of the Republic and have revealed conflicting results.

Liebenberg and Pardey (2010) showed that South African agricultural output growth has been lagging behind compared to other African countries by applying the Divisia aggregation approaches. This study followed the comparison of low agricultural productivity compared to productivity in other sectors of the economy. The study by Kirsten and Vink (2003) was in line with Thirtle *et al*., (2005) and Thirtle *et al*., (1993) that reported fluctuations between 1993 and 1999. While in the Chinese agricultural sector, Chen and Ding (2007) applied the Malmquist Index to a province level panel dataset for the period 1988–2002 to decompose the impact of infrastructure trends on productivity. The study conducted by Jin *et al*., (2010) showed that a parametric Stochastic production function can be applied in examining productivity trends in the Chinese agricultural sector after the reforms. Multilateral comparison studies reviewed below applied the Malmquist Index to compare the agricultural productivity of different countries.

In recent literature, Temoso *et al*., (2018) also applied SFA to decompose TFP growth and its determinants in Botswana for the period 1979–2012. The study showed a low growth in agricultural output, attributed to similar low growth in factors of production as opposed to TFP growth. The last study also applied the production function framework to investigate TFP in South Africa by measuring the aggregated output per unit of aggregated input. This study reported low TFP in some districts (Thirtle *et al*., 1993).

Similarly, in the early 90's Bureau *et al*., (1995) applied the Malmquist Index together with the Fisher and Hulten estimates to decompose productivity of nine countries of the developed EU and the USA for the period 1973–1989. In both the developing and the developed worlds, the application of the MI approach revealed technical inefficiency with the significant impact of technical change on productivity (Arnade, 1998). Furthermore, in the new millennium, Nin *et al.,* (2003) pioneered productivity studies focused on the agricultural sector. However, Nkamleu (2004) argued that technical efficiency was the driver of productivity growth rather than technical change. This study decomposed the productivity growth of sixteen African countries over the period 1970–2001. The study examined the productivity change for twenty developing states and concluded that technical change was the driver of productivity growth between 1961and 1994. Coelli and Rao (2005) revealed an average productivity change by applying the MI approach in ninety-three countries covering the period 1980–2000.

The third group of studies compared different approaches to decomposing agricultural productivity growth. A study conducted by Rezek *et al*., (2011) applied both the parametric and non-parametric models in the DEA and Stochastic Frontier models to decompose agricultural growth for thirty-nine African countries for the period 1961–2007. Alston *et al*., (2010) showed different results based on both the DEA and SFA methods, inputs and the length of the time period. Headey *et al*., (2010) used both SFA and DEA to decompose growth rates in agriculture for eighty-eight countries covering the period 1970–2001 and concluded reasonable SFA results compared to those of DEA. However, Thirtle *et al*., (1993) outlined the relationship between production functions and TFP indices in South Africa spanning 1947–1991 and revealed an increase in TFP, with an average rate of 1.3% per annum.

The last cohort of studies measured TFP by applying the Tornqvist index, the Fisher index and the Malmquist index as proposed by Caves *et al*., (1982). Khan *et al*., (2015) showed that neither the Tornqvist index or the Fisher index offers the direct and indirect comparison of two firms over the period of production and transitional firm over period to yield the same estimate of productivity change. Färe *et al*., (1994) argued that Malmquist productivity indexes can be fully decomposed as either parametric and non-parametric approaches. However, O'Donnell (2012b) showed that the Malmquist indexes tend to offer incomplete measures of productivity changes because of the inefficiency of capturing productivity changes associated with changes scale.

Lastly, Tozer and Villano (2013) applied the FPI to decompose productivity growth of 45 farmers producing grain in Western Australia over the period 2004–2007. The study revealed that producers were efficient in technical, mix and scale efficiency while input and output mix efficiency had variations. Moreover, in the context of decomposing agricultural productivity in Africa, Mohamed *et al*., (2016) and Majiwa *et al*., (2015) applied both the parametric and parametric Translog production function and Färe-Primont index to estimate TFP growth across countries.

Thus far, there is no known study that has applied the Färe-Primont index to decompose productivity and efficiency change of small-scale farmers and also the investigation of determinants of TFP growth at farm-level. To fill this gap in the literature, this chapter contributes to this sector with more focus on small-scale sugarcane growers in the northern part of KwaZulu-Natal.

3.7 Conceptualisation of the barriers to technical efficiency

3.7.1 Grounded theory

Grounded Theory (GT) is one of the qualitative methods that was introduced by the work of sociologists (Glaser and Strauss, 1967; Glaser, 1998; Strauss, 1987; Charmaz, 2006). The pioneering work on GT defined this method based on its ability to collect and analyse data, construct analytic codes, and make a comparison of each stage of the analysis. There are two approaches to analysing the GT developed by Glaser (1998) and Strauss and Corbin (1990). The difference between the approaches is focused on the theoretical coding of data, with Glaser advocating an open and selective method of coding while Strauss and Corbin favour an open and selective yet focused coding.

However, fundamental to GT is that analysing data with existing theory is not enough to generate new theories. Moreover, in qualitative research, there are different views on induction, deduction and verification of the data and its interpretation. Baker *et al*., (1992) contributed to the understanding of data issues by suggesting that researchers as social beings have a role to play in understanding the social processes to be observed. Therefore, the researcher's knowledge about the subject being studied and the availability of data in applying the grounded theory methodology is of importance.

This theory does not make any prior theoretical assumptions about the subject being studied or the data. In this regard, the data is allowed to speak for itself. Moreover, the theory emerging from the empirical data from GT is central to this theory. Flick (2004) argued that the purpose of GT is not to limit the variables of subjects to be studied. Recently, Charmaz (2006) proposed theoretical sampling as a process of selecting the group to be studied, and analysing it until it generates new information.

In this part of the thesis, the thematic analysis approach that forms part of GT will be used to investigate barriers to technical efficiency. Studies that investigated barriers to efficiency in agriculture are limited, with empirical work focused on the description of determinants of efficiency. However, with the vast literature on the application of GT in fields that lack clear theoretical certainty, GT will narrow the focus of barriers to technical efficiency.

3.7.2 Thematic analysis

Unlike quantitative methods, qualitative approaches have gone through scrutiny to be accepted as analysis tools in social and behavioural science research. One of the qualitative methods applied motivated by GT is Thematic Analysis (TA). Thematic analysis is the context of grounded theory that analyses qualitative interview data using a systematic approach (Chapman *et al*., 2015). Further, Fennell *et al*., (2016) argued that TA can be conducted to identify kinds of themes from participants to encounter situations based on past experience. It also offers researchers qualitative approach models that can be used in the modification of information collected using different designs. The term TA has been used for a long time and has been used in a lot of different contexts to find a pattern of meaning in things, with it benefits focused on its flexibility (Braun and Clarke, 2006).

In literature, there have been views expressed on the similarity between TA and GT. However, studies (Glaser, 1999; Kellerhear, 1993; Ezzy, 2002) have shown contrasting views on some claims made on the similarity of thematic analysis and grounded theory. These studies were focused on theoretical sampling that is inspired by a typical case and verification of theory that is developing from the subject in the analysis. Moreover, the importance of analysis is centred on the comparison of pieces of data that, which then builds a particular theme. This approach organises and describes the dataset in detailed themes.

Theoretically, there has been work conducted on the different analytical methods and TA applied in qualitative data such as Thematic Decomposition Analysis, Interpretive Phenomenological Analysis (IPA) and grounded theory. The work of Smith *et al*., (1999) showed that TA shows the daily experience of the people in analysis, while grounded theory analysis is used to generate theory and guides the coding process of the data that can be used in TA. Lastly, IPA and GT seek patterns in the data and are more oriented to theory rather than application.

There is a need for clarity on the term ‘theme’ that is commonly used in TA. Braun and Clarke (2006) described a theme as “a tool that captures something important about data and in relation to the research question, and represents some level of patterned response or meaning within the data set". Corbin's approach argued that a coding process is used to develop themes that can develop by using flexibility in the data set to even change themes. The underlying philosophy tends to be quantitative rather than the positivist philosophy which is commonly used in the applied context to inform a particular policy that is policy related. This umbrella approach is useful compared to other approaches because it shapes the way data is analysed and lacks sophistication and relies on the chosen theory to guide its analysis.

3.7.3 Concept of barriers to technical efficiency

The relationship between quantitative and qualitative approaches to the measurement of underlying factors that hinder technical efficiency draw conflicting views based on economic principles. Flexible qualitative approaches may play a role in the development of themes that affect optimal efficiency. These qualitative approaches may provide rich insights for an economist into phenomena that quantitative methodologies cannot penetrate, especially since they involve an investigation into subjective issues like an individual's perceptions and interpretation of reality. Therefore, the clear identification of themes from the growers' experience will provide an in-depth understanding of barriers that are very difficult to quantify. The definition of barrier comes from the work of Weber (1997) that breaks the definition down into three components i.e. "*What is the barrier?*", "*Who or what is it an obstacle to?"* and "*What does it prevent?".* Therefore, in answering these questions clear and sound definitions were applied. To answer the first question, the process of abstraction by maximising routing and the relative importance of social structures is carried out to offer a clear understanding. The second question seeks to identify the relevant actor. Lastly, the focus is on the general context of production decision- making within a farm business.

The definition of "technical efficiency" comes from the work of Farrell, (1957) that defined this concept as the ability of a small-scale sugarcane grower to obtain maximum attainable output from a given set of physical inputs. Coelli et al., (2005) are of the view that for a small-scale sugarcane grower to be technically efficient her maximum quality of output must be produced from sets of inputs. Thabethe, (2013) ranked constraints faced by small-scale sugarcane growers according to the levels of importance. This chapter applied the qualitative analysis of barriers to technical efficiency in developing countries using two vigorous approaches that interrogate the participants' experiences and knowledge. Other, empirical, literature on barriers to agricultural production in developing countries focused on climate change (Ziervogel *et al*., 2006), infrastructure and government policies (Atser, 2007), development constraints (Oni, 2013), and macroeconomic policies (Etim, 2015).

3.7.4 Literature review: Barriers to technical efficiency

The literature on barriers to agricultural productivity has developed across three main themes i.e. economical, organisational and behavioural. Each of them is reviewed in turn. Theoretical and empirical studies (Fafchamps and Minten, 2002; Kassie and Holden, 2007; Di Falco *et al*., 2011; Di Falco and Veronesi, 2013; Asfaw *et al*., 2016) have revealed several barriers that impact agricultural production as a consequence of technological choice, limited access to credit, and impact of production risk. These studies contributed to the three main themes mentioned above. Concerning the economic theme, lack of capital in the form of limited access to credit is still a challenge in small-scale farming. The study by Fafchamps and Minten (2002) showed that social network capital has a positive effect on the performance of agricultural firms. Moreover, the role of social capital is important for efficiency in economies that are characterised by high costs of production like sugarcane farming (Fafchamps and Minten, 2002).

Concerning institutional barriers, the theoretical approach by Kassie and Holden (2007) revealed how kingship allocation influences output and land productivity. The study went further and introduced a hypothesis focused on the uncertainty of the particular small-scale grower related to future allocation of plots. Di Falco *et al*., (2011), focusing on behavioural barriers, showed the rate at which a particular small-scale grower adapts to the effect of climate change on productivity and its contribution to farm productivity and relative efficiency. Similarly, Di Falco and Veronesi (2012) argued that small-scale growers that have past adaptation skills to climate change experience have the ability to reduce the risk of crop failure. Lastly, variations in climatic conditions have become the strongest influence on the kind of adapted practice. Furthermore, inputs such as fertilisers are negatively related to variations in rainfall and temperatures.

The institutional support of non-governmental and governmental organisations remains the strongest point to uplift small-scale sugarcane growers. A study focused on the effects of institutional environment and technical efficiency of cotton producers revealed constraints in performance (Theriault and Serra, 2013). This study proposed policies focused on reducing financial stress through improving farm-gate prices. However, this prevailing challenge of farm-gate prices declining over time is common to sugarcane growers. Serra *et al*., (2008) applied SFA to determine the impacts of production risks and risk preferences of farmers in Kansas that enjoyed government programmes. The study concluded that government support was not positively related to production, contributing to the body of knowledge that showed that government support in the form of transfers has little effect on input use and may be responsible for technical inefficiencies.

The other group of studies focused on constraints that affect technical efficiency and agricultural production. In addition to the studies reviewed above, this body of literature used descriptive statistics to quantify these constraints. Komicha and Ohlmer (2007) revealed that credit constraint affects technical efficiency in a study focused on Ethiopian household farmers. However, (Haji and Anderson, 2006; Backman *et al*., 2011; Duy, 2012, Zhao and Barry, 2014) showed mixed results regarding the effect of credit on technical efficiency. Although these studies produced different results there is the need to link credit constraint to technical efficiency. Moreover, Heriqbaldi *et al.,* (2015) argued for improved farmers' income and support in financial aspects to ease resource input constraints, in order to stimulate technical efficiency.

3.8 Chapter summary

This chapter has presented the theoretical concepts of agricultural efficiency, productivity and barriers to technical efficiency. The qualitative approach was outlined to identify the barriers to efficiency. There are a limited number of studies that have shown the hindrances of external and internal factors to technical efficiency. The following chapter provides a study on the application of DEA to measure productive, chemical-use efficiency and its determinants as well as input-slacks. The next chapter four apply the DEA to measure technical, cost and allocative efficiency, input-slack and the determinants of technical efficiency in the King Cetshwayo district.

CHAPTER FOUR

APPLICATION OF DEA TO MEASURE TECHNICAL, COST AND ALLOCATIVE EFFICIENCY AS WELL AS INPUT-SLACKS AND DETERMINANTS OF TECHNICAL EFFICIENCY

This chapter focuses on measuring technical, cost and allocative efficiency as well as the determinants of technical efficiency. Furthermore, the chapter seeks to account for input-slacks on technical efficiency. With this in mind, the chapter utilises the DEA technique to test some of the objectives outlined in chapter 1. To estimate and identify efficiency and its determinants, the DEA with VRS technologies are bootstrapped and a regression model applied to estimate determinants of technical efficiency. The chapter introduces the central theme of the chapter, which is followed by an outline methodological framework and empirical results. It concludes with a discussion.

4.1 Introduction

In the Zululand region which is in the northern part of KwaZulu-Natal, there are three mills (Umfolozi, Felixton and Amatikulu) that crush sugarcane for growers. This region was second to the irrigated northern part of Pongola, Komati and Malalane, whose combined irrigated area accounted for 5 153 142 tons of crushed sugarcane, while the Zululand region was at 3 299 070 tons. According to SASID (2017), there has been a marginal decline of sugarcane production from the 2014/2015 to 2015/2016 season.

The efficiency of small-scale farmers is important because of the productivity gap between large and small farmers, with large farmers being more efficient (Rios and Shively, 2005). Furthermore, measuring the efficiency of small-scale sugarcane growers might identify the factors that have resulted in the decline in production. The small-scale farmers tend to have limited land, labour, capital, and farming acumen and operate in the poor rural areas of South Africa. Small-scale sugarcane growers fall into the broad category of small-scale farmers and are subject to the same challenges faced by others in the category. Small-scale farmers need to understand how to achieve optimal output using the lowest level of inputs.

The adaptation of chemicals as herbicides and pesticides is vital for the performance of small-scale sugarcane growers and the livelihood generated through sugar production. According to Khan *et al.,* (2014) under or over-utilisation of resources has resulted in a decline of agricultural productivity growth in developing countries. The efficiency of small-scale farmers is important in order to eliminate the productivity gap between sugarcane growers in their three categories (Rios and Shively, 2005). The inefficiency of small-scale sugarcane growers stems from their having limited land, labour, capital and farming acumen. Therefore, benchmarking and estimation of technical and chemical use efficiency among small-scale sugarcane growers is of vital importance to mills, sugarcane growers, extension officers and policymakers as well as other stakeholders involved in the sugar industry. Within this context, it becomes crucial to study the productive efficiency of small-scale sugarcane growers as it will provide insight into the nature of the decline in production of sugarcane among small-scale growers as well as the appropriate measures that may be adopted to improve yields.

Empirical studies (Thabethe *et al*., 2014; Dlamini *et al*., 2010) have focused on the efficiency scores of the sugarcane growers and factors that affect efficiency and inefficiencies. This present study measured technical efficiency and chemical input-use efficiency as proposed by (Chemak *et al*., 2010). Because of the prevalence of drought over-application of chemicals might lead to soil degradation which, in turn, might hamper the sustainability of the farm business in the long run. While, on the other hand, the over- utilisation of the chemical input might result in a higher production cost. The key performance management tools of technical and allocative efficiency can be used to improve agricultural production (Tang *et al.,* 2015; Henderson, 2015; Ndlovu *et al.,* 2014). As a result, small-scale sugarcane growers need to be aware of their performance management shortcomings in order to improve maximum yield.

The work of Charnes *et al.,* (1978) and Banker *et al*., (1984) originated the ranking of productive performance using DEA. DEA ranks the Decision-Making Units (DMU's) that are characterised by the input and output vector in the production of farming enterprise against other DMUs. This Linear Programming (LP) non-parametric approach has the ability to measure efficiency in both the heterogeneity and homogeneity farming samples. It measures the production gap between each farmer's managerial acumen benchmarked against best practices. The LP approach of DEA is measured using two basic components; the first rationale is to maximise output

(output-oriented approach), while the second is input-oriented approach and is focused on the minimisation of the input (input-oriented).

This chapter reports on the measurement of efficiency using the input-oriented approach because of small-scale sugarcane growers. The input-oriented approach measures efficiency by benchmarking a DMU in a frontier that holds when a decrease in a particular input cannot result in a decrease of other inputs, subsequently decreasing output (Charnes *et al*., 1981). The second main component of DEA models is related to the properties of the Production Possibility Set (PPS) constructed relying on the production axioms given above. These properties are identified through the constraints of the linear programming model (Atici, 2012).

In the agricultural set-up, DEA with VRS technologies is more favoured than CRS technologies due to its ability to benchmark technical efficiency of DMUs with varying scales, implying that DMUs with different productions scales can be efficient (Benicio *et al.,* 2015). Small-scale sugarcane growers produce on small portions of land with different plot sizes, therefore the DEA BCC (Banker Charnes Cooper) model account for their DMU's while minimising the input under the VRS. In empirical literature (Battese and Coelli, 1992; Bojnec and Latruffe, 2013; Chaitip *et al.,* 2014), the efficiency of agricultural productivity is characterised by different socio-economic characteristics. Moreover, in sugarcane production, the efficiency of small-scale sugarcane growers is influenced by socioeconomic determinants of technical efficiency (Thabethe *et al.,* 2014). Socio-economic factors such as age, education level, access to extension, access to credit, land holding size and access to improved technologies influence technical efficiency.

The purpose of this chapter is to estimate input-oriented technical, cost and allocative efficiency, identify the determinants of the technical efficiency as well as to determine the impact of input slacks on the technical efficiency of small-scale sugarcane growers. The input-oriented model of DEA with VRS technology was applied to analyse the objective of this chapter. The chapter pursues the following hypotheses: There is no input-oriented technical, allocative and cost efficiency in small-scale sugarcane growing within the King Cetshwayo district of KwaZulu-Natal. There are no known determinants of technical efficiency in small-scale sugarcane production in the King Cetshwayo district of KwaZulu-Natal. There is no impact of input-slacks on technical efficiency in small-scale sugarcane growing in the King Cetshwayo district of KwaZulu-Natal.

In answering the above hypotheses, this chapter contributes to efficiency analysis in the small-scale sugarcane growers in the following aspects, namely: DEA analysis of sugarcane growers with emphasis on minimising their inputs to attain optimal output; key determinants that trigger efficiency; and, lastly, input-slack that impacts productive efficiency. This gap was identified in the northern sugarcane production region of KwaZulu-Natal.

4.2 Methodological Framework

4.2.1 Data Envelopment analysis and efficiency measurements

The work of Farrell (1957) is the pioneering methodology behind the measurement of relative efficiency across different disciplines. This approach uses DMUs to estimate their efficiency, using either SFA, which is a parametric approach, or the nonparametric approach of DEA. In the application of the efficiency measurement with DEA it is achieved through a linear programming approach, with two components i.e. the first, on how the efficiency is measured, and the second, focused on setting the nature of the objective function of the LP model.

There is empirical evidence that explains why this study applied the DEA approach to measuring the productive efficiency of small-scale sugarcane growers. A number of studies (Lovell and Pastor, 1995; Allen *et al.,* 1997; Tone, 2001; Coelli *et al*., 2005; Fried *et al*., 2008) showed the merits of using DEA to be as follows: (i) DEA has the ability to handle multiple inputs and outputs simultaneously; (ii) it offers researchers the freedom of not specifying restrictive functional forms; (iii) it has the ability to decompose efficiency into several components; (iv) it is unit variant and has the ability to work with variables of different units without the need for standardization; (v) it generates relative prices/weights if desired and/or required.

4.3 Theoretical framework

4.3.1 Estimation of input-oriented technical and scale efficiency

The theoretical framework for DEA efficiency was discussed in detail in chapter 2. In the first stage of the analysis, this study applies the input-oriented VRS model of Banker *et al.,* (1984), on the assumption that small-scale sugarcane growers have more control over quantities of inputs than output. To facilitate the measurement of small-scale sugarcane growers' efficiency, we assume the n DMU producing an output Y by applying input $X. X$ as an $i \times n$ matrix of inputs and with Y representing a $k \times n$ output row vector. It is to be noted that many if not all of the inputs that small-scale sugarcane growers use can be considered as variable, and given these inputs, the small-scale sugarcane growers are expected to minimise them to attain technical efficiency. With this in mind, an adequate efficiency measurement would consider the extent to which output can be expanded without altering the quality of inputs. The input-oriented technical efficiency under the variable return to scale for a given DMU_P was computed by solving the following standard linear programming problem:

$$\text{Min}_{(\lambda,\theta)}\theta \tag{4.1}$$

subject to:

$$\sum_{j=1}^{n} \lambda_j\, x_{ij} - \theta x_{ig} \le 0,$$

$$\sum_{j=1}^{n} \lambda_j\, y_{kj} - y_{kg} \ge 0,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \ge 0,$$

where: θ is a scalar and represents technical efficiency; λ_j is a vector of j elements which represents the influence of each farm in determining the technical efficiency of the observed grower; p, x_{ig} and y_{kg} are the input and output vectors of the grower g; the equation [$\sum_{j=1}^{n} \lambda_j = 1$] is a convexity constraint which specifies VRS in the model.

To account for scale efficiency, the study imposed another restriction [$\sum_{j=1}^{n} \lambda_j \leq 1$] in equation 4.1 to estimate scale efficiency by computing TE under CRS, as explained in equation 4.2 below:

$$SE = TE(CRS)/TE(VRS) \qquad (4.2)$$

However, because the above measure of scale efficiency falls short in the indication of whether a particular DMU is operating in an area of increasing, decreasing or constant returns to scale. The additional DEA model with a non-increasing return to scale restriction [$\sum_{j=1}^{n} \lambda_j \geq 1$] was solved. Accordingly, Coelli *et al*., (2005) showed that the relationship $TE_{(NIRTS)}$ = $TE_{(VRTS)}$, $TE_{(NIRTS)}$, ≠ $TE_{(VRTS)}$ and $TE_{(VRTS)}$ = $TE_{(CRTS)}$ indicates the existence of increasing, decreasing and constant return to scale.

4.3.2 Estimation of cost and allocative efficiency

The cost efficiency for a DMU_g was computed by solving the following linear programming of the DEA with a cost minimisation objective, where x_g^* represents the cost minimisation vector of input qualities and w_g' is the vector of input prices:

$$\text{Min}_{(\lambda, x_p')} \, w_g' x_g^* \qquad (4.3)$$

subject to:

$$\sum_{j=1}^{n} \lambda_j \, x_{ij} - x_g^* \leq 0,$$

$$\sum_{j=1}^{n} \lambda_j \, y_{kj} - y_g \geq 0,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \geq 0.$$

The total cost efficiency for DMU_g was calculated as CE = $w_g' x_g^* / w_g' x_g$, hence cost efficiency is the ratio of minimum cost to the actual cost for the DMU. To calculate allocative efficiency, the ratio CE and TE was calculated as demonstrated in equation

4.4, below as follows;

$$AE = CE/TE \tag{4.4}$$

Regardless of the vast application of the conventional DEA technique, like any other analytical technique, it still has several inherent constraints. To precisely point out one, the DEA has no statistical properties and consequently leads to the generation of biased estimates and limits the DEA's optimal application to decision makers, failing which, point estimates of inefficiency will not offer insight on uncertainty concerning sampling variation (Ferrier and Hirschberg, 1997; Simar and Wilson, 2000). With this said, there was a need to apply a bootstrapping technique of (Simar and Wilson, 1998) to simulate the data generating process and to apply the original estimator to each simulated sample to mimic the resampled estimates based on the estimator of the original distribution. To overcome the above-mentioned limitations of the DEA this study applied the homogenous bootstrap algorithm introduced by Simar and Wilson (1998; 2000).

4.3.3 Chemical use efficiency

In order to measure the efficiency of a particular input, the DEA sub-vector (SVM) and slack-based DEA model (SBM) are traded off. These non-radial models differ in the sense that the SVM does not take into consideration the non-zero slack values, while the SBM calculates efficiency together with slack values. Based on the above advantage of the SBM the slack-based DEA model under the assumption of VRS introduced by Cooper *et al*., (2011) was formulated as follows:

$$\mathrm{Min}(\lambda, \theta, S^{-} S^{+}) \left[\theta - \varepsilon\left(\sum_{i=1}^{m} S_i^{-} + \sum_{k=1}^{s} S_k^{+}\right)\right], \tag{4.5}$$

subject to:

$$\sum_{j=1}^{n} \lambda_j \, x_{ij} - S_i^{-} = 0 x_{ig},$$

$$\sum_{j=1}^{n} \lambda_j \, y_{kj} - S_k^{+} = y_{kg},$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \geq 0$$

where S_i^-, $S_k^+ \geq 0 \forall i$ and $k. X$ is an $i \times n$ matrix of inputs, Y represents a $k \times n$ output row vector and S_i^- and S_k^+ represent the input and output slacks, respectively. The non-Archimedean infinitesimal order that is expected to be small or any real positive number is denoted by the symbol ε. The slack-based model to estimate pesticides efficiency as proposed by Chemak *et al*., (2010) as the analysis for the efficiency of each input is expressed as follows:

$$CME = TE - \frac{Ve_p}{Vo_p} \tag{4.6}$$

where TE is the technical efficiency estimated using equation 1, Ve_p is the slack value of the input p, and Vo_p is the observed quantity of the input p.

4.3.4 Determinants of technical efficiency

In the second stage of the DEA analysis, the truncated regression proposed by Simar and Wilson (2007) was bootstrapped to analyse the socio-economic factors that drive technical efficiency. Studies (Stanton, 2002; Wijesiri *et al*., 2015) which regressed the DEA estimates of technical efficiency in the second stage have opted to use either censored (Tobit) or Truncated regression models. In measuring agricultural efficiency Watto and Mugera, (2014) applied the Truncated regression to investigate the determinants of technical and irrigation efficiency. During the second stage of the DEA both dummy and continuous variables were applied; these explanatory variables tend to be correlated with the error term since input and output variables are correlated with explanatory variables. Furthermore, in the second stage, DEA estimates are biased and serially correlated, which results in the yielding of inconsistent estimates (Simar and Wilson, 2007).

Moreover, the truncated regression performs well in the estimation of confidence intervals in the single bootstrap and performed even better in the double bootstrapping, although empirical studies (Wadud and White, 2000; Speelman *et al*.,

2008) justified the application of Tobit regression in the second stage investigation of determinants of technical efficiency. This study followed the path of Watto and Mugera, (2014) that applied the truncated regression solely based on the point that fractional values of the OLS in the second stage analyse more precise results compared to the Tobit regression (McDonald, 2009). Based on the argued empirical evidence the study applied the single bootstrap truncated regression to identify determinants of technical efficiency as follows:

$$Y_j = \alpha_j + \sum_{j=1}^{n} \beta_j z_j + \varepsilon_j \geq 0; j = 1, \ldots., N \text{ and } \varepsilon_j \rightarrow N(0, \sigma^2), \qquad (4.7)$$

where Y_j is technical efficiency, Z_j is the set of explanatory variables for $j = 1, \ldots, 9,$ and e_j is the error term.

4.4 Study area and data

4.4.1 Study area

The primary aim of this section is to provide a description of the study area, research design, data collection and socio-economic characteristics of the sampled small-scale sugarcane growers. The study was conducted in the King Cetshwayo district of KwaZulu-Natal province. King Cetshwayo was formally known as the uThungulu district. The area has favourable climatic and soil conditions for sugarcane production and hosts two Tongaat Hulett mills. The mills operate in the rural set-up and have different mill capacity.

The Tongaat Hulet mills extension services together with the KwaZulu-Natal Department of Agriculture and Rural Development service sugarcane growers in the district. Small-scale sugarcane production takes place across the district. According to the Tongaat Hulett small-scale grower extension office there were approximately 4 500 small-scale sugarcane growers who were working their lands to produce sugarcane in the region in the last season (information sourced from mill data, Tongaat Hulett, Felixton branch, 2016). However, there is a need to confirm this number because during the data collection process many growers we leasing and leaving their land fallow because of unfavourable climatic conditions.

The King Cetshwayo district covers an area of 8213 km^2 extending from the agricultural town of Gingidlovu in the south to the uMfolozi River in the north and inland to the mountainous beauty of rural Nkandla. The district boasts favourable agricultural climate and soil and vast land for sugarcane production. The district has experienced a number of difficulties hampering economic development. Crippling droughts and deep rural livelihood in poverty are part of the district (IDP, 2016). The district was chosen because it hosts two mills under Tongaat Hulett, in the Felixton and Amatikulu mills. These mills provide extension support, seeds subsidies, transportation through the supplier, and crushing of the cane. The other interesting aspect of sugarcane production in this region that contributed to the decision to sample the district was based on dry land production by entirely all the small growers that were sampled.

4.4.2 Data and variables

Primary data was collected through structured questionnaires for the 2015–2016 sugarcane production season. The study applied the multi-stage sampling technique to interview household heads and main decision-makers in sugarcane enterprises in the absence of the household head in the region. The sample size of 300 small-scale sugar growers was tendered a questionnaire in early and mid-2017 with the help of five field workers. A simple random sampling of the selected sample was out of the population that operated in the chosen season using the confidence level of 95% and a 5% confidence interval to obtain a sample of 300. The 300 small-scale sugarcane growers comprise 220 and 80 growers from the Felixton and Amatikulu mills respectively. The other reason the Felixton mill sampled the higher number of growers was based on the sugar crushing capacity of the mill and sub-station they operate from and the number of growers in both mills. Basically, the mill caters for a fair share of the cane crushed in the district. The other reason for these uneven numbers was the declining amount of planted land for many small-scale sugarcane growers in the Amatikulu mill and most of the land is under co-operatives farming.

The extension supervisors (officials of the mills who render free technical assistance to client farmers) played a major role in the sampling procedure. The group of Felixton small-scale sugarcane growers were randomly selected in the villages of KwaDlangezwa, Mangezi, KwaMbonambi, and Ngwelezane, while the remaining growers from the Amatikulu region were also randomly selected using their growers' numbers. The instrument was used to collect production data and socio-economic background information from individual small-scale sugarcane growers through interviews. Various inputs and output quantities were measured, including labour, machinery, seeds, chemicals and fertilisers. The output (sugarcane yield) for each small-scale sugarcane grower was obtained from the extension officers' production estimates for that particular season. Information on prices of inputs was obtained from the local agro-retailer the small-scale sugarcane growers indicated as the source of their production inputs. The prices of these inputs were collected in South African Rand.

The study had already acquired output data from the mills and the list of grower codes that operates in the five villages that were sampled out of 1532 small-scale sugarcane growers that produced in the sampled season. The procedure that was followed to randomize the selected sample was as follows. After obtaining the growers codes from the extension officers, the list was printed and torn into strips and placed in the box. The strips identified each individual and were folded and shuffled in the box. Lastly, the 300 strips were picked randomly picked with names of small-scale sugarcane growers. The randomised small-scale sugarcane growers were administrated a questionnaire with the help of extension officers who knew the area to get a specific grower.

4.4.2.1 Descriptive statistics

Various inputs and output quantities were measured, i.e. labour, machinery, seeds, chemicals and fertilisers. The output (sugarcane yield) for each grower was obtained from the extension officers' production estimates for that particular season.

As illustrated in table 4.1, the average sugarcane yield is 121.01 tons/ha while an average of 2.47 litres of chemicals was utilised to improve the overall yield per hectare. Fertiliser use was an average of 542 kg. Both family and hired labourers were used. The number of hours was used to analyse variable labour. The average number of hours spent on sugarcane production was 513.60 hours/ha. On average, 6.40

implements were used in the production system. The seeds used by other growers that were certified by the mill was on average 3.10 tons/ha.

TABLE 4.1: DESCRIPTIVE STATISTICS FOR OUTPUT AND INPUT VARIABLES

Variable	Mean	Standard Deviation
Sugarcane yield (tons/annum)	121.01	177.02
Chemicals (litres/ha)	2.47	0.65
Fertiliser (kg/ha)	542.00	411.87
Labour (hours/ha)	513.60	317.50
Machinery (farm operations) in what? Hours? Litres petrol?	6.40	0.93
Seeds (tons/ha)	3.10	2.65

TABLE 4.2: DESCRIPTIVE STATISTICS OF TRUNCATED REGRESSION VARIABLES

Variable	Median	Average	Standard Deviation	Min	Max
Age of HH head/decision maker (Years)	48	47. 6	10.04	27	82
Extension support (number of visits/season)	4	4	0.35	0	4
Area under cultivation (ha)	7.43	6.18	2.49	0.20	18.31
Dummy variables (N = 300)	1	2	3	4	
Access to Credit (1= yes, 2 = no)	19	281			

Education of HH head (1 = no formal education, 2 = up to matric, 3 = above matric)	131	104	65	
Employment status of HH head (1 = unemployed, 2 = employed, 3 = pensioner)	110	131	59	
Experience of HH head (1 = up to 5 years, 2 = up to 10 years, 3 = above 15 years)	16	111	173	
Gender of HH head (1= male, 2 = female)	146	154		
Land tenure of HH	252	48		
head (1 = owners, 2 = tenants)				
Marital status of HH head (1 = single, 2 = married, 3 = widowed, 4 = divorced)	48	198	35	19
Size of household (1 = up to 5 members, 2 = up to 10 members, 3 = above 10 members family)	37	219	44	
Off-farm income (1 = yes, 2 = no)	148	152		

In Table 4.2, the 12.3% represents households with family members that were fewer than 5 in total. The majority of the households (73%) accommodated 10 or fewer members. The remaining percent of 14.6% accounts for households that have more than 10 people. Lastly, the total number of 49.3% of households' head in the sugarcane production earned off-farm income in the sample. However, a total of 50.6% of these households did not have any off-farm income at their active labour age. It is also worth noting that 19.7% received social grants as senior states members.

The average age of the growers was 47.6 years, with the minimum and maximum years of 27 and 82 respectively. The statistics revealed 31% consists of growers above 60 years, followed by 29.3% between 50 to 59 years, and other age groups accounting for the remaining percentages. The majority of these growers cultivated sugarcane on 6.18 hectares of land, with none of them exceeding 20 hectares. Out of 300 growers 6.3% had access to formal credit institutions and this can be attributed to lack of collateral on the part of small-scale sugarcane growers. In the analysis, 43.7% of the growers had no formal education. With the average age being almost 50 years old it was surprising that 34.7% had access to schooling until matric.

Moreover, a total of 36.7% small-scale growers were unemployed outside of their sugarcane enterprises, hence these growers may devote their whole time to farming. While 43.7% were employed one needs to point out that 19.7% of these growers were pensioners. Concerning the experience of the growers, growers with less than 5 years' experience were 5.3%. This was followed by 37% with sugarcane production experience below 10 years. Furthermore, concerning the number of years spent growing sugarcane, the majority (57.7%) had seen more than 10 seasons in the sector. On average, growers were exposed to 4 extension visits to their enterprises per season (not including farmers' days where other stakeholders come and advise on best practices and varieties of production inputs).

Most of the growers are female (51.3%) and work the tribal land as opposed to communal and privately-owned land. 84% of the growers grow their sugarcane on the owned tribal land under their family names, with only 16 % leasing from the fellow growers who do not have resources to produce. The total of 66% sugarcane growers were married, followed by 16% who were single, while widowed growers accounted for 11.6% and the remaining 6.3% were divorced.

4.4.3 Selection of input and output variables

Empirical studies (Cooper *et al*., 2000; Stern *et al*., 1994) in the application of DEA advocate for the sample size to be three times the sum of input and output variables. The study focused on the production approach of small-scale sugarcane growers and looked that DMUs that produce sugarcane for the mills using chemicals, fertiliser, labour, machinery and seeds. In modelling agricultural performance management, the KLEMS (Capital, Labour, Energy, Material input and purchased services) approach is commonly used in the classification of inputs. This approach advances the aggregation of the last three inputs (Coelli *et al*., 2005).

In small-scale sugarcane production most growers hire machinery, hence the best practice for quantifying the implements was to account for the aggregated implements and their costs. Labour remains a critical input in agriculture due to its nature, and the literature recommends labour hours as the appropriate measure of the labour input. This can be attributed to the nature of family, skilled, unskilled and temporary labourers that helped in the production of sugarcane. The influence from previous literature dictated the choice of the inputs such as seeds, chemicals and fertiliser.

4.5 Empirical Results and Discussion

The results in this chapter were analysed using the software R-studio and the required packages for benchmarking performance management. The empirical results of the study benchmarked each grower against the best performing practice in the production of sugarcane. The DEA efficiency estimation in Table 4.3 was computed under variable returns to scale. The frequency distribution of technical, scale, cost and allocative efficiency showed variation, bearing in mind that for a farm to be fully efficient TE, SE, CE and AE must be equal to 1.

The findings reveal that small-scale growers ought to produce 27.5%, 22.1%, 74% and 50.7% more using the same input levels to optimise their production. Based on table 4.3 the mean technical score of 72% was presented, the small-scale sugarcane growers are operating with an inefficiency of about 28%. However, out of the sample, only 21% of the sugarcane growers were fully efficient, followed by some 5.3% in the region between 80 and 99% of mean scores. It is worth mentioning that 45% of the sugarcane growers showed mean efficiency scores below 60%. Although, 15% of the sugarcane growers had mean efficiency scores of less than 20% there is room to improve the growers' productivity by proper application of inputs and by striving to operate at the optimal scale.

TABLE 4.3: FREQUENCY DISTRIBUTION OF TECHNICAL, SCALE, COST AND ALLOCATIVE EFFICIENCIES

Frequency (%)	TE (N = 300)	SE (N = 300)	CE (N = 300)	AE (N = 300)
< 20	45	39	128	45
20 - 40	62	51	119	82
40 - 60	28	37	28	155
60 - 80	86	95	25	18
80 - 99	16	47	0	1
100	65	31	0	0
Mean	0.72	0.77	.26	0.49
Standard deviation	0.22	0.18	0.73	0.11
Minimum	0.28	0.24	0.07	0.10
Maximum	1	1	0.61	0.88

AE, CE, SE, TE denote allocative efficiency, cost efficiency, scale efficiency, and technical efficiency respectively.

Concerning scale efficiency there is a lot one can draw from its parameters; it showed mean efficiency scores of 77%, hence 23% inefficiencies. Although 10% of the sugarcane growers showed full-scale efficiencies, 32% averaged between 60 and 80% while 42% operated in the range below 60%. The analysis showed the least of small-scale sugarcane growers with less than 20% across the sample at the figure of 39 growers translating to 13%. Based on the above scale efficiency scores, sugarcane growers need to work harder to operate optimally under the current technology and consider reducing production to improve technical efficiency.

Much focus needs to be directed to cost and allocative efficiency in Table 4.3, the cost efficiency showed 26% implying 74% inefficiencies, with none of the small-scale sugarcane growers operating in full efficiency and the region between 80–99%. This implies that the maximum parameter for both cost and allocative will never reach the maximum fully efficiency (CE = AE = 1). The group of small-scale sugarcane growers (82%) operated below the 40% level while the remaining 18% were in the range between 40–80. With the minimum and maximum scores being 07% and 61%

respectively one can draw the conclusion that small-scale sugarcane growers need to decrease their production cost by 74% to maximise their profit while minimising their inputs. Subsequently, allocative efficiency score showed 49% efficiency, suggesting that these small-scale sugarcane growers ought to reduce their inefficiency by 51% relating the price and the available inputs. Almost half of small-scale sugarcane growers i.e. 52% operated between 50% and 60%, while only one small-scale sugarcane grower was operating between 80–99%.

These results are in contrast to Padilla-Fernandez and Nuthall (2009) who applied DEA and found higher TE and SE inefficiency scores. However, the study can draw a similar conclusion concerning TE being the major source of inefficiency compared to SE. However, parametric studies (Babalola *et al*., 2009; Dlamini *et al*., 2010) found varied mean technical efficiency scores. Since all these studies were conducted outside of South Africa's borders. Thus far the only study Thabethe *et al.,* (2014) conducted in South Africa applied a parametric analysis using the Stochastic Frontier production frontier in the Nkomazi region of the Mpumalanga province, producing TE, EE and AE mean scores of 68.3, 41.8 and 61.5 respectively. This study concluded that small-scale growers are not fully efficient and, in that regard, the analysis of small-scale sugarcane growers supports this finding.

However, as explained earlier in equation (4.1) this measure of scale efficiency has a shortcoming regarding whether the growers are operating under increasing or decreasing returns to scale. Watto and Mugera (2014) applied the disaggregation of scale efficiency to investigate farms that reveal increasing and decreasing returns to scale as illustrated by table 4.4.

TABLE 4.4: DISTRIBUTION OF RETURNS TO SCALE

Returns to scale (%)	Percent (N = 300)
TEC	30.4
TED	32.3
TEI	37.3

TEC, TED, TEI denotes constant return to scale, decreasing return to scale and increasing return to scale.

Table 4.4 showed that 30.4% of the sugarcane growers operated at the optimal scale of constant return to scale, while 32.3% of the growers exhibited a decreasing return to scale. These growers need to properly allocate inputs to increase technical efficiency. While the highest number (37.3%) of the growers exhibited an increasing return to scale, these growers are operating below the optimal scale.

The slack based measure model was applied to estimate the chemicals use efficiency of small-scale sugarcane growers. Pesticides and herbicides were the applied chemicals in the production of sugarcane in the King Cetshwayo district. Table 4.5 below reports on the frequency distribution of slack-based chemicals use efficiency and shows inefficiencies in the application of the input chemical. The mean estimates of 68% chemical use efficiency implies that growers ought to reduce chemical application and continue to maintain the available quantities of inputs to yield the desired output level.

TABLE 4.5: FREQUENCY DISTRIBUTION OF SLACK-BASED CHEMICALS USE EFFICIENCY

Frequency (%)	Slack-based chemicals use efficiency (N = 300)
< 20	6
20 – 40	31
40 – 60	96
60 – 80	59
80 – 99	18
100	90
Mean	0.68
Standard deviation	0.26
Minimum	0.15
Maximum	1

Out of 300 hundred sugarcane growers, 90 showed 0% of input-slack, while 18 were in the region between 1–20% inefficiency. On the other hand, 59 growers showed inefficiencies between 20–40%, while the majority of the sugarcane growers estimated inefficiencies in the region of 40–60%. The growers in the region of 60–80% inefficiencies numbered 31. However, 6 sugarcane growers, who happen to be the lowest number, estimated 80–100% of inefficiency.

TABLE 4.6: SPEARMAN'S RANK CORRELATION AMONG TECHNICAL EFFICIENCY AND SLACK-BASED CHEMICAL USE EFFICIENCY

	Technical Efficiency	Slack-based chemical use efficiency
Technical efficiency	100	
Slack-based chemical use efficiency	0.657**	100

Table 4.6 revealed a positive relationship between technical efficiency and slack-based chemical use efficiency. Figure 4.1 showed that chemical use efficiency is more distributed compared to technical efficiency. To test the difference between technical efficiency and chemical use efficiency, a paired t-test was analysed as indicated in Table 4.7. We then reject the null hypothesis that technical efficiency and chemical use efficiency are equal. The t-test revealed that technical efficiency is significantly higher than chemical use efficiency.

TABLE 4.7: PAIRED SAMPLES T-TEST BETWEEN TECHNICAL EFFICIENCY AND CHEMICAL USE EFFICIENCY

	Mean	Standard deviation	t-statistic
Technical efficiency: Chemical use efficiency	0.8345	0.276	5.228***

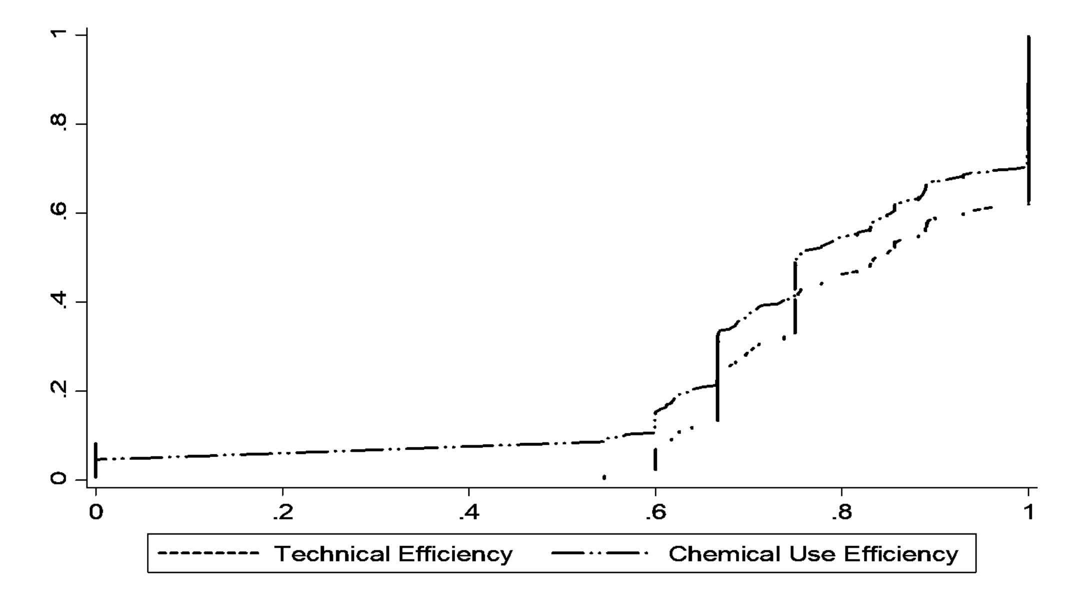

FIGURE 4.1 CUMULATIVE DISTRIBUTION FOR TECHNICAL AND SLACK-BASED CHEMICAL USE EFFICIENCY.

The truncated regression model was bootstrapped in the second stage of the study to analyse the socio-economic background determinants of technical efficiency. The empirical findings are shown in Table 4.8.

TABLE 4.8: BOOTSTRAP TRUNCATED ESTIMATES OF DETERMINANTS OF TECHNICAL EFFICIENCY

Variable	Estimate	Standard Error	Pr(>ItI)	Confidence
Age of HH head/decision maker	0,113	0,068	0,099	0,3482
Age^2 of HH head	-0,022	0,013	0,082	0,2132
Gender of HH head	0,005	0,022	0,815	0,2402
Marital status of HH head	-0,028	0,022	0,216	0,2072
Education of HH head (up to matric)	0,021	0,025	0,001**	0,2562

Off-farm income status of HH head	0,062	0,021	0.006**	0,2972
Size of household (above 5 but fewer than 10 members)	0,019	0,034	0,575	0,2542
Size of household (above 10 members)	0,029	0,039	0,412	0,2642
Land tenure of HH head (tenants)	-0,018	0,031	0,543	0,2172
Employment status of HH head (employed)	-0,037	0,025	0,218	0,1982
Experience of HH head (above 10 but less than 30 years)	-0,093	0,025	0.001***	0,1422
Extension visits (Four/season)	-0,157	0,076	0.040*	0,0782
Access to Credit	0,009	0,047	0,847	0,2442
Sugarcane land size	-0,287	0,082	0.000***	-0,0518

Note: *, ** and *** indicates significant at 10, 5 and 1 percent respectively. Number of bootstraps = 3000

As illustrated in Table 4.8, the relationship between the age of the household head and technical efficiency exhibited both positive and negative impact and significant at 10% relationships. Thus, threshold effects could not be estimated. The negative effect is attributed to small-scale sugarcane growers or decision-makers that need necessary experience over years. However, either positively or negatively related to technical efficiency the findings on age of the small-scale growers is interesting; the finding is in contrast to Thabethe *et al.,* (2014) who concluded a significant relationship between the age and technical efficiency of small-scale sugarcane growers. The inclusion of the age^2 allowed the model more accurately the effect of age, which may have a non-linear relationship with the technical efficiency. The use of age^2 to age allowed the truncated regression model to model the effect of different ages without assuming that the effect is linear for all ages.

Concerning the gender of the small-scale sugarcane growers there was a positive impact of gender on technical efficiency and it was significant at all levels. This finding is in line with the study of Quisumbing (1996) that argued that both female and male growers are equally productive. Furthermore, the results show that gender does not have any effect on productivity, as proposed by Kinkingninhoun-Me^dagbe *et al.,* (2010). The marital status of the small-scale sugarcane growers showed a negative relation to technical efficiency. As elaborated above, the study conducted by Mishra *et al.,* (2017) argued that female-headed households had a significant effect on productivity.

Furthermore, level of education up to matric was significant at the 5% level, suggesting that a matriculant possesses the requisite skills to become a successful small-scale sugarcane grower. The effect of education on technical efficiency was positive and significant at 5%, while the availability of income from other sources was significant at 5% and positively related to technical efficiency. The positive effect was also noted by (Watto and Mugera*,* 2015; Kumbhakar *et al.,* 2014).

Furthermore, the ability to provide an alternative source of off-farm income is attributed to the sufficient income that have an on the livelihood of the farming household (Adelekan and Omotayo, 2017). Just like the effect of education on technical efficiency, the availability of income from other sources was significant at 5% and positively related to technical efficiency. This implies that small-scale sugarcane growers' head of household or a decision-maker with alternative sources of income tend to adopt the technologies needed in production. It is worth noting that this variable only offers growers diversity in production. The result is consistent with the effect showed by (Thabethe *et al.,* 2014; Bojnec and Ferto, 2013; Babatunde, 2013).

The size of the household is positively related to technical efficiency but is not significant at any level. For this variable two categories of household members, above 5 and 10 members together, and houses with more than ten members, were analysed. The rationale behind this variable was to measure the effect of families with many members who offered family labour. It is important to note that big families had a positive effect on technical efficiency either directly or indirectly, similarly to Mochebelele and Winter-Nelson (2000).

Most of the small-scale sugarcane growers are leasing their plots to mitigate the low production. The land leasing of small-scale sugarcane growers was negatively related to technical efficiency and not significant at the conventional levels. This result is in contrast to Watto and Mugera (2014), possibly because growers leasing commits most of their resources to servicing the lease agreement.

In situations when a small-scale grower was employed elsewhere there was a negative relationship between technical efficiency and employment status, which makes sense since the grower is often not available to run the farm and has to rely on helpers. Interestingly, a positive relationship exists between pensioner growers and technical efficiency, perhaps due to the availability and years of experience of the pensioner. Most of these pensioner growers receive their grant and allocate it to farming; the results are in line with (Kwon *et al.,* 2006; Pfeiffer, 2009) who have shown that off-farm income increases investment in purchasing inputs, labour and adaptation of innovative technology. Technology, to our understanding, may impact positively on technical efficiency.

The experience of the small-scale sugarcane grower was negatively related to technical efficiency but was significant at 1%, which might suggest that older farmers are less technically efficient. Perhaps they are not keeping abreast of new technologies and know-how. In table 4.8 there was a negative and significant at 10% relation between technical efficiency and access to extension support. Only four visits per season to growers through the farmers' day event negatively affected their technical efficiency. Perhaps growers are receiving confusing advice that is affecting efficiency to Zhou *et al.,* (2011) and is in line with a study by Gebrehiwot (2017). The other point to ponder might be on the time spent in meeting venues with extension officers as opposed to the same time farming.

On the other hand, access to credit by small-scale sugarcane growers was found to be positively related to technical efficiency but not significant at conventional significance levels, implying that access to credit offers capital injection to purchase new technologies and inputs. This finding contributes to the variable that in the study by Masuku *et al.,* (2014) had both a positive and negative effect on technical efficiency. Because the notion of access to credit, in general, exists in both formal and informal sources the study opted to look at the formal sources since there is proof that it has either been from a micro or macro-financer. The positive effect of access to credit on technical efficiency is inconsistent with Sossou *et al.,* (2014).

Lastly, the size of the land showed a negative impact on technical efficiency and was significant at the 1% level. The negative relation between land size and technical efficiency can be attributed to different land qualities scales, the return to scales distribution in the middle of this work showed fairly low allocation amongst the three scales. This negatively related effect was in line with the study conducted by Barret *et al.,* (2010); however, in the small-scale sugarcane production context of South Africa the findings are in contrast to the study of Thabethe *et al*., (2014) that found land size not to be significant for technical efficiency.

4.6 Summary of the findings

This chapter decomposed technical, allocative and cost efficiency as well as the chemical-use efficiency of small-scale sugarcane growers. The chapter went further and identified socio-economic factors that drive technical efficiency. The use of the slack-based measure model to measure chemical-use efficiency allowed understanding of input allocation to optimally produce sugarcane. Moreover, it is evident that the application of the chemical-use input needs improvement.

The study draws empirical evidence from 300 small-scale sugarcane growers operating in nine villages in the King Cetshwayo district of KwaZulu-Natal province of South Africa. The small-scale sugarcane growers produce and send their sugarcane to both the Felixton and Amatikulu mills operated by the Tongaat Hulett mills company in the northern part of the province and the mills also provide extension supervision to the small-scale sugarcane growers. In the context of small-scale sugarcane production in South Africa there are limited studies that have decomposed technical, allocative and economic efficiency and, to our knowledge thus far, the application of nonparametric DEA with the previous study had applied the parametric approach.

Input-oriented DEA under the assumption of VRS was applied in this chapter to cater for the following objectives: (i) estimate input-oriented technical, cost and allocative efficiency of small-scale sugarcane growers; (ii) determine the impact of chemical use input slacks on technical efficiency of small-scale sugarcane growers; (iii) identify determinants of technical efficiency of small-scale sugarcane growers. In order to answer these objectives, the dataset consisted of data collected for the 2015–2016 season based on the production and socioeconomic dynamics of the head of the household or decision- maker. The random sampling technique was used in the selection of respondents. The input-output results were analysed using DEA, and the Slack-Based Model was used to analyse the use of chemical input on technical efficiency, while socioeconomic analysis for factors that affect technical efficiency was explored using a Truncated regression model to help provide policy direction.

The estimated technical, scale, cost and allocative for small-scale sugarcane growers in the King Cetshwayo district municipality decomposed using input-oriented DEA were 72.5, 77.9, 26.0 and 49.3% respectively. With respect to these results, small-scale sugarcane growers are operating with 28% of inefficiencies concerning technical efficiency. A host of growers scored mean technical efficiency below 60%. The scale efficiency with 77.9 showed 22.1% of inefficiencies in the production scales. These findings call for the reduction in production scale based on the available technologies to operate optimally. The findings are mixed and contribute to other studies (Padilla-Fernandez and Nuthall, 2009; Thabethe *et al*., 2014; Babalola *et al.,* 2009; Dlamini *et al*., 2010) that showed both higher and lower inefficiencies scores of sugarcane growers. Concerning scale efficiency, Watto and Mugera (2014) argued for disaggregation of production scale into three scales and this study is in line with their findings.

The cost efficiency of small-scale sugarcane growers showed the highest inefficiencies mean scores of 74% and this result calls for serious intervention to advise small-scale sugarcane growers in the district to use the necessary inputs at the right costs. Out of the entire sample, 82% operated below 40%, which translates to over 60% of inefficiencies. The higher cost and low efficiency experienced by small-scale sugarcane growers in the district indicate that inefficient growers use more inputs and pay higher prices given the level of sugarcane yield. Small-scale sugarcane growers witnessed 51% of inefficiencies concerning allocative efficiency, with only one grower operating with 1% inefficiency. Consequently, small-scale sugarcane growers ought to reduce their inefficiencies by purchasing right combinations of inputs at the right price. Lastly, chemical uses input efficiency estimated 32% of inefficiencies in the application of chemicals. Concerning this input, small-scale sugarcane growers need to reduce chemical application to avert soil degradation and also yield desired output levels.

On the other hand, the empirical results of the truncated regression analysis found that education, off-farm income, experience, extension support and land size were significant for technical efficiency. However, experience, together with extension support and land size, were negatively related to technical efficiency. This finding suggests that when the number of experiences increases, growers tend to be less efficient. The negative result was discussed in Li and Sicular (2013) by examining the ageing agricultural labour force and technical efficiency in crop production. Extension support was measured based on visits of supervisors to the farm and hosting of farmers. The results revealed that fewer farmers' days need to be organised as it negatively affects small-scale sugarcane production when growers are away from farming. Lastly, differences of scale in the production of sugarcane resulted in a negative but significant impact on technical efficiency. The findings mean that small–scale sugarcane growers can achieve optimal combinations on smaller plots, a result that is in contrast to Thabethe *et al.,* (2014).

The empirical findings revealed that small-scale growers are not efficient, meaning simply that small-scale sugarcane growers need to allocate more and necessary inputs to produce a given yield of sugarcane. Nor this these inefficiencies small-scale sugarcane growers may improve their productivity compared to their peers by reducing the unnecessary inputs applied in production, regardless of the support they receive from the different stakeholders. Lastly, this chapter contributes to the body of knowledge in many respects. Firstly, it decomposes the productive efficiency of small-scale sugarcane growers, using input-oriented DEA within a South African framework. Secondly, the different production scales were disaggregated into three returns to scales, while the input-slack model was applied to investigate the chemical-use efficiency of a particular input applied in sugarcane production. Lastly, socio-economic factors that affect technical efficiency were determined using a Truncated regression. By applying a bootstrapped DEA and regressing the socio-economic drivers of technical efficiency using the truncated regression the study contributes to the literature by obtaining unbiased results. The following chapter will analyse technical, cost and allocative efficiency and factors that impact them in the Amatikulu and Felixton regions using the DEA methods applied in this chapter.

4.7 Chapter summary

This chapter measured technical, cost and allocative efficiency using DEA. The chapter went further and outlined empirical studies measuring technical, scale, allocative and cost efficiency, and determinants of technical efficiency as well as the input-slackness model. The estimation of these performance management tools and socio-economic factors that affect technical efficiency gives policy makers, mills and governmental departments the scope for small-scale agricultural development. The findings of this chapter motivated the analysis of technical, cost and allocative efficiency and the determinants of small-scale sugarcane growers in Felixton and Amatikulu regions that follows in chapter five.

CHAPTER FIVE

TECHNICAL, COST AND ALLOCATIVE EFFICIENCY AND THE DETERMINANTS OF SMALL-SCALE SUGARCANE GROWERS IN FELIXTON AND AMATIKULU REGION: AN APPLICATION OF DATA ENVELOPE ANALYSIS

5.1 Introduction

Driven by concerns of feeding a rapidly increasing world population and promoting thriving agricultural businesses to stem the tide of urban migration the focus on the role of small-scale agriculture to create sustainable livelihoods has gained popularity among development specialists globally. Small-scale agriculture in the impoverished rural communities remains a noble contributor to food security, sustainable livelihood and a vehicle for poverty reduction (Lefophane *et al*., 2013). The natural shocks such as drought, flooding and other externalities impact directly or indirectly on small-scale agriculture, which raises concerns for long-term food insecurity and production. The 2015–2016 drought episode in South Africa decimated the agricultural sector and posed a serious challenge to incomes of indigent farmers and the promotion of food security among rural communities. In general, small-scale agriculture operates in dire circumstances and needs government support to produce at optimum levels.

Amidst the mentioned unfavourable conditions, the South African government has shown special interest in small-scale agriculture (Land Bank, 2003), but lack of access to funding, adaptation of innovative machinery, and structural land ownership still threaten their agricultural production. The improvement of agricultural productivity, in the face of various negative externalities, is the one of effective strategy to address food security in rural communities compared to other solutions (Aye and Mungatana, 2011), and reducing over-dependence on other sectors of the economy as well as alleviating poverty in rural areas through employment creation and improving farm income that results in access to food. Government support of small-scale agricultural development resulted in policy initiatives that were aimed at land reform, agricultural credit provision, infrastructure development and comprehensive support services to farmers.

Whilst the demand for sugarcane production increases and the agricultural production is decreasing, the key performance management tools of productive efficiency are estimated to improve agricultural production (Tang *et al*., 2015; Henderson, 2015; Ndlovu *et al*., 2014). As a result, growers need to be aware of their performance management abilities to foster maximum yield. These small-scale farmers tend to have limited resources and operate in the poor rural areas of South Africa. The contribution of agricultural efficiency to marketing, employment, economic opportunities and subsequently food security is of extreme importance in the small-scale sector. Small scale farmers need to understand how optimal output of a given unit of input or at any given level of output using the lowest level of inputs can be yielded at the available cost. Consequently, high cost for production of sugarcane can dictate the cost and allocative efficiency of sugarcane production (Murali and Prathap, 2017). Therefore, benchmarking and measuring productive efficiency in the small-scale agricultural sector in the South African context is an important topic for farmers, extension officers and policy makers as well as other stakeholders.

Empirical studies on the efficiency of small-scale farmers in developing countries are focused on both DEA and SFA, with these previous studies (Serasinghe *et al.,* 2003; Alene and Zeller, 2005, Lihn, 2012, Aye and Mungatana, 2011) that have applied these two approaches. The debate on whether DEA or SFA is better is still topical in performance management circles. However, Fried *et al.,* (2008) merited the DEA based on its ability to make non-prior assumptions about the technology of the firm. Applying the DEA, Watto and Mugera (2015) found contrasting technical efficiency scores between tube-well and water buyer growers. In a different study, inefficiencies in sugarcane production affected the technical efficiency of farmers in three districts using a household sample of 198 (Murali and Prathap, 2017). On the other hand, Mahjoor (2013) focused on the technical, allocative and economic efficiency of farms in Iran and concluded high levels of returns to scale and inefficiencies in socio-economic factors.

Moreover, economic efficiency estimation assumes homothetic technologies when benchmarking efficiency using technical and allocative criteria (Aparicio *et al.,* 2015). This notion was further observed in the study of Khan *et al.,* (2015) that applied both the CRS and VRS DEA models to estimate the technical, allocative and economic efficiency of rice farmers in Malaysia. Efficiency mean scores of VRS technologies showed higher performance compared to the CRS technologies using DEA. However, (Kelly *et al.,* 2013) found that technical, allocative and economics scores applying VRS DEA were not fully efficient.

The influence of determinants of technical efficiency was purely on different agricultural practices and commodities. In essence, labour intensive practices tend to draw different determinants compared to modernised practices. Traditional studies on determinants of farm productive efficiency are mainly indecisive on the question of a positive or negative effect of socio-economic and policy related factors on production. Studies (Mishra *et al.,* 2017; Adelekan and Omotayo, 2017; Duy *et al.,* 2015; Chang and Wen, 2011) focused on the effect of gender, income, credit, labour, off-farm income and farm size of agricultural productive efficiency have produced mixed results. Hence, there is a need to explore the effect of socio-economic factors on the agricultural efficiency of small-scale sugarcane growers.

The focus on productive efficiency was introduced in the early days of Adam Smith but was extensively analytically expanded by the works of (Koopmans, 1951; Debreu, 1951). Farrell (1957) took it to the next level of empirical application and contributed to theoretical significance. Shepard's models of technology and the distance function (Shepard, 1970) contributed immensely to the development of efficiency and productivity. The work of Charnes and Cooper (1961) contributed extensively to the application in the early stages of linear programming and, to be precise, made it famous through the development of the DEA approach, as elaborated in (Charnes *et al*., 1978). However, Forsund and Sarafoglou (2002) focused on Farell's seminal paper that introduced the DEA methodology and made interesting historical reconstruction of literature. However, Leontief (1951) limited linear programming analysis to input-output analysis in the quest to advocate for direct construction of a general equilibrium model.

Derived from the efficiency measurement models for cross-sectional and panel data are the Nonparametric Deterministic Models as proposed by Fare *et al*., (1994), Fried *et al*., (1993) and Charnes et al., (1994) that made developments in the application of DEA by benchmarking DMUs as well as inputs and output slacks. In the more improved developments Cooper *et al*., (2000), Ray (2004) and Fare and Grosskoof (2004) improved on these DEA approached to benchmark performance management. The Data Envelope Analysis framework is the main nonparametric estimator that is available in the literature on performance management. As proposed by Farrell (1957), and Charnes *et al.,* (1978) this linear programming approach assumes free disposability and convexity of the production set (Daraio and Simar, 2007). DEA will show the performance of each grower's optimal efficiency using the available farm resources in the sugarcane production system. This chapter seeks to show the possible production cost reduction set to improve the sugarcane output through optimal efficient use of resources. This chapter was conducted (1) to compare technical efficiency, cost and allocative in two regions and (2) to investigate determinants of technical, cost and allocative efficiency in both the Felixton and Amatikulu growers' regions.

5.2 Methodology

5.2.1 Sampling and Data collection

As previously mentioned, the Tongaat Hulett sugarcane company operates two sugar crushing mills in the Northern part of KwaZulu-Natal namely the Felixton and Amatikulu mills. These two mills operate in regions with different climatic conditions and service small-scale sugarcane growers with extension support. The survey of the study was conducted across the 18 villages that host small-scale growers that cultivates sugarcane and send it for crushing to both mills. A standardised and pre-tested data collection instrument was used to collect cross-sectional data for the 2015–2016 season. A number of 160 small-scale sugarcane growers surrounding both the Felixton and Amatikulu mills were sampled. Random sampling was applied to sample 80 growers from both mills to collect production data based on inputs and inputs prices data. The two datasets for the regions were analysed separately using input-oriented DEA to benchmark each grower compared to their peers.

The questionnaire was given to the household head or the decision maker in the sugarcane plot to source inputs and output quantities and the data included labour, machinery, seeds, chemicals and fertilisers. The sugarcane yield was our output for each grower and was obtained from the extension officers' production estimates for that particular season. Information on prices was obtained from the local agro-retailer the growers indicated as the source of their production inputs. The prices of these inputs were collected in South African Rand.

5.2.2 DEA Methodology

The input-oriented technical efficiency under the VRS for a given $\mathrm{DMU_s}$ was computed to estimate technical, cost and allocative efficiency in the Felixton and Amatikulu regions by solving the following standard linear programming problem developed by Coelli *et al.,* (2005). This approach was outlined fully in Chapter four.

5.2.3 Truncated regression

Truncated regression was applied in the second stage to investigate the determinants of technical, cost and allocative efficiency in both regions. This approach was also presented in Chapter four.

5.3 Empirical results and Discussion

5.3.1 Descriptive statistics for input variables

Table 5.1 presents descriptive statistics of the variables used in the DEA analysis. This variable included five inputs and one output. Overall, the average sugarcane yield for the Felixton growers is higher than for the Amatikulu growers yield, 170.49 and 153.21 tons/ha respectively. These figures are above the Tongaat Hulett estimated average yield in the Northern KwaZulu-Natal region of 60 tons/annum based on average rainfall of 1000–1300 mm/annum. The small-scale sugarcane growers applied both herbicides and pesticides in their production. On average, 10.27 and 5.26 litres of chemicals were utilised to improve the overall yield per hectare in both the Felixton and Amatikulu growers' regions. The average cost of the applied chemicals was R2285.50 in the Felixton region and R3136.75 per hectare in Amatikulu. This figure illustrates that growers in the Amatikulu region spend more money on purchasing of chemical inputs. Fertiliser application for the Amatikulu growers 8.38kg was double the average kg utilised in the Felixton region 3.86kg. Nonetheless, the Felixton growers spent R3036.75 on average purchasing fertiliser with their counterparts spending R1268.00.

TABLE 5.1: DESCRIPTIVE STATISTICS FOR OUTPUT AND INPUT VARIABLES

Variable	Felixton growers		Amatikulu growers	
	Average	Standard Deviation	Average	Standard Deviation
Sugarcane yield (tons/annum)	170.49	141.24	153.21	198.21
Chemicals (litres/ha)	10.27	9.13	5.26	2.46
Fertiliser (kg/ha)	8.38	8.87	3.86	2.34
Labour (hours)	5.48	2.66	3.00	1.90
Machinery (Farm operations)	6.88	5.70	6.40	5.36
Seeds (tons/ha)	2.81	2.90	2.95	2.86
Cost of Chemicals (per/ha)	2282.50	2528.28	3163.75	2937.77
Cost of Fertiliser (per/ha)	3036.75	6152.21	1268.00	792.78
Cost of Labour (Rands - hours/ha)	94.12	42.56	100.43	2937.77
Cost of Machinery (Rands/ha)	4055.65	4434.50	4325.27	2351.32
Cost of Seeds (Rand/ha)	1980.00	227.78	2545.00	2692.13

The data showed that both family and hired labourers were sampled; the number of hours were used to analyse this variable. The average number of hours spent on sugarcane production in the Felixton region 5.48 while the Amatikulu region growers committed 3 hours on average. Concerning labour, an average wage of R94.12 per hour was paid to labourers in the Felixton region and R100.43 in Amatikulu. It is worth mentioning that growers with big families relied on family labour and did not incur any cost attached to labour. On average, the implements such as tractor, plough, ripper, bell loader and disc were used in the production system. If is worth noting that some individual growers used irrigation pumps that explain the maximum of implements used being 6.88 and 6.40 farm operations per hectare in the Felixton and Amatikulu regions respectively. The total cost aggregated for the implements used was R4055.65 for the Felixton region while other growers in the Amatikulu region paid a higher cost R4325.27. The seeds used from other growers that was certified by the mill for purchase was on average 2.81 and 2.95 tons per hectare in the Felixton and Amatikulu regions respectively. Small scale sugarcane growers in both regions with certified seeds by mills did not pay any cost for this input. On average, R1980.00 in the Felixton region and R2545.00 was spent on seeds in the Amatikulu region.

5.3.2 Descriptive statistics for socio-economic variables

Table 5.2 presents the descriptive statistics of socio-economic variables that affect TE, CE and AE in the Felixton and Amatikulu regions. On average, the age of small-scale sugarcane growers was 41 and 45 years in the respective regions. An average of 1.73 extension visits was reported in Felixton compared to the 1.73 that were described in the Amatikulu region. The average hectares of 3.14 and 2.60 were utilised for sugarcane production in the regions, respectively. The total number of growers who have access to credit was very small in both regions, with 94% and 98% of the respondent reporting no access to credit in the Felixton and Amatikulu regions. Concerning education, the majority of these growers reported having had primary education.

Moreover, few respondents were employed 42% in the Felixton region, compared to 41% in the Amatikulu region. The majority of the growers recorded sugarcane production experience of more than 10 years in both regions. Off-farm income, in any form of grants, business ventures and livestock sales showed mixed results. The total of 49% of growers in Felixton contrasted with 69% from the Amatikulu region. Lastly, the total of 49 respondents were female in the Felixton region compared to 48 of the male growers in Amatikulu.

TABLE 5.2: DESCRIPTIVE STATISTICS FOR SOCIO-ECONOMIC VARIABLES

	Felixton region growers				Amatikulu region growers			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Age of HH head/decision maker(Years)	41.43	8.06	25	80	45.89	9.35	21	74
Extension support (number of visits/season)	1.73	1.88	0	12	1.31	0.58	1	3
Area under cultivation (Hectares)	3.14	2.35	0.2	15	2.60	3.09	0.2	18
Dummy variables (N=160)	1	2	3	4	1	2	3	4
Access to Credit (1= yes, 2 = no)	5	75			2	78		
Education of HH head (1 = no formal education, 2 = up to matric, 3 = above matric)	32	27	21		44	27	9	
Employment status of HH head (1 = unemployed, 2 = employed, 3 = pensioner)	46	25	9		45	21	14	
Experience of HH head (1 = up to 5 years, 2 = up to 10 years, 3 = above 15 years)	13	35	32		8	48	24	
Off-farm income (1 = yes, 2 = no)	41	39			55	25		
Gender of HH head (1= male, 2 = female)	31	49			48	32		

5.3.3 DEA technical, cost and allocative efficiency

The study benchmarked each grower against the best performing practise in the production of sugarcane in both the Felixton and Amatikulu mills. The DEA efficiency estimation in Table 5.3 was computed under variable returns to scale. The frequency distribution of technical, cost and allocative efficiency showed variation, bearing in mind that for a grower to be fully efficient the mean score must be equal to 1 (Watto and Mugera, 2014). The mean TE, CE, and AE efficiency were 95.6, 55.2 and 57.5% for the Felixton growers and 95.2, 69.1 and 72.6% for the Amatikulu growers.

Based on the mean technical score of 95.6 and 95.2% in both the Felixton and Amatikulu regions, the small-scale sugarcane growers are operating at inefficiency levels of about 4.4 and 4.8%, respectively. However, out of the sample, the vast majority of growers were fully efficient, with 136 growers in both regions operating at optimal technical efficiency. Table 5.3, shows that in Felixton the number of small-scale sugarcane growers that exhibited full (100%) technical, cost and allocative efficiency were 67, 3 and 3 respectively, compared to 57, 3 and 3 growers operating in Amatikulu. In Felixton, fully efficient growers numbered ten respondents operating within the region of 60–80%, while in Amatikulu the growers in the 80–99% category were seventeen. It is worth mentioning that none of the growers exhibited 0 to 60% in either region. The minimum and maximum mean technical efficiency score was 66 and 100% for Felixton, while that of Amatikulu was 71 and 100%. The findings of this study are in contrast to another study (Murali and Prathap, 2017) that showed a lower technical inefficiency score of sugarcane growers above 15%. The study by Thabethe *et al.,* (2014) conducted in the Mpumalanga province of South Africa showed fairly low technical efficiencies scores of below 70%. Both studies applied the Stochastic Frontier Production Function approach and included input variables different from this study.

TABLE 5.3: FREQUENCY DISTRIBUTION OF TECHNICAL, COST AND ALLOCATIVE EFFICIENCIES

	Felixton region growers			Amatikulu region growers		
Frequency (%)	TE	CE	AE	TE	CE	AE
< 20	0	8	7	0	0	0
20 – 40	0	14	12	0	2	1
40 – 60	0	25	25	0	18	15
60 – 80	10	21	21	6	42	39
80 – 99	3	9	12	17	15	22
100	67	3	3	57	3	3
Mean	0.95	0.55	0.57	0.95	0.69	0.72
Standard deviation	0.11	0.23	0.23	0.84	0.15	0.14
Minimum	0.66	0.09	0.09	0.71	0.29	0.35
Maximum	1	1	1	1	1	1
N	80	80	80	80	80	80

AE, CE, TE denotes allocative efficiency, cost efficiency, technical efficiency.

Concerning cost efficiency there is a lot one can draw from its parameters; it showed mean efficiency scores of 55.2% in Felixton and 69.1% in Amatikulu, implying that small-scale sugarcane growers from Amatikulu were more efficient compared to their counterparts. These growers experienced 30.9% of inefficiencies, while growers in Felixton exhibited 44.8% inefficiencies. Small-scale growers operating at less than 20% were eight and zero for the Felixton and Amatikulu regions. Overall, 12 and 25 growers in the Felixton region operated between 20–60% of cost efficiency compared to only 2 and 18 in the other region. A little more than half the sample (42) of the small-scale growers in the Amatikulu region exhibited cost efficiency between 60–80% compared to 21 growers in the Felixton region. The total number of small-scale growers in the 80–99% were fifteen and nine for the respective regions.

Lastly, only three small-scale growers in both regions were fully efficient. For cost efficiency, 9 and 29% were the minimum scores for the Felixton and Amatikulu region respectively and the maximum of 100% for fully efficiency growers. As pointed out in equation (3), allocative efficiency was decomposed by taking the ratio between technical and cost efficiency. The minimum mean score for allocative efficiency was 9 and 35% for the respective Felixton and Amatikulu regions. However, the mean score of 72.6% means score in Amatikulu was higher than the 57.5% obtained in the Felixton region. The mean allocative efficiency scores imply 27.4 and 42.5 inefficiencies, with only seven small-scale growers from the Felixton region operating at less than 20% and zero in the Amatikulu growers. The total of 12 and 25 growers operated in the region between 20–60% in the Felixton region compared to 1 and 15 in the same category in the Amatikulu region. A majority of 61 growers in the Amatikulu region operated between 60–99 in comparison to only 33 in the Felixton region, with only three growers fully efficiency in both regions.

5.3.4 Determinants of technical, cost and allocative efficiency

The results in Table 5.4 indicate that the grower's age was positively related to TE, CE and AE in the Felixton region. However, there was a negative relationship between age and CE in the Amatikulu region. Moreover, extension support reported negative association with TE in both regions, and was significant at 1% in relation to CE, AE and CE in the Felixton and Amatikulu regions, respectively. The positive relationship between Area under cultivation and TE, CE and AE were estimated in the respective regions. The relationship between access to credit and performance efficiency reported mixed results in both the regions. In Felixton, a significant (5%) and positive relationship was estimated between credit and TE, but CE and AE estimated negative relationship to access to credit. The opposite was the case in Amatikulu, with all the estimates revealing a negative effect of TE, CE and AE.

The level of education, experience and employment status had a positive impact on productive TE, CE and AE in all regions. Other determinants such as experience and the gender of the grower also reported positive impact on productive efficiency. Furthermore, in the both the regions TE was significant at 5%. Lastly, off-farm income estimated a negative effect on TE, CE and AE in the Amatikulu region but had a positive relationship with TE in the Felixton region, followed by negative effect on CE and AE.

TABLE 5.4: ESTIMATION OF DETERMINANTS OF TECHNICAL, COST AND ALLOCATIVE EFFICIENCY IN FELIXTON AND AMATIKULU REGION

	Felixton region growers						Amatikulu region growers					
	TE		CE		AE		TE		CE		AE	
Explanatory variables	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
Age of HH head/decision maker(Years)	0.005	0.006	0.003	0.001	0.003	0.001	0.062	0.024	-0.033	0.071	0.001	0.010
Extension support (number of visits/season)	-0.002	0.011	0.113***	0.015	0.113***	0.015	-0.007	0.004	0.151***	0.114	0.143	0.014
Area under cultivation (Hectares)	0.001	0.001	0.014	0.019	0.014	0.019	0.004	0.009	0.002	0.001	0.000	0.001
Access to Credit (1= yes, 2 = no)	0.041**	0.013	-0.026	0.018	-0.026	0.018	-0.001	0.011	-0.013	0.022	-0.012	0.012
Education of HH head (1 = no formal	0.022	0.016	0.002	0.038	0.002	0.038	0.006	0.006	0.004	0.002	0.003	0.001

education, 2 = up to matric, 3 = above matric)												
Employment status of HH head (1 = unemployed, 2 = employed, 3 = pensioner)	0.033	0.027	0.001	0.024	0.001	0.024	0.010	0.014	0.03	0.022	0.010	0.021
Experience of HH head (1 = up to 5 years, 2 = up to 10 years, 3 = above 15 years)	0.034**	0.017	0.005	0.029	0.005	0.029	0.026**	0.011	0.003	0.013	0.031	0.013
Off-farm income (1 = yes, 2 = no)	0.003	0.011	-0.002	0.029	-0.002	0.029	-0.009	0.012	-0.013	0.014	-0.020	0.013
Gender of HH head (1= male, 2 = female)	0.035*	0.021	0.043	0.043	0.043	0.043	0.003	0.012	0.013	0.014	0.023	0.010

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively.

The empirical analysis of the study showed different efficiency scores in the application of input and output combinations in the production of small-scale sugarcane in the Felixton and Amatikulu regions of KwaZulu-Natal. Both the regions revealed almost equal technical efficiency mean scores, as totals of 95.6 and 95.2% were revealed in both regions, respectively. These high scores imply that, given the available resources, small-scale growers could increase their output by 4.4 and 4.8% respectively and they are highly efficient in their application of inputs to maximise output. However, there was a significant difference between cost and allocative efficiency. Small-scale sugarcane growers in the Amatikulu region scored higher cost and allocative efficiency mean scores (69.1 and 72.6%) compared to growers in the Felixton region (55.2 and 57.5%). The findings show the need to cut the production costs by 30.9 and the need to enhance allocative efficiency by 27.4% in the Amatikulu region while adjustments of 44.8 and 42.5% need to be affected in the Felixton region.

Higher costs and low efficiency experienced by small-scale sugarcane growers in both the regions indicate that inefficient growers pay higher prices for the inputs given the level of sugarcane yield. Consequently, growers need to reduce their inefficiencies by purchasing appropriate combinations of inputs at the right price. Proper allocation of the available resources and adaptation of innovative technologies in the use of new implements at a lower cost will improve the performance of small-scale sugarcane growers because they are already exhibiting higher technical efficiency scores. The inefficient small-scale sugarcane growers may improve their productivity compared to their peers by reducing unnecessary inputs applied in production.

Socio-economic variables show varying coefficients for age, gender, access to credit, employment status, education level, off-farm income, experience and extension support. The age, extension support, and off-farm income exhibited a negative effect on agricultural efficiency. Previous studies have argued the same results and attributed the negative effect to the reluctant and sceptical behaviour of older growers to extension support, innovative technology and adaptation of modern practices. This indicates that the unwillingness to change, and the semi-traditional practices of small-scale sugarcane growers affect agricultural efficiency. The positive relationship of experience, education, access to credit and employment status contributes to the existing debate that has had mixed reactions. This finding can be attributed to the fact that growers with education and extra income may apply and afford more inputs in the production of sugarcane. The relationship between off-farm income and agricultural efficiency in the two regions may be explained by the allocation of time and resources to sugarcane farming by the growers. In a case were a particular grower neglects the plot because of the need to earn income in another sector the relationship may become negative. But after earning income in the other sector and allocating it for sugarcane production the effect may be positive.

As noted above in both regions, the small-scale sugarcane growers' extension needs are serviced by the Tongaat Hulett sugar company operating two sugar mills in Felixton and Amatikulu. The governmental provincial department interacts with growers mostly during farmers days, and there is the need for subsidies to overflow from merely seeds to other inputs and in particular implements and chemicals to improve output quality. Therefore, there is a need for public and private initiatives aimed at training and development and subsidising inputs as well as an opportunity to provide low-cost support focused on inputs and equipment purchase, and the need to address unfavourable resource allocation. Because of the higher technical efficiency of small-scale sugarcane growers, proper interventions targeted at the allocation of resources based on minimising cost need to be introduced to trigger higher production in order to improve the livelihoods of poor small-scale sugar growers.

5.4 Summary for these chapter

The input-oriented DEA with VRS assumption was applied to analyse cross-sectional data collected using a structured questionnaire based on 2016–2017 production data. The DEA inputs consisted of five variables (chemicals, fertiliser, labour, machinery, seeds) and one output (sugarcane yield) which were applied in the estimation of efficiency scores using computer software R-Studio. The small-scale sugarcane growers exhibited very high technical efficiency mean scores producing at different scales. The findings were otherwise in relation to cost and allocative efficiency, meaning that there is a need for small-scale sugarcane growers to minimise their production cost. In this quest, public and private initiatives aimed at financial management training, and subsidies for machinery and equipment will contribute to reducing the cost burden of production. These subsidies are especially crucial since small-scale growers do not hold land title deeds, which prevents them from securing collateralised loans from commercial banks.

Therefore, this chapter suggests policy reforms focused on training, inputs subsidies and developmental initiatives channelled through extension advice aimed at improving cost and allocative efficiency. Moreover, the key policy line concerned with subsidisation of small-scale sugarcane growers with inputs and implements needs to be revisited benchmarking the Tongaat Hullet seeds subsidy model.

Chapter six will decompose productivity change and efficiency change of small-scale sugarcane growers in the Amatikulu region using the DEA approach. The chapter was motivated by the decline in production that was experienced in the Amatikulu region over the period of two years, (2016–2017).

CHAPTER SIX

ANALYSING THE PRODUCTIVITY AND EFFICIENCY CHANGE OF THE SMALL-SCALE SUGARCANE GROWERS IN THE AMATIKULU MILLING REGION

This chapter decomposes the efficiency and productivity change and the determinants of TFP growth of the small-scale sugarcane growers in Amatikulu. Moreover, the chapter decomposes TFP growth and its components into finer measures of efficiency and productivity. To answer the objective of the chapter the DEA technique will be applied to analyse a Färe-Primont index under the VRS technologies. To investigate the determinants of TFP growth the Bayesian Modelling Averaging technique will be applied to analyse the policy related variable. The policy implications for the chapter relate to the improvement of TFP growth to stimulate productivity of small-scale sugarcane growers. Lastly, the chapter will outline the literature review, methodological framework, and empirical results and provide a conclusion and discussion for future research.

6.1 Introduction

In recent seasons, the number of small-scale sugarcane growers fallowing and leasing their plots has been on the rise, as was evident in the Tongaat Hullet production estimates for the 2016–2017 season. In the Northern part of KwaZulu-Natal, the Tongaat Hulett sugar company operates two mills in the Felixton and Amatikulu mill respectively. The Amatikulu mill, like the other Tongaat Hulett mills, operates for thirty-six weeks between April and December. In this period small-scale sugarcane growers are expected to interact with extension supervisors as well as sending the sugarcane yield to be crushed in the mill. This mill has 385 tons of sugarcane milling capacity per hour, which is about two thirds the capacity of the Felixton mill (600 tons). The main reason for the low output is the unavailability of peer farmers to rent most of the fallow tillable land in the Amatikulu area, which threatened the mill closure in 2016.

According to SASA (2017), the Zululand region crushed 3 299 070 tons of sugarcane, becoming second highest producer after the Northern Mpumalanga province. The Amatikulu mill crushed the least number of tons at 650 603 compared to Umfolozi and Felixton with 1 076 588 and 1 571 884, respectively in 2016. The decline in the Amatikulu mill is in relation to the sugar production trends exhibiting serious variations between the 2008/2009 and 2015/2016 production season. There is a vast number of small-scale sugarcane growers tending small plots under tribal authorities in both regions as compared to emerging and commercial growers. In the dawn of democracy government policies aimed at uplifting mainly black and previously marginalised farmers were introduced to regulate land ownership and also focus on technological introduction through different loans schemes and initiatives. Such changes in policy affected small-scale sugarcane growers differently, with small-scale sugarcane growers been adversely left behind in credit, capital and management skills compared to the latter groups, mainly due to lack of collateral to secure loans, poor bookkeeping to reconcile the financial statements to manage the needed capital for the coming production season, and also limited managerial acumen in the changing technological innovation.

When policies aimed to develop a targeted group of small-scale sugarcane growers are not fully focused the targeted group tend to be in the shadow of their former past and are barely able to develop in their production. As a result, the mills and government have made a concerted effort to uplift the sugarcane industry of KwaZulu-Natal through supporting small-scale growers Although, the support is welcome certain aspects of the support tend not to meet the desired need of the poor small-scale sugarcane growers' development (Mote, 2015). Therefore, one needs to fully understand the small-scale sugarcane growers' quest for sustainability of the farm business by decomposing performance management techniques to analyse the efficiency levels and efficiency changes in their small plots.

Consequently, agricultural economics and development specialists have in the past shown interest on the contribution of sugarcane production to the well-being of small-scale sugarcane growers (Bates and Sokhela, 2003; Cockburn *et al*., 2014). These studies attributed the planting of crops to the need to reduce poverty, and contribute to income and overall improvement in livelihood. Dubb (2015) showed a significant decline in the number of small-scale sugarcane growers in the Umfolozi mill of KwaZulu-Natal province. The declining productivity comes on the back of decreasing farm production that threatens the sustainability of the small-scale sugarcane grower's enterprise as well as increasing output and overall food security without degrading the natural resource base. Hence an understanding of how to increase productivity of the remaining small-scale famers becomes all the more critical.

Small-scale sugarcane production in the rural set-up has the potential to remain relevant and significant for the well-being of the dwellers, while better agricultural performance is needed to bridge the gap between sugarcane demand and production. In the context of poor and rural farming, the overall growth in the agricultural sector stimulates earnings and employment as well as linking the sector to other non-agricultural sectors and results in poverty reduction (Nkamleu, 2004). Moreover, the overall growth in the agricultural sector and linkages to other sectors leads to technological innovations and investments that may impact on agricultural productivity. According to O'Donnell (2010), the rise in agricultural productivity stimulates sustainable economic development and leads to increased resources and, subsequently, surplus resources from the agricultural sector may be transferred to other sectors of the economy. In the quest to understand productivity and efficiency change the impact of a group of variables over time on the productivity on small-scale cane growers will be of valuable assistance in developing appropriate policies to assist needy growers.

However, many small-scale growers operate with higher inefficiencies and yield low output with the available inputs as a result of the slow innovative adaptation of technology (Juma, 2016). This in turn threatens efficiency and productivity growth. Furthermore, the production of multi-outputs (diversified farming of multiple crops) with the same set of inputs exacerbates the issues to do with performance management of small-scale farming. The declining agricultural productivity is seen as a long-term threat to food prices, while renewed productivity growth is the nearest answer to this challenge. The challenge also overlaps with the environmental aspects of the farm business, driven by the need to produce more outputs by the application of hazardous inputs that deplete the land (Fuglie, 2008; Diao *et al*., 2008).

The decomposition of agricultural productivity has been quite robust in the past decades; however, it was limited to specific inputs, notably labour and land, because they contributed to the reduction of unemployment and poverty. With changing times, the need to grow the economy led to the focus on other input sets in the measurement of productivity change. The choice of the other sets of inputs was based on the link between agricultural research and investments, as proposed by Alston *et al.,* (1995) and Alene, (2010). When research and development are introduced into the agricultural sector productivity tends to rise. In the quest to improve agricultural productivity, both public and private institutions introduced initiatives and policies focused on increasing output. The mills in their capacity are expected to offer training, and provide extension support, seed subsidies and contractors to the small-scale sugarcane growers in the region while the provincial department provides training and extension support.

To reach an empirical understanding of the topic related to agricultural productivity growth and efficiency change this chapter focuses on the following goals. The chapter decomposes the small-scale sugarcane growers' productivity growth by measuring maximum TFP, technical, scale, mix, residual scale, and residual mix efficiency levels. The growers' total factor productivity changes by measuring its components of technical, technical-efficiency, scale-efficiency, mix-efficiency, residual scale-efficiency, and residual mix-efficiency changes in years. Therefore, this chapter contributes to the sugarcane industry by empirically decomposing the productivity and efficiency change of small-scale sugarcane growers. The upcoming section focuses on the review of the literature on productivity measurement and related studies on agriculture. Subsequent sections discuss the methodology, data, and empirical results, while the last section comprises a discussion of the results and concluding remarks.

6.2 Methodological Framework

6.2.1 Introduction

This section applies the DEA approach to compute the distance function as proposed by O'Donnell (2010, 2012a, 2012b) as a tool to decompose productivity and efficiency change. Khan *et al*., (2015) and Rahman and Salim (2013) also applied this approach in the estimation of nonparametric productivity and efficiency change in Australian Broadacre Agriculture. The merit of using the DEA approach is based on its ability to make non-prior assumptions about the behaviour of the small-scale sugarcane growers, and also its functional form of the technology and efficiency distribution.

However, there is a need to be cautious when interpreting the results because the DEA does not make allowance for statistical noise.

The seminal work of Jorgenson and Griliches (1967) introduced the concept of TFP in the application of multiple-output multiple-input firms. The ratio of an output quantity index to that of output quantity index defines the index numbers that measure changes in TFP. O'Donnell (2008) introduced the term “multiplicatively complete” to explain the TFP indexes and showed that the complete multiplicatively is considered a TFP indexes when it provides technical change and efficiency change. Because both the Malmquist TFP index and the Hicks-Moorsteen index are not reliable to compute and decompose TFP growth the Färe-Primont index approach is more favoured but the study will apply the Bayesian modelling average technique (BMA) to investigate the determinants of TFP scores derived from both the FPI models. Majiwa *et al*., (2015) argued that traditional methods that analyse data tend to ignore the issue of model uncertainty, and therefore showed that the BMA is one of the pivotal methods that address model uncertainty.

6.2.2 Färe-Primont index approach

Chapter Two provided a detailed description of the theoretical model of productivity of which the Färe-Primont index forms is one. This chapter provides a brief insight into the decomposition of the total factor productivity of small-scale sugarcane growers using the Färe-Primont index. In order to decompose productivity and efficiency change, the DEA framework developed by O’Donnell (2011) was applied to estimate the distance-based index of the Färe-Primont index. The approach assumes that the frontier of a firm follows the linear form in the neighbouring of the technically efficient point. Therefore, the output distance function holds only in the neighbourhood of the technically efficient point $(x_{nt},\ q_{nt}/OTE_{nt})$ and takes the form:

$$D_O(x_{nt}, q_{nt}, t) = (q'_{nt}\alpha)/(\gamma + x'_{nt}\,\beta) \qquad (6.1)$$

The standard output-oriented DEA problem involves finding the solutions for the unknown parameters in Equation (6.1) to minimise technical efficiency: $OTE_{nt} = D_O(x_{nt}, q_{nt}, t)$. If α and β are non-negative, then the only constraint that needs to be satisfied is $D_O(x_{nt}, q_{nt}, t) \leq 1$. Setting an additional constraint $q'_{nt}\alpha = 1$, the DEA problem takes the following linear programming form:

$$D_O(x_{nt}, q_{nt}, t)^{-1} = OTE_{nt}{}^{-1} = \min \{\gamma + x'_{nt}\,\beta : \gamma\tau + X'\beta \geq Q'\alpha;\ q'_{nt}\alpha = 1;\ \alpha \geq 0;\ \beta \geq 0\} \quad (6.2)$$

where Q is a vector of observed outputs, X is a vector of observed inputs, and τ is a unit vector. Subsequently, the computation of the Färe-Primont aggregates was solved by applying the variant of LP as:

$$D_O\left(x_o, q_o, t_o\right)^{-1} = \min \{\gamma + x'_o\,\beta : \gamma\tau + X'\beta \geq Q'\alpha;\ q'_{nt}\alpha = 1;\ \alpha \geq 0;\ \beta \geq 0\} \quad (6.3)$$

Estimates of aggregate outputs, Q_{nt} and aggregated input, X_{nt} for all i and t are then estimated as:

$$Q_{nt} = (q'_{nt}\alpha_o)/(\gamma_o + x'_o\,\beta_o) \quad (6.4)$$

$$X_{nt} = (x'_{nt}\eta_o)/(q'_o\,\phi_o - \delta_o) \quad (6.5)$$

where $\alpha_o, \beta_o, \gamma_o$ solves Equation 6.2. The computer software DPIN[1] 3.0 was used to decompose productivity into various efficiency indexes as applied by Rahman and Salim (2013) that estimated the FPI assuming that the production technology exhibits Variable Return to Scale (VRS).

6.2.3 Determinants of Total Factor Productivity change

In the second part of the analysis the study went further and applied the BMA to investigate the determinants of TFP scores derived from the FPI model. This approach used the policy-related variables and the TFP scores to determine policy direction. Accordingly, Majiwa *et al*., (2015) argued that traditional methods that analyse data tend to ignore the issue of model uncertainty, and therefore showed that the BMA is one of the pivotal methods that addresses model uncertainty. Pioneering studies (Madigan and Raftery, 1994; Raftery, 1995) made the BMA favourable in statistics to solve uncertainty when selecting methods. In this chapter, the BMA was favoured to investigate uncertainty over the control variables and because of its ability to test the results using the posterior distribution. In the early millennium, empirical studies (Bunnin *et al*., 2002; Fernandez *et al*., 2001; Oehler *et al*., 2009; Yeung *et al*., 2005) applied the BMA in economics, medicine, ecology and biology.

However, Majiwa *et al*., (2015) showed that analysing determinants of TFP in agriculture is under threat because of model uncertainty emanating from an inadequate theoretical basis to determine which control variables affect TFP. Consequently, the BMA emerged as the right method to investigate the determinants of TFP in African agriculture. Therefore, this chapter applies this method to investigate the determinants of TFP in small-scale sugarcane production in the rural provinces of South Africa as applied by Majiwa *et al*., (2015) and which was inspired by the work of Fernandez *et al*., (2001).

6.2.4 Bayesian modelling average technique

As just noted, the application of BMA in agriculture was recently applied by Majiwa *et al*., (2015), who was inspired by the work of Fernandez *et al*., (2001) that assessed the output value of TFP and environmental variables. Suppose a linear model structure with the dependent variable y**,** a constant expressed as α, while coefficients expressed as β and a normally distributed error term ε with variance σ^2, expressed as follows:

$$y = \alpha + \beta_i X_i + \varepsilon \qquad \varepsilon \sim N(0; \sigma^2) \qquad (6.6)$$

With several potential explanatory variables existing in a matrix Z, we face difficulties with the choice of variables to be included in the model, and therefore their importance. However, BMA provides assistance by solving the uncertainty problem by approximating models for all possible sets of Z and constructing a weighted average over all the variables. Suppose Z contains G possible variables, then an estimate of 2^G models will be made to imply that the anticipated number of explanatory variables in a model will show G/2 as proposed by Fernandez *et al*., (2001). Therefore, the model weights over models S was expressed as:

$$P(S_G| y, Z) = \frac{P(y|M_G, Z)P(M_G)}{P(y|Z)} = \frac{P(y|M_G, Z)P(M_G)}{\sum_{S=1}^{2K} P(y|M_S, Z)P(M_S)} \qquad (6.7)$$

where $P(y|M_G, Z)$ expresses the posterior model probability, $P(y|Z)$ is the integrated likelihood which is a multiplicated term, and p(M) denotes the prior model probability. Therefore, the posterior model probability of a given model will be specified as the model likelihood conditional on the assumed model M times a prior model probability. Hence, the weighted posterior distribution for any data is expressed as:

$$\theta\colon \sum_{S=1}^{2K} p(\theta|M,Y)p(M|X,y). \quad (6.8)$$

6.3. Study area and data

6.3.1 Study area

The study was conducted in the Amatikulu sugarcane region in the Umlalazi municipality of KwaZulu-Natal. The region hosts the Tongaat Hulett mill that crushes 385 tons per hour of sugarcane produced in the area. Four sites were visited in the pursuit of field survey in the region i.e. Amahubhu, KwaGingindlovu, Mabhokweni and Mtunzini communities because of the number of small-scale growers that produce sugarcane as individuals in an area that is dominated by co-operatives, and where a number of small-scale sugarcane growers have been in operation for the past five seasons.

The Amahubhu village is situated to the west of the mill and covers 5.49 km^2 with 311 households hosting 1617 people, while KwaGingindlovu is a small town that hosts the mill and accommodates 1109 people with the area capacity of 2.39 km^2. On the western part before reaching the Amahubhu village the study visited the Mabhokweni community that covers 6.45 km^2 and is home to 2217 people. Lastly, Mtunzini town to the south-east of the mill covering approximately 10.43 km^2 and hosting 874 families with 2199 people were also visited (Census, 2011). The Umlalazi municipality that hosts the four communities enjoys temperatures that range between 28 degrees and 30 degrees celcius and with an annual average rainfall of 1000–3000 mm that is received mainly from November to March. The municipal land area is dominated by unspecified land, followed by communal farming of small-scale sugarcane for subsistence.

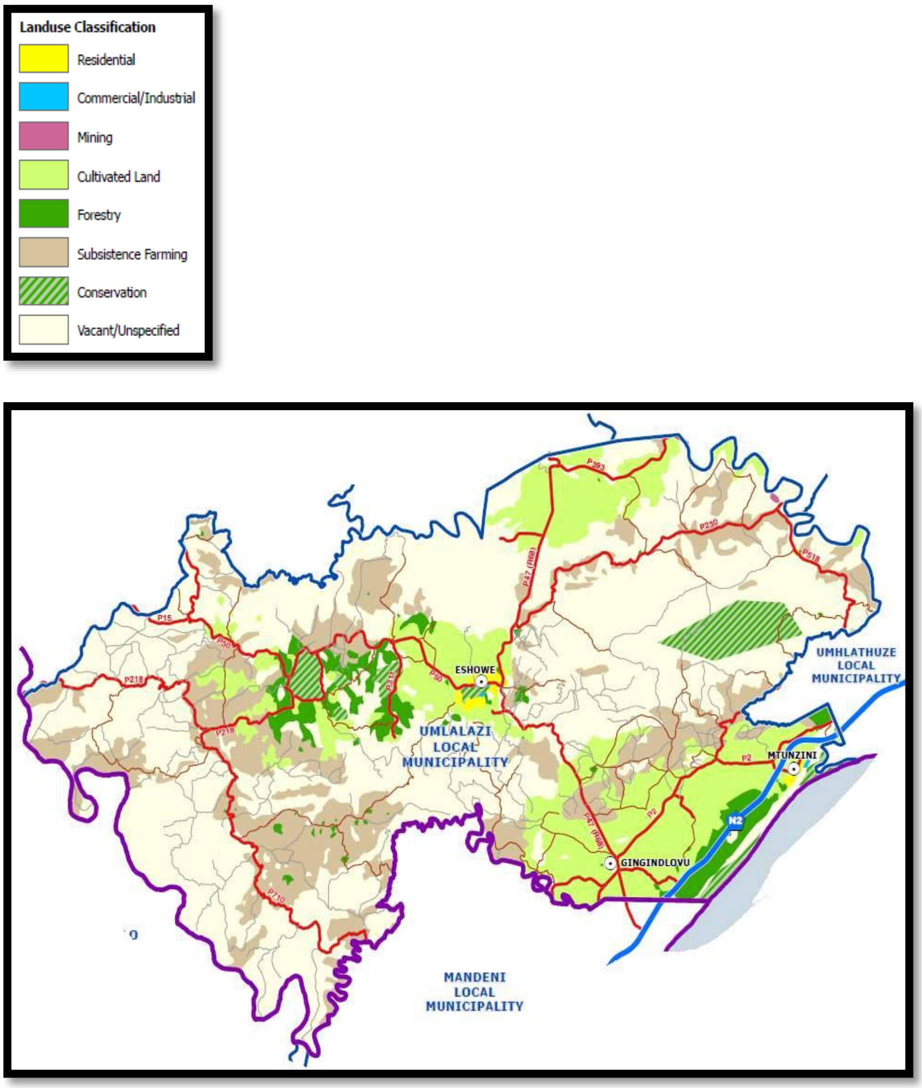

FIGURE 6.1 MAP OF UMLALAZI MUNICIPALITY

Source: Umlalazi IDP, 2017

6.3.2 Survey procedure

6.3.2.1 Questionnaire Design

This section provides a description of the comprehensive approach taken to designing a questionnaire to collect data for the chapter. This study was limited to the availability of input data for the desired production seasons (2013–2016) to complement the available output and policy-related data to decompose productivity and efficiency change. In developing a sound questionnaire, a literature review, personal meetings with extension officers and area managers, and a pilot survey were very instrumental.

During the discussions key policy-related variables covered in the study were identified. Moreover, it was in these discussions that socio-economic and policy-related factors that hinder the productivity and efficiency change of small-scale sugarcane growers were uncovered, these factors encourage the alignment of policy related variables to TFP growth.

The primary information obtained during the discussions and the detailed literature review were used to structure the questionnaire. The questionnaire included both input and output data on sugarcane, livestock, land, fertiliser, capital and labour and also information on policy related variables. With the questionnaire in hand, the pilot survey was conducted on ten randomly selected small-scale sugarcane growers, and a senior extension manager working in the sugar industry was asked to look at the questionnaire. The small-scale sugarcane growers were asked to be critical of the questions and to provide constructive comments on the suitability and correctness of the required information. The structured questionnaire was developed to collect primary data to supplement secondary data used for this study, (see Appendix 1A). The study obtained ethical clearance from the University research ethics committee and permission from the tribal authorities, Tongaat Hulett extension department, and the provincial department of agriculture and rural development.

6.3.2.2 Sampling procedure

There are a limited number of small-scale growers that practise dual production of sugarcane and livestock in the Amatikulu region. The combined production of livestock and sugarcane provides security to the small-scale growers in sustaining their livelihood. The mill production estimates were used to source the sugarcane production data for the interviewed small-scale sugarcane growers using their mill number, consisting of over 900 growers that produced for the period 2013–2016. A total of 98 growers produce livestock and sugarcane and, after applying a random sampling technique, a total number of 38 small-scale sugarcane growers were used as a sample for this chapter, because they provided complete production data that was verified after the sample to decompose productivity and efficiency change over the period of 4 seasons. The sugarcane output data was obtained from the mills, while inputs and livestock data were sourced from the 38 small-scale sugarcane growers themselves.

6.3.3 Data and Variable construction

6.3.3.1 Data

The rationale of this section is to provide a description of the data applied in the decomposition of productivity and efficiency change and the data applied to investigate the determinants of TFP change. Both primary and secondary panel data was applied to construct inputs and outputs data by using a weighted aggregative method to decompose efficiency and production growth. Secondary sugarcane output data was sourced from the Tongaat Hulett extension services department, while livestock, sugarcane seeds stalk output and input data were collected using structured questionnaires. To collect primary data on sugarcane seed cane inputs and output the study applied a random sampling technique to interview household heads and main decision- makers producing sugarcane to be crushed by mills and its seed cane to be sold to other growers. The 38 small-scale sugarcane growers in the sample in the Amatikulu region were tendered a questionnaire and their data registered. The questionnaire (see Appendix 1A) was designed to elicit production inputs and output data covering four seasons.

The production inputs i.e. land, fertiliser, capital and labour and outputs i.e. sugarcane output, seed cane stalk and livestock output were used in the analysis. Moreover, to decompose productivity and efficiency change the aggregated variable inputs and outputs were used. The literature dictates the application of the weighted aggregative method to construct input and output variables. The constructed sugarcane output variable was constructed by taking a weighted aggregate quantity of sugarcane harvested, with weights based on revenue shares of sugarcane, while livestock output was generated by a weighted aggregate of the number of cattle and goats during the survey period using revenue share as a weight. Seed cane output is the total seed cane stalk produced during the survey period in kilograms.

To construct the land input variable all the land area (measured in hectares) operated on by the farm business, whether owned or rented by the growers, was used. The fertiliser was calculated by the aggregate quantity of all fertiliser used in kilograms, while capital was calculated as the average of the total closing value of capital on the closing of business and opening value of capital. It included the value of all assets used on the farm, including leased equipment with the exception of machinery contractors' equipment. Lastly, labour was computed as the total number of hours worked by all farm workers including family labour. Table 6.1 shows the summary of statistics for the production data.

The average sugarcane yield was 96 767.7 kilograms per season for small-scale sugarcane growers in the Amatikulu region out of which, 20 483.07 kilograms per season was certified by the mill to be used as seed cane stalks and was sold to other growers. It is very difficult to compare these figures to the annual estimated average yield in the Northern KwaZulu-Natal region of 6000 kg/ha when the average rainfall is 1000–1300 mm/annum, because of the drought that occurred in the 2016 production season.

6.3.3.2 Descriptive statistics of production data

TABLE 6.1: SUMMARY STATISTICS OF PRODUCTION DATA

	Sugarcane output	Livestock	Seed Cane	Land	Fertiliser	Capital	Labour
Mean	96767.70	116835.90	20483.07	2.62	633.61	14186.52	556.49
SD	85929.51	73011.93	23284.51	2.28	436.50	9028.36	335.57
Min	9141	15000	668	0.20	50	875	100
Max	765564	360000	152152	15	2250	42300	1698

The average revenue share for livestock was R116 835.90 for the aggregated cattle and goats that a particular small-scale sugarcane grower owns. On average, a total of 2.62 hectares of land was milled for sugarcane production, with the minimum and maximum hectares standing at 0.2 and 15 respectively. With regard to fertilisers, an average of 633.61 kilograms were applied in the production of sugarcane between 2013–2016, with a minimum of 50 kg and a maximum of 2 250 kilograms. Lastly, the total of 556.49 hours was allocated on average for the production of the three outputs.

6.3.3.3 Descriptive statistics of determinants of TFP growth data

The study went further and investigated the determinants of TFP change using variables that are considered relevant to small-scale sugarcane production and influenced by the policy reform of the relevant stakeholders. These were education of the grower, experience of the grower, extension visits to the grower, millable land size of the small-scale sugarcane grower and lastly, development funding in a form of an investment in sustainability. The summary statistics of the variables are presented below in Table 6.2. Variables on determinants were constructed as follows:

- Education: This refers to the total number of years schooling a particular small-scale sugarcane grower had.
- Experience: This was defined as the total number of years a particular small-scale sugarcane grower has been producing sugarcane for crushing with interaction with the mill and other stakeholders.
- Extension visits: This is represented by the number of days constituting a direct visit to a grower's production plot by extension officers for any kind of advice.
- Land size: This is the total size of millable agricultural land available for sugarcane production for any particular small-scale sugarcane grower.
- Sustainability Investment: This is the total expenditure on operating costs incurred by the mill in terms of subsidies for any particular small-scale sugarcane grower.

As illustrated in Table 6.2 the average education of the small-scale sugarcane grower was 4.32 years, with the minimum and maximum of 0 and 15 years of schooling. The average experience of small-scale sugarcane growers was 20.51 years while the less experienced small-scale sugarcane grower has produced for a season. The average visits to a plot occupied by a small-scale sugarcane grower for technical advice by either the non-governmental and governmental stakeholders were 1.79 visits, while the maximum visits were 12 trips, with some small-scale sugarcane growers not having any contact at all with the extension officers.

TABLE 6.2: SUMMARY STATISTICS OF DETERMINANTS OF TFP GROWTH DATA

	Education	Experience	Extension visits	Land size	Sustainability Investment
Mean	4.38	20.51	1.79	8.48	3392.65
SD	4.15	11.06	1.95	5.22	2090.91
Min	0	1	0	3.00	1200
Max	15	42	12	25.8	10320

The land used to produce sugarcane averaged 8.48 hectares, with a minimum and maximum of 3 and 25.8 hectares worked, respectively. Lastly, the mill funds sustainable expenses to contribute to the development and sustainability of the small-scale sugarcane growers. An average of R3 392.65 was spent on supporting small-scale sugarcane growers with the subsidy, while the minimum subsidy was R1 200 and the maximum of R10 320.

6.4 Empirical Results and Discussion

6.4.1 Results of Färe-Primont Index

Table 6.3 below presents the multilateral agricultural TFP indices and efficiency levels estimated using the Färe-Primont Index for the Amatikulu region small-scale growers between 2013 and 2016. The Geomean estimates of average TFP level and TFP efficiency in the last two columns are at 19 and 71%, respectively, while the technical-efficiency level is at 81%, followed by a 90% estimation for scale-efficiency level. Furthermore, the mix-efficiency level was at 79% and the residual-scale efficiency level at 53%, followed by scale mix efficiency of 76%, and residual-mix efficiency level of 47%. The results show 18% variation over the period of time expressed by the range of between 67 and 87% of the output mix efficiency.

The results indicate that small-scale sugarcane growers in the Amatikulu region need to improve productivity by producing at the maximum productivity point. Thus, despite doing fairly well on both technically or scale efficiency growers should focus on improving residual scale, scale mix and residual mix efficiency to the level higher than or equal to technical and scale efficiencies. The results are in line with the study by Majiwa (2017), which showed a lower residual scale, scale mix and residual mix efficiency compared to technical and scale efficiencies in African agriculture. However, it is very difficult to compare these results to previous studies that estimated TFP in agriculture.

This study applied farm level data sourced directly from the small-scale sugarcane growers for a short period due to lack of proper data to model productivity and efficiency change, while other studies used secondary panel data sourced from various databases. Overall, the results indicate that small-scale sugarcane growers have experienced different technical efficiency mean scores ranging between 28 and 95%. The results show that small-scale sugarcane growers experience challenges in maintaining the use of inputs. The results also reveal the gap between the observed TFP and the maximum frontier TFP as a consequence of low mix efficiency compared to technical efficiency levels of small-scale sugarcane growers. The gap is a concern for small-scale sugarcane growers' quest of achieving economies of scale over the long-run by applying an optimum combination of input and output mixes.

TABLE 6.3: TOTAL FACTOR PRODUCTIVITY AND EFFICIENCY LEVELS

	Maximum TFP	Technical-efficiency	Scale-efficiency	Mix-efficiency	Residual scale-efficiency	Scale mix efficiency	Residual mix-efficiency	TFP efficiency	Average TFP
	1	2	3	4	5	6	7	8	=(1*2*3*7)
2013	0.56	0.90	0.95	0.76	0.50	0.80	0.40	0.74	0.19
2014	0.69	0.83	0.93	0.69	0.45	0.78	0.31	0.73	0.17
2015	0.68	0.67	0.84	0.82	0.53	0.73	0.53	0.68	0.20
2016	0.41	0.82	0.88	0.87	0.63	0.74	0.63	0.70	0.19
Geomean	0.59	0.81	0.90	0.79	0.53	0.76	0.47	0.71	0.19

TABLE 6.4: SUMMARY OF INPUT USAGE

Year	Input Technical Efficiency	Input Scale Efficiency	Input Mix Efficiency	Residual Input Scale Efficiency	Input Scale Mix Efficiency
2013	0.91	0.95	0.71	0.51	0.38
2014	0.85	0.91	0.70	0.41	0.28
2015	0.74	0.76	0.77	0.50	0.40
2016	0.85	0.83	0.79	0.64	0.51
Geomean	0.84	0.86	0.74	0.51	0.39
Growth (%)	- 0,07	- 0.12	0.31	- 0.47	0.45

Table 6.4 provides the annual input growth rate for the years 2013 – 2016 as follows: input technical efficiency reduction of 7% input scale efficiency decreases of 12%, input mix efficiency increases of 31%, residual input scale efficiency decreases of 47% and lastly, an input scale mix efficiency increases of 45%. The results revealed low input mix efficiency, something that is associated with the poor optimal combination of inputs experienced by small-scale sugarcane growers that may lead to inefficiencies as a consequence of failure to apply inputs optimally.

Table 6.5 presents the results for TFP productivity change and its components for the period under review. The results revealed an annual rate of TFP growth of 55%. This positive TFP growth estimate is encouraging because of the harsh climatically conditions that have affected yields. However, this estimate of TFP growth is lower than the estimate generated by Majiwa (2017) but higher than that of Rahman and Salim (2013), although it proves to be difficult to compare these studies because the above studies used continental and regional data. The observed technological progress estimated by technical change grew at an annual rate of 42%.

The results revealed that the positive TFP growth is influenced by technological progress and mix efficiency, a finding which is in line with Coelli *et al*., (2003), Rahman

(2007) and Majiwa (2017). Moreover, the results also revealed a decline in technical efficiency and scale-efficiency annual growth rate of 6 and 17%, respectively. The results imply that small-scale sugarcane growers failed to maintain technical efficiency and scale-efficiency over the short period of 4 production seasons. On the other hand, residual scale-efficiency and residual mix-efficiency grew at an annual rate of 28 and 67%, respectively.

6.4.2 Results of Bayesian Modelling Averaging

As mentioned earlier, the Bayesian Modelling Averaging technique was applied to investigate the determinants of TFP growth. Table 6.6 below presents the results from BMA relating to the TFP growth of each small-scale sugarcane grower in the Amatikulu regions to various socio-environmental variables. The results of the coefficients averaged over all models are presented by the post mean. To give a possible explanation of the representatives of the variables, the Posterior Inclusion Probabilities (PIP) is considered. The coefficient sign for all models that contained experience of the small-scale sugarcane grower showed a positive association with TFP growth and a PIP of 0.534, indicating a confidence level of 53.4%, meaning that posterior model mass rests on models that included experience. Likewise, sustainability investment also showed a positive association with TFP growth, but a fairly low PIP of 0.343, indicating a confidence level of 34.3%.

TABLE 6.5: TOTAL FACTOR PRODUCTIVITY CHANGE AND ITS COMPONENTS

Year	Technical change 1	Technical-efficiency change 2	Scale-efficiency change 3	Mix-efficiency change 4	Residual scale-efficiency change 5	Residual mix-efficiency change 6	TFP change 7 =(1*2*3*6)
2013	0.57	0.90	0.96	0.81	0.81	0.64	0.32
2014	0.39	0.83	0.93	0.68	0.73	0.50	0.15
2015	0.48	0.67	0.84	0.83	0.86	0.85	0.23
2016	0.72	0.81	0.89	0.87	1.04	1.01	0.52
Geomean	0.54	0.80	0.91	0.80	0.86	0.75	0.29
Growth(%)	0.42	- 0.06	- 0.17	0.10	0.28	0.67	0.55

TABLE 6.6 DETERMINANTS OF TFP GROWTH

	PIP	Post mean	Post SD	Cond Pos Sign	Idx
Land size	0.197	- 0.004	0.151	0.000	1
Sustainability Investment	0.343	0.113	0.219	1.000	2
Extension visit	0.167	0.014	0.081	0.000	3
Experience	0.537	0.190	0.218	1.000	4
Education	0.308	0.068	0.136	1.000	5

Furthermore, the education of the small-scale sugarcane growers also revealed a positive association with TFP growth with a PIP of 0.308, with the confidence of 30.8%. These results imply that both encountered models that contained both sustainability investment and education as variables were partially included in the results. In contrast, both land size and extension visit revealed a PIP of 0.197(19.7%) and 0.167(16.7%), respectively. The results revealed a negative coefficient sign for all models that included both land size and extension visits.

Given the contrasting relationship between TFP growth and the socio-environmental variables, there is need to draw the possible influence of each variable to TFP growth and align it to existing studies in the field of agricultural TFP growth and efficiency. As stated earlier, the land size of any particular small-scale sugarcane grower represented by the total hectares of millable land revealed a negative relationship with TFP growth. These findings are in line with the results of Townsend *et al*., (1998) and Sheng *et al.,* (2014), that increasing land size does not improve productivity, because of the weak inverse relationship between farm size and productivity. Furthermore, access to extension support was also negatively related to TFP growth, indicating that more days devoted to extension supervisors visiting plots impacted on productivity.

The finding is in contrast to Shiferaw *et al*., (2011) that access to extension support plays a role in increasing productivity.

On the other hand, the experience of small-scale sugarcane growers was positively associated with TFP and was the most dominant determinant, as shown by the confidence values. This finding implies that small-scale sugarcane growers with experience achieve higher TFP growth rates than growers with less experience. Sustainability investment as a proxy for development spending also showed a positive association with TFP, a finding which is in line with the study of Alene (2010) and Majiwa (2017) that revealed the positive effect of development expenditure on agricultural TFP growth. Lastly, the education level of the small-scale sugarcane grower also had a positive relationship with TFP, implying that growers who have spent more years in school achieved higher TFP growth rates. The finding supports the work of Asadullah and Rahman (2009) that revealed the positive influence of education on production efficiency.

6.5 Summary and conclusion of the chapter

The purpose of this chapter was to decompose productivity and efficiency change and also investigate the determinants of productivity growth. This chapter applied the Färe-Primont Index to decompose productivity and efficiency change indices for thirty-eight small-scale sugarcane growers operating in the Amatikulu sugarcane producing region of Northern KwaZulu-Natal over a four-year period (2013–2016). The chapter decomposed the TFP index into finer components (Maximum TFP, Technical efficiency, Scale-efficiency, Mix-efficiency, Residual scale-efficiency, Scale mix efficiency, Residual efficiency, TFP efficiency and Average TFP). The chapter went further and investigated the sources of total factor productivity growth using five policy-related variables. There are limited studies focused on farm-level agricultural efficiency and productivity change in Africa, with the existing studies comparing nations and regions.

The DEA-oriented Färe-Primont Index without prior assumption on production technology was applied in the chapter to analyse the following objectives: (i) decompose efficiency and productivity growth in small-scale sugarcane growers; (ii) investigate determinants of total factor productivity growth of small-scale sugarcane growers. Both production and policy- related variables were analysed to fulfil the objectives above. A random sampling technique was used, insourcing the primary data, which was supplemented by secondary data obtained from the Tongaat Hulett supervisor. The Färe-Primont Index analytical framework proposed by O'Donnell (2012) was used to decompose components of total factor productivity; furthermore, the Bayesian Modelling Averaging technique was used to investigate determinants of total factor productivity growth.

The estimates of maximum TFP, technical efficiency, scale-efficiency, mix-efficiency, residual scale-efficiency, scale mix efficiency, residual efficiency, TFP efficiency and average TFP for small-scale sugarcane growers in the Amatikulu region, decomposed using the FPI, were 59, 81, 90, 79, 53, 76, 47, 71 and 19%, respectively. An examination of input growth revealed an increase of 31 and 45% in both input mix efficiency and input scale mix efficiency, respectively. However, there negative input growth of 7, 12, and 47% of input technical efficiency, input scale efficiency and residual input scale efficiency. The results are in line with other studies (Hadley *et al*., 2013; Majiwa, 2017) which revealed that low input mix efficiency in agriculture productivity is associated with the poor optimal combination of inputs. The low mix efficiency compared to technical efficiency was observed by the gap between the TFP and the maximum frontier TFP.

Empirical results of the BMA technique analysis revealed that policy-related variables were positively and negatively associated with total factor productivity growth. The coefficients for all models that contained experience, sustainability investment and education of the small-scale sugarcane grower showed a positive relationship with total factor productivity growth. However, land size and extension visit revealed a negative link to total productivity growth. The PIP confidence as per ranking of the models that contained land size, sustainability investment, extension visit, experience and education were 19.7, 34.3, 16.7, 53.7 and 30.8%, respectively. These findings are consistent with empirical studies (Townsend *et al.,* 1998; Asadullah and Rahman, 2009; Alene, 2010; Shiferaw *et al*., 2011; Sheng, 2014) that have found both positive and negative links between total factor productivity growth and policy- related variables in the agricultural TFP growth literature.

Overall, policies aimed at increased farm size with limited support or proper resource allocation prove to hinder TFP growth. This arose within the context of small-scale sugarcane growers having failed to attempt to adjust the input mixes, which was shown by a lower mix efficiency. The findings confirmed the conclusions reached by studies that have shown that technical change is not the sole cause of dwindling TFP growth in agriculture. The implication for policy makers and other stakeholders involved in providing advice on small-scale sugarcane production is to consider components of TFP growth and its determinants in recommending plausible ways of improving small-scale sugarcane productivity. Therefore, policies focused on agricultural research and development to aid with educational development aimed on equipping small-scale sugarcane growers with valuable experience to sustain the farm business which is key to agriculture TFP growth are necessary. Much focus needs to be directed to managing the different scale of production plots. Also, improving extension support would help to improve overall TFP growth. Chapter seven will analyse the qualitative method used to investigate barriers to technical efficiency. This chapter is important and links to other analytical studies because it aims to provide in-depth information on the experiences and knowledge of small-scale growers in dealing with the factors that minimise technical efficiency.

CHAPTER SEVEN

BARRIERS TO TECHNICAL EFFICIENCY OF SMALL-SCALE SUGARCANE GROWERS IN THE KING CETSHWAYO DISTRICT

This chapter investigates barriers to technical efficiency that are faced by small-scale sugarcane growers. To identify these barriers the chapter will apply a qualitative method to unearth themes. The chapter will apply the TA approach to answer research questions outlined in chapter 1. To discover theme, focus group discussion and semi-formal interviews were conducted to gather data that was later analysed. The following section introduces this chapter, which will be followed by an outline of methodology and empirical results. The chapter concludes with a discussion.

7.1 Introduction

Sugarcane growers have been faced with challenges that threaten the long-term productivity, performance and efficiency of the farm (Anderson, 2018; Thabethe, 2013). Among many challenges faced by sugarcane growers are lowered yields, low sucrose level and sustainability of the sugar business. Small-scale sugarcane growers are faced with a myriad of constraints because of the limited resources, implements, skills, institutional support and unfavourable climatic conditions. There is literature and information on the potential of small-scale sugarcane growers to control their destiny and commit to the long-term development of the farm business by developing effective organisational structures, proper interaction with support service providers and less dependency on the sugar industry (Sokhela, 1999). Furthermore, the development of small-scale growers has been slow in the sugar industry and has contributed to the organisational structural reforms of millers, stakeholders and grower's association.

Accordingly, (Thabethe, 2013) attributed low productivity levels as a stand-out constraint experienced by small-scale sugarcane growers. Moreover, other constraints identified in small-scale sugarcane production were poor marketing, cost of finance and high operational costs. Whilst these constraints were for small-scale growers in Mpumalanga there is a need to identify challenges common in the production of sugarcane in KwaZulu-Natal. Investigating the constraints in KwaZulu-Natal faced by small-scale sugar growers will contribute to the long-term need of improving technical efficiency. Moreover, small-scale growers will harness technical challenges that hinder their prospects of maximising yield using minimum inputs. As a result, small-scale sugarcane growers need to be aware of both external and internal challenges that affect the performance of the farm enterprise and its ability to optimise profit.

With the exception of Thabethe (2013), there is limited research on challenges faced by small-scale sugarcane growers in South Africa. In other African countries, Anderson (2018) underlined external factors such as rainfall and loss of labour productivity because of HIV in the Kingdom of Eswatini. Furthermore, studies (Christie *et al*., 2008; Sanders and McCormick, 1993) have shown that manual labour affects labour productivity, something that is still common to poor small-scale sugarcane growers. These constraints are accompanied by institutional challenges that prove to be very complicated to resolve because of the different stakeholders that are expected to play a role in the supply chain of sugarcane, especially because sugarcane production is labour intensive, relies on fertiliser, and is more mechanised. Lastly, operational costs are a part of a myriad of constraints that are faced in the production of sugarcane (Thabethe, 2013).

Identifying barriers in the small-scale set-up of the South African agricultural sector is interesting to different stakeholders. This is because the sugar industry is not in isolation to the interest of different role players. Policy makers, sugarcane growers, extension officers, mills and regulatory bodies in the sugar industry give their undivided attention to challenges and constraints faced by small-scale sugarcane growers. Mdemu *et al.,* (2017) suggest that lack of finance is an important barrier to agricultural productivity. The work of Amadhila and Ikhide (2016) identified the lack of finance for agricultural enterprises as one of the challenges in small and medium-scale farming. Therefore, there is a need to identify barriers that hinder small-scale sugarcane growers.

Measuring technical efficiency in agriculture has enjoyed special attention from various empirical studies focused on animal production, plant production, fisheries and forestry. The concept of technical efficiency relates to the analysis of the effectiveness of the quantities of inputs used to produce the quantity of output. In the previous chapter of this study socio-economic variables were applied to determine the drivers of technical efficiency. In the empirical literature Thabethe (2013) measured efficiency and identified socioeconomic variables that influence productive efficiency of small-scale sugarcane production in Mpumalanga. This study went further and identified constraints faced by small-scale sugarcane growers that can affect their performance and productivity. Technical efficiency is an important tool in measuring the performance and productivity of the farm. Therefore, this chapter aims to identify barriers to technical efficiency faced by small-scale sugarcane farmers. To identify such challenges an in-depth qualitative approach will be applied to unearth common themes that small-scale sugarcane growers identify as of concern in their quest to optimise technical efficiency.

The in-depth analysis of challenges faced by small-scale sugarcane growers will help provide policy certainty and advance the need to broadly advise the day to day operation and management of the farm business. Clearly defined themes will emerge from the discussion with both small-scale growers and extension officers. To discover the barriers to technical efficiency TA will be used to identify patterns of challenges faced by small-scale sugarcane growers that are perceived as hindrances to technical efficiency. Therefore, this chapter contributes to the small-scale sugarcane industry by identifying barriers to technical efficiency using a content-rich qualitative approach. The chapter aims to answer the following research question: what are barriers to technical efficiency in the King Cetshwayo district of KwaZulu-Natal? What strategies have small-scale sugarcane growers adopted in response to drought conditions to improve technical efficiency and lastly, are government support intervention programmes effective for technical efficiency and what is considered to be an appropriate government intervention support programme to improve technical efficiency?

Therefore, in answering these questions and contributing to the gap in the literature, this chapter will contribute to small-scale sugarcane efficiency analysis by identifying barriers to technical efficiency, investigating strategies adopted in response to environmental shock such as drought and lastly, understanding what the respondents perceive as appropriate government intervention.

7.2 Methodology

7.2.1 Theoretical Framework

Empirical studies have focused on the constraints faced by small-scale sugarcane growers in their production. There is little evidence that links the constraints to technical efficiency. In order to address this gap, a clear, transparent and replicable qualitative approach was applied to identify themes to unearth barriers to the technical efficiency of small-scale sugarcane growers. The analysis of barriers to technical efficiency using TA is centred on grounded theory. Grounded theory was discussed extensively in chapter 2 and it provides the application for the TA.

This chapter focuses on factors that hinder small-scale sugarcane growers in optimising their technical efficiency. Technical efficiency measures how small-scale sugarcane growers minimise inputs in the production of maximum output. Accordingly, (Komicha and Ohlmer, 2007) capital in a form of credit is still a serious constraint on technical efficiency. Moreover, Serra *et al*., (2008) focused on the use of inputs under production risk with farmers enjoying government support and concludes it may lead to inefficiencies. Small-scale sugarcane growers engage in sugar production to improve their livelihood and have been faced with transport, cost of finance, production level, and operational cost constraints as identified by Thabethe (2013). They are driven by their generational vision and livelihood to optimise production to support their families in an economy that is struggling to provide formal employment.

7.2.2 Description of the study sites

Primary data was collected from two sugarcane production regions that are part of the King Cetshwayo district municipality in the northern part of KwaZulu-Natal, namely the Amatikulu and Felixton areas. The Amatikulu region is situated in the southern part of the district and is home to the town of Gingindlovu which operates the Tongaat Hullet sugar mill. The economy of this small town is driven by sugarcane production with almost the entire population owning individual, co-operative, or estate production plots. This region was chosen because it is known for many growers that operate under different forms of ownership and enjoy support from different stakeholders. Moreover, with many growers operating in the region either as individuals or in partnership, there was a need to identify barriers faced by small-scale sugarcane growers in the region.

The Felixton region is situated in the north-eastern part of the district and operates the Tongaat Hullet sugar mill. The area is near the town of Empangeni and provides sugar industry-related employment for both the urban and rural population. Tongaat Hullet investment in this mill has resulted in major agricultural development in the area. The Felixton region was chosen because it services the diverse growers that operate at the coast and areas inland to the north and west of the mill. Lastly, understanding the barriers experienced by small-scale growers in minimising their production inputs in the two regions is of interest from the perspective of creating a more inclusive economy for historically marginalised groupings.

7.2.3 Research Design

A qualitative research design was used to answer the research questions listed in chapter 1. Maguire and Delahunt (2017) argue that credible qualitative research provides research with an ability to understand, describe and interpret the experiences and perceptions of the population to unearth circumstances and contexts. Moreover, Babbie and Mouton (2001) defined qualitative research as a tool used for describing and understanding human behaviour. There are a number of qualitative methodologies that one can use, as explained by Sarantakos (2005). This study used both focus group discussion and semi-structured interviews to investigate the subject in question. The constructivist paradigm serves as the foundation for this chapter, based on the belief that the sampled population construct reality using an active process of creating a word (Amadhila, 2012).

Therefore, the barriers experienced by small-scale sugarcane growers in their sugar production is part of their respective realities. Hence the impressions created by a researcher after interacting with small-scale sugarcane growers and stakeholders talking about the reality (barriers) they have in producing sugarcane are re-constructions of that reality. Research focused on both the construction and reconstruction of reality is focused on the interpretation and understanding of social life. The views, opinions and perceptions of the small-scale sugarcane growers in this particular piece of research as experienced and expressed in everyday life are accessed to fully understand the issues involved. The crux of the process is to understand the subjective meaning of how small-scale sugarcane growers make sense of their industry and the barriers to production. The epistemological position of this chapter is rooted in TA, as explained in Braun and Clarke (2006), and focus on realism and the construction of people's experience. Therefore, the chapter aims to study the barriers (reality) of small-scale sugarcane growers using an understanding of their everyday experiences.

7.2.4 Selection of participants

This chapter conducted two Focus Group discussions (FGDs) with extension officers in both the Amatikulu and Felixton region. The focus groups consisted of 7 (four men and three women) and 6 (three men and three women) extension officers in the respective regions. Purposive sampling was used after the discussion with the extension service manager in both regions. The focus groups were conducted in English and participants were asked for their verbal consent on the day prior to the discussion.

The second stage of the research focused on small-scale sugarcane growers' experience. Qualitative in-depth semi-structured questionnaires were used to guide the one-on-one interviews with the small-scale sugarcane growers. Purposive sampling was used to select small-scale sugarcane growers based on their leadership roles, age, experience, gender and land size in order to obtain data on a wide range of realities. The total number of 10 (six women and four men) respondents were interviewed to cover the total scope of the research. The participants were interviewed using the preferred local language to give all the small-scale sugarcane growers an opportunity to express themselves freely.

TABLE 7.1: DATA COLLECTION METHOD AND NUMBER OF RESPONDENTS

Data collection method	Number of participants in Amatikulu	Number of participants in Felixton
FGDs	07	06
Semi-structured interviews	06	04

Table 7.1 provides the method of data collection and number of the respondents interviewed and those that participated in focus group discussions. A total of 13 extension officers participated in the FGD's in both the Amatikulu and Felixton regions. The FGD's in the Amatikulu region was attended by 07 participants while in the Felixton region 06 extension officers were present. Of all the participants the 08 were female and 05 male. The semi-structured interviews were carried out in the mill's field offices that are operated by Tongaat Hullet. The field office provides administrative and technical support to the small–scale sugarcane growers and is operated by the extension officer and her/his clerk. A total of 10 small–scale sugarcane growers were interviewed. In the Amatikulu region, 06 respondents were interviewed, while 04 were interviewed in the Felixton region. A total of 06 females were interviewed, with 03 women each from the Amatikulu and Felixton regions.

7.2.5 Techniques of Data analysis

The collected data were audio–taped and transcribed. In the case of the semi-structured interviews isiZulu was used, the transcript was translated to English and was re-read and then the recordings were listened to again to ensure the accuracy of the transcription. The computer package Nvivo 12 was used to identify unique identifier codes that were used to analyse the qualitative data. The coded data were analysed following the interview questions in categories, and the categories were subjected to re-scanning of the data. This process resulted in the identification of sub-categories and new categories and the analysis was continued until no new categories were discovered.

7.3 Results

7.3.1 Description of the respondents

The primary rationale of this part of the thesis was to discover qualitative themes to identify barriers to technical efficiency experienced by small-scale sugarcane growers in the Amatikulu and Felixton regions. Table 7.2 presents the gender, age and the employment status of the respondents in the Amatikulu and Felixton regions. In the Amatikulu region, the majority of the participants were female (62%) compared to 38% that represented male respondents. The participants in the age range between 35–49 years were 46% followed by 39% and 15% that represent the ages of 50–64 and 20–34 years, respectively.

TABLE 7.2: CHARACTERISTICS OF THE RESPONDENTS

	Amatikulu		Felixton	
	Number	Percent	Number	Percent
Gender				
Male	5	38	3	30
Female	8	62	7	70
Age categories				
20-34	2	15	1	10
35-49	6	46	5	50
50-64	5	39	4	40
Employment				
Employed	10	77	7	70
Unemployed	3	23	3	30

Lastly, the participants that were employed and unemployed comprised 77 and 23%, respectively. In the Felixton region, 70% of the participants were female compared to 30% female. Participants with the age between 35–49 were represented by 50% of the respondents, while 50–64 age category were represented by 40% of the participants, followed by 10% that denotes respondents between 20–34 years. Finally, 70% of the participants were employed, compared to 30% of the respondents that were unemployed.

7.3.2 Thematic analysis results

Athematic analysis process was applied to the transcripts to elicit key concepts from the data to determine the understanding of all the participants. The categories were labelled as "Structural change", "Environmental challenges", "Technical constraints" and "Institutional barriers." The following categories are discussed in detail below.

Structural change

This theme was defined by the shift or change in the basic ways the sugar industry or market operates. Such change is typically defined by new economic developments, capital, labour and political reforms. The impact of the structure of the industry on optimal sugarcane production will be demonstrated through evidence from the transcript. The participants in the Felixton and Amatikulu regions expressed the different structural issues in relation to their personal experiences. When they were asked to point out the key market and industry related issues that affect technical efficiency, they did so. For example, one of the respondents in Amatikulu reported that:

"*It is very difficult for me to keep up with the market dynamics, and that affects my yield because of less capital"*

(Male, small-scale sugarcane grower – Amatikulu)

In Felixton another participant put it this way:

"*The sugar industry is very tricky; the effect of inflation affects the RVP and that affects our profit. That's, in turn, have a serious issue when it comes to the number of labourers one needs to hire. The low profit also affects the allocation of other key inputs that are necessary to produce high yields"*

(Female, small-scale sugarcane grower – Felixton)

On the other hand, we also asked the experience of extension officers in relation to structural changes in the sector. One of the Focus Group participants reported that:

"Our small-scale sugarcane growers are very slow to the adaptation of new innovative technology. Based on this challenge their yield suffers."

(Male, extension officer – Amatikulu)

After probing this answer, one of the participants explained in detail as:

"We strive by all means possible to share the new developments. However, certain industrial related issues like the RVP is still a challenge, especially to small-scale

growers. Their lack of capital and continues changing industrial developments really affects technical efficiency."

(Female, extension officer – Felixton)

"The government is killing us with this RVP. You harvest thinking you will get a lot of money, but because we don't charge them for our sugarcane, they pay us a little money. You invest a lot of money in working on the farm and do not get half the money you used for production".

(Female, small-scale grower – Felixton)

However, despite showing that they are aware of their industry-related issues, there is evidence of no knowledge of political reforms in this theme. This suggests that the participants do not yet understand the role political reform plays in technical efficiency. We then asked a question to test their experiences as:

I: "*What are your views on the political reforms and your ability to maximise yield?"*

(Interviewer–Felixton)

*: "*There is great uncertainty in our production plans, with the issues of land expropriation with no compensation there is a lot to worry about."*

(Male, small-scale grower–Felixton)

This understanding proves that the small-scale sugarcanes are aware of the political climate and the issues that might affect their farming. It is also important to consider the growers' understanding of policies that are intended to shape the sugar industry.

I: "*So do you think the land reform process was successful in changing land ownership in the sugar industry?"*

*: "*The land reform process resulted in many farms idling because of power struggles between the beneficiaries. However, small-scale sugarcane growers farm in communal lands with the permission to occupy from the traditional leaders."*

(Female, extension officer – Felixton)

It is evident that the understanding and knowledge of small-scale sugarcane growers and those of extension officers as their advisors are important in the application of their experience and narrate them in a context. This understanding was exhibited by growers with leadership roles. Having a leadership role leads to participation in the industry-related decision-making process that impacts on production.

The next theme focuses on the environmental challenges faced by small-scale sugarcane cane growers. The difference between these two themes is that structural changes focuses on industry-related factors that affect technical efficiency, while the environmental challenges mainly relate to external factors, chief among them being concerns related to climate change.

Environmental challenges

The recent concerns of low agricultural production because of global warming, climate variation, air pollution and soil degradation are also common in the sugar industry. The environmental challenges theme was defined based on the environment- related factors that are perceived by small-scale sugarcane growers and extension officers to have an effect on production and subsequently, technical efficiency. In both the Amatikulu and Felixton region, environmental challenges were discussed in detail and were reported as follows:

"The recent occurrence of drought has been a setback in our production, the low yield over-lapped to the money that was needed to carry over the next production season."

(Male, small-scale grower–Amatikulu)

The other participant in Felixton expressed the experience of drought in this way,

"Right now, there is a part of my farm affected by drought. I'm still trying to figure out how to revitalise the land."

(Female, small-scale grower–Felixton)

There were some strategies that small-scale sugarcane growers adopted to try to minimise the damage caused by drought. Small-scale sugarcane growers relied more on extension officers for support during that challenging time. The example below demonstrates how an understanding of one's surrounding environment can influence the decision taken to curb the severity of drought. After a probing question their response was as follows:

I: "How did you recover from the drought?"

**: "We did nothing. I do not know any recovery measures. However, we sought support from extension officers."*
(Female, small-scale sugarcane grower–Felixton)

There was some evidence that small-scale sugarcane growers resorted to destroying their crops. In Amatikulu, one of the participants explained this in detail as:

"We just mowed the crop because it won't grow."

(Male, small-scale sugarcane grower–Amatikulu)

These experiences that showed that growers struggled with the advent of drought. We then asked extension officers to give us their views on strategies used by small-scale sugarcane growers and what was their role during the process. A number of extension officers in the focus group highlighted fallowing as an intervention that was taken to minimise the damage caused by drought, as the excerpt below shows:

"In relation to poor and resource-limited growers we opted for fallowing of the land minimise the loss that may be faced because of drought."

(Female, extension officer–Amatikulu)

"It was the worst season that I have ever experienced, however, we had prevention measures and encourage the growers not to lose hope. But we also teach them about crop quality and how to choose the soil and how to maintain the moisture of the cane to try to improve yields in such seasons".

(Male, extension officer–Felixton)

This extract showed some evidence of the extension officers' involvement and advice during the drought season. However, there is no clear evidence to prove the benefit of the extension officers' advice to production and technical efficiency. This comes amid the negative relationship between extension support and technical efficiency. There were many aspects of the transcripts that highlighted the awareness of extension growers to environmental challenges that affected growers. However, there were participants who were not all happy with the support from extension officers. This leads on to the next theme.

Technical constraints

The technical aspect of small-scale sugarcane production is the most worrisome constraint that extension officers strive to reduce. Technical constraints may lead to inefficiencies in production that affects the long-term sustainability of the growers. There is general agreement amongst the participants that technical constraints are things to avoid in small-scale sugarcane production to optimise technical efficiency. Elements of this theme demonstrate the role that extension officers play in sharing information, knowledge and training on the adaptation of innovative technologies, inputs and good practices. In the Felixton region, technical constraints were common to all the participants when they related their experiences. This was supported by the following excerpts:

"There are many technical challenges that we face, they range from chemicals, labour and machinery."

(Female, small-scale grower–Felixton)

In Amatikulu one of the participants showed that institutional set-up and extension support lead to technical constraints. He elaborated that:

"It is very difficult to manage technical constraints because of the structure of the industry, government support and limited support from extension officers."

(Male, small-scale grower–Amatikulu)

These excerpts show that small-scale sugarcane growers do not understand their role in managing technical constraints. Because technical constraints are an essential performance tool we asked a probing question to understand the knowledge and experience of the small-scale growers on technical aspects of sugarcane growing.

I: *“So who is responsible for the allocation of minimum inputs, innovative technologies and general production of sugarcane on the farm?”*

**: "It is my sole responsibility to produce good sugarcane. However, there is a need for extension officers to advise on new chemicals, cane seeds and where possible liaise with contractors in time".*

(Female, small-scale grower–Amatikulu)

**: “I believe extension officers must offer timeous training to improve production in our farms. We struggle with many production related issues during drought and diseases. The other issue is because we do not have money to chemicals.”*

(Female, small-scale grower–Felixton)

In addition to these responses, one of the growers who is a chairman of the growers in the region stressed a few issues that lead to technical constraints. This participant felt growers with limited experience and no training were mostly constrained. There was also a sense of low production levels as a result of the high cost of input.

“As the chairman of the growers in the region, I have observed that mostly inexperienced growers have technical constraints. We need to prioritise training to improve their yields. The role of extension services and other sugarcane supporting bodies needs to be targeted on reducing technical challenges.”

(Male, small-scale grower–Amatikulu)

It is clear that the participants’ understanding is that technical constraints are negatively affecting sugarcane production and technical efficiency. However, there is over-reliance on extension officers by small-scale sugarcane growers, as reflected by their experiences. The participants seem to struggle with the term ‘technological constraints’, and in trying to understand the depth of the technological constraints and how they are commonly dealt with in small-scale sugarcane production. We asked extension officers their understanding of the concept of technological constraints. The excerpts below relate to their views:

“It is challenges faced by small-scale growers that hinders their ability to apply desired inputs, resources and knowledge to yield sugarcane.”

(Female, extension officer–Amatikulu)

“These issues relate to the managerial motivation of the particular grower to produce sugarcane.”

(Male, extension officer–Felixton)

From the above explanations, and the need to elaborate the somehow understanding of the theme. We asked probing questions to understand the knowledge and experience of extension officers about promoting technical efficiency in small-scale sugarcane production.

I: *“What is your role in minimising technical challenges?”*

**: “We promote good practices, however, this is not easily welcome by small-scale growers because of their slow adaptation to change. Recently, we encouraged the use of certified seeds cane and proper planting schedule.”*

(Male, extension officer–Felixton)

*: *“We communicate planting schedules, ratoon and crop management. But we are let down by contractors who take time to fetch sugarcane from the growers.”*

(Female, extension officer–Amatikulu)

This category of technical constraints showed the small-scale sugarcane growers’ understanding of issues affecting production. This theme presented mixed experiences from growers and extension officers, as illustrated in the data. Some factors that are related to institutions and entities that serve the small-scale sugarcane growers were mentioned. The existence of institutions regulating and providing support to growers provided a pathway to the next theme focused on institutional barriers.

Institutional barriers

An institution, for the purpose of this chapter, is defined as a place or people that make choices about the production, processing and marketing of sugarcane produced by small-scale growers. Institutional barriers are the main concern in small-scale sugarcane production where a large group of growers are resource and knowledge poor. The recent introduction of a parallel growers association to the sugar industry offers a lot of choice to help with the need of improving small-scale sugarcane production. This theme provided the participants' experience in relation to the external influence of contractors, tribal authorities, growers associations, mills and government departments. The participants in the Felixton and Amatikulu regions mentioned the different institutional barriers as analysed fully below. When they were asked to point out key institutional issues that have an influence on technical efficiency, some of the barriers were reported as:

I: "What are institutional related issues do you face in sugarcane production, and how do they affect technical efficiency?"

**: "They are many challenges that one can think of concerning land allocation by the chiefs, the way we work with contractors and the issue of RVP."*

(Male, small-scale sugarcane grower–Amatikulu)

I: "Tell me more about those challenges. "

**: I have limited land and opt for leasing to increase my production potential, this is because my PTO gives me one plot to grow my sugarcane while I have a burning desire to have more land. We struggle with contractors when it's time to cut and send the cane to the mills. Let me tell you, they take time to come and collect and the cane loses the sucrose level in the field. That issue results in me getting low profit because the RVP is not stable.*

(Male, small-scale sugarcane grower–Amatikulu)

I: "How are these issues related to technical efficiency?"

*: *“Land allocation gives me an opportunity to produce more and use my labour, chemicals and fertilisers in all the land I would like to grow sugarcane. The issue of contractors results in poor yield because of their failure to come early. I can't talk much about RVP as we have marched to the government to complain about this issue.”*

(Male, small-scale sugarcane grower–Amatikulu)

From the excerpts above, the participants shared the experience and thought that institutional barriers affect technical efficiency. For the majority of the participants in the Felixton region, their knowledge and experiences reflected different views. This was not so surprising; each participant has different experiences. The excerpt below relates to their views:

“*We hardly get support from the government as small-scale sugarcane growers, and only rely on Tongaat Hulett for production related support.”*

(Female, small-scale sugarcane grower–Felixton)

I: “How do you work with contractors”?

*: *“We wait for a long time before they come and fetch sugarcane from the field, their priories are growers with many loads.”*

(Female, small-scale sugarcane grower–Felixton)

*:” I *work very well with contractors when you follow your harvesting schedule communicated by the extension office."*

(Female, small-scale sugarcane grower–Felixton)

There was uncertainty on the role played by the extension officers from the provincial department of agriculture and rural development. It is worth reiterating that participants do not believe in the services offered by the departmental officers. Examples of such experiences included the unavailability of departmental officers to offer farm advice. We considered the experience of small-scale sugarcane growers in relation to their interaction with the departmental officers. Another respondent complained that governmental extension officers hardly provide service and advice to them. They put it this way:

"We only see those guys when there are farmers days and meetings. Instead, we only work with people from the mill."

(Female, small-scale sugarcane growers–Felixton)

“The government extension officers do not help us, they should have been working very hard to give us seeds, tractor and fertilisers.”

(Female, small-scale sugarcane growers)

In addition to this, particular growers also pointed out they felt there is nothing government can do to improve performance management. Moreover, they would appreciate it if the government could focus on regulating the industry to help improve their turnover by stabilising the RVP. One particular participant when questioned revealed that:

I: "What are key strategies that government must adapt to help promote technical efficiency?"

**: “There is little they can do, this is motivated by their non-involvement to data. We would appreciate if they can help improve the RVP.”*

(Male, small-scale sugarcane grower–Amatikulu)

Lastly, the extension officers from the mills stressed the same point elaborated by small-scale sugarcane growers in relation to their interaction with their governmental counterparts. This was a topical issue in focus groups and one of the participants said:

“*Those guys are so few and only stationed in Eshowe, we hardly see them in farms. Otherwise, we only meet in meetings and farmers days.”*

(Female, extension officer–Amatikulu)

I: “*What about regular farm visits?”*

*: *“It is hard working with them, we have taken it to ourselves to service these growers.”*

(Male, extension officer–Felixton)

I: "What key strategies must the government take to improve overall production?"

**: "There is a need to train and support our small-scale growers, we try by all means to assist but government need to also employ more officers and provide implements where possible."*

(Female, extension officer–Felixton)

The understanding of the direct and indirect barriers to technical efficiency experienced by small-scale growers can help to explain low productivity and contribute to programmes aimed at improving and sustaining the farm business. The above themes provided small-scale growers' experience and understanding of complex everyday practices and knowledge of mills, government departments and their colleagues on how these stakeholders can help them to produce optimally. The next part of the chapter discusses the results.

7.4 Discussion and Conclusion

7.4.1 Summary of the findings

The aim of this study was to investigate barriers to technical efficiency faced by small-scale sugarcane growers in Amatikulu and Felixton region. The identified barriers to technical efficiency were grouped into four themes: structural change, environmental challenges, technical constraints and institutional barriers. The results highlighted some important findings as to how small-scale sugarcane growers understand barriers to technical efficiency. It was clear that knowledge and experience were discovered using the four themes. It appears that the experiences and involvement of certain stakeholders do not directly influence technical efficiency. Further, the examination of the results provided the opportunity to discover reasons behind the low yields in small-scale sugarcane production.

7.4.2 Discussion

The results of the study conducted in the form of the focus group with extension officers and individual interviews with small-scale sugarcane growers showed different experiences. *Structural change* provided the nature in which the market and the sugar industry in general operates. There is a wide range of new developments in the market in the form of subsidies from mills, training, capacity development and research on new technologies. *Environmental challenges* were concerned with drought, soil erosion and how growers adapt their production to thrive in this unfortunate time. *Technical constraints* were seen by all participants as a threat to production. Lastly, *institutional barriers* were challenges that emanate from processes, contractors and other institutions that play a role in sugarcane production. The results highlighted some important findings as to how small-scale sugarcane growers understand barriers to technical efficiency. It was clear that knowledge and experience were discovered using the four themes. It appears that the experiences and involvement of certain stakeholders do not directly influence technical efficiency. Further, the examination of the results provided the opportunity to uncover reasons behind the low yields in small-scale sugarcane production.

(i) *Structural change*

What was important in terms of *structural change* and technical efficiency, is that the rate at which the market changes and the fluctuation of the inflation rate affect the overall production. In the analyses, this was evident from the examples of the male and female sugarcane growers who pointed to the fact that market dynamics are hard to keep up with and that it is also very tricky. Providing the small–scale growers with an opportunity to engage stakeholders may help give time and space to air their experience. The existence of extension officers provides the possibility for small–scale growers to acquire market–related knowledge and information that informs good production practices. Therefore, the dedication and commitment of extension officers in sharing new developments and constant motivation to the small-scale sugarcane growers may try to mitigate the challenges emanating from structural changes. The role of political reforms and land reform leading to uncertainty about future land ownership patterns was worrisome to participants - this is after the proposed call to transfer land to a state entity that is going to regulate land ownership as opposed to the *status quo*. In this study, that was the case with examples from an extension officer and a grower who were worried and also the negative experience of idling plots because of land claims (Andrew *et al*., 2003). What was interesting is that most of the growers produce on communal land, but that land reform uncertainty still hangs in their heads, due to the uncertainty over the question of land ownership in the republic.

(ii) *Environmental challenges*

In the quest to promote sustainable production, food security and improved the livelihoods of small-scale growers the threat of global warming is very familiar across the globe. The participants were able to relate the negative effect of drought to their production and yields. It is interesting to note that regardless of the set back the drought season had on their production, small-scale sugarcane growers implemented certain strategies to recover from the drought. Moreover, they followed strategies that were introduced by extension officers. These findings contribute to the body of knowledge on the role played by extension support in production and technical efficiency in agriculture, (see Gebrehiwot, (2017), but this study was quantitative in nature). It is possible that the involvement of extension officers gives small-scale sugarcane growers options for specialised support and advice. This may also help draw away the pressure and stress growers face during unexpected adverse climatic conditions.

(iii) *Technical constraints*

It is interesting to note that there are many *technical constraints* faced by growers in relation to inputs. The participants pointed out difficulties faced because of poor support from extension officers and government departments. It might be that growers did not understand the role they can play in improving the performance of the farm business. It is well documented that extension support contributes to technical efficiency, but one of the participants also stressed that extension officers must provide timeous training. Focus on the ability of the grower to minimise technical constraints were also pointed out by one of the participants who observed that growers' experience is an important factor in reducing technical constraints. This notion was further explained by the involvement of extension officers in promoting good practices, communicating planting schedules and crop management. These findings are in line with the study by Wilson and Hadley (2001) that revealed that growers with more years of managerial experience have higher levels of technical efficiency.

(iv) *Institutional barriers*

Institutional barriers included issues and challenges that are a consequence of public and private structures that influence the choice of producing, processing and marketing channels. These barriers are unique to small-scale sugarcane growers. For example, the slow response of the contractor to fetch sugarcane from the plot affects the quality of sucrose that, in turn, results in low RVP. It is worrying to note that there are many institutional challenges faced by small-scale growers as a result of limited land allocated to each grower. The participants pointed out that there is no government support and that leads to overreliance on other bodies. The poor support of government overlapped with extension support and was noted by the unavailability of extension officers to provide services. This issue has resulted in little confidence of both the private extension officers and the growers in the involvement of government and public extension officers.

7.4.3 Concluding remarks for this chapter

The main objective of this study was to investigate the barriers to technical efficiency that are faced by small-scale sugarcane growers. To meet this objective, focus groups and individual informal interview data were analysed using thematic analysis (TA). The TA provided unique themes explaining the experience and understanding of both small-scale growers and extension officers. There is little research on this issue, which is why TA was chosen to analyse the data. Hopefully, future research will include the understanding and experiences of small-scale sugarcane growers as an integral part of research which is focused on agricultural production efficiency.

The evidence in this study suggests that private extension officers work endlessly to minimise barriers to technical efficiency, while little can be said about public extension officers, who were reported as being inactive in small-scale sugarcane production in this study. Although the failure to provide adequate extension support to growers may seem inevitable from a low public resource, it is also not clear whether the current approach will help sustain the growers and optimise technical efficiency. In the opinion of this researcher, to eliminate barriers and meet the production needs aimed at improving technical efficiency there must be the will and support from all the stakeholders who provide support to the small-scale sugarcane growers. However, the role of growers in maintaining their performance management tools should not be ignored. This notion requires training, development and empowerment with skills, tools and resources aimed at improving the plight of the growers. Of particular importance was the finding that government support for small-scale sugarcane growers is very limited. This is of great relevance when considering the pathway for policies and strategies aimed at benefiting growers.

There were some issues that were raised in both the interviews and focus groups that was outside the scope of this chapter, because of the diverse group and experiences of growers and extension officers. It is important to note that a possible reason for the small-scale sugarcane growers suggesting that the extension officers were unhelpful might have arisen due to the drought conditions which decimated their crops and the extension officers were powerless to avert the losses farmers faced, despite being equipped with the latest technical insights. Overall, the governmental and Tongaat Hulett extension officers were mentioned in parallel with different contributions to the sector using different themes. It will be only by answering the lived experiences and being aware of the barriers that impact technical efficiency, that how external factors identified as barriers will contribute to sugarcane productivity. The unearthing of these barriers will begin to address the problem of low technical efficiency in sugarcane production.

7.4.4 Validity, Reliability and Generalisability

Assessing the quality of research is critical if findings are to inform policy makers and stakeholders for the purpose of transforming practice. The term validity speaks to the integrity and application of the methods undertaken and the efficiency and accuracy of the findings reflecting the data, while reliability describes consistency within the adopted analytical procedures. While generalisability refers to whether the findings in a localised small sample setting can be used to understand similar cases in other contexts (Li *et al.,* 2013). In other words, one addresses the question: can the findings concerning small-scale sugarcane growers in the Northern KwaZulu-Natal region shine light on the issues affecting other small-scale sugarcane growers (perhaps even maize and other produce farmers) in other provinces around the country? If the study was undertaken with the appropriate scientific rigour then the findings ought to be valid in other contexts as well.

Assessing the reliability of study findings requires one to make judgements about the ‘soundness’ or ‘correctness’ of the research in conjunction the application and appropriateness of the methods undertaken and the integrity of the final conclusions.

Frequently, qualitative research is criticised for lacking scientific rigour and is fraught with dubious justification of the methods adopted, absence of transparency in the analytical procedures and that the findings are merely a collection of personal opinions subject to researcher bias. Quantitative studies involve the application of statistical methods for establishing validity and reliability of research findings whereas qualitative researchers aim to design and include methodological strategies to ensure the trustworthiness of the findings (Yilmaz, 2013).

Three strategies were used in this study to ensure trustworthiness. Firstly, data triangulation, where the quantitative method involving the administration of a questionnaire to 10 respondents, was employed and the finding in this context corroborated many of the findings in the qualitative results, as discussed above. Secondly, the findings were presented in Faculty seminars which included other researchers in the field, and interesting debates were raised which helped shape the findings presented above. Thirdly, the reports were shown to 13 extension officers and to 25 available small-scale famers where they were asked to make comments on the themes. They validated the findings as an accurate reflection of the issues that emerged out of group discussions. Chapter eight provides the conclusion and policy recommendations for this thesis.

7.5 Summary of this chapter

This chapter investigated barriers to technical efficiency using the thematic analysis approach. The chapter conducted both interviews and focus groups to source qualitative data that was used in the analysis. The findings revealed that extension support is somehow not enough to help optimise technical efficiency. Moreover, there were no clear knowledge or existence of government extension officers. The focus group conducted with extension officers argued for lack of motivation and other managerial related issues that affects technical efficiency. Chapter eight present the conclusion and policy recommendations for the study.

CHAPTER EIGHT

CONCLUSION AND POLICY RECOMMENDATIONS

8.0 Introduction

This chapter presents the conclusion and policy recommendations drawn from seven objectives that were successfully met in the previous chapters. First, conclusions drawn from the empirical investigations will be discussed, followed by the outline of the limitations of the study and thereafter, stemming from the current study, future research directions will be suggested.

8.1 Conclusions from the studies

This thesis applied a multi-method approach to study how efficient small- scale sugarcane growers were in the King Cetshwayo District Municipality of Kwa-Zulu Natal. The study employed a quantitative approach to assess the agricultural efficiency and efficiency-change by applying the methodology and theory of DEA to evaluate determinants and sources of agricultural efficiencies, productivity and efficiency-change, together with their mean scores. Thereafter the study used the qualitative thematic content approach to identify barriers to technical efficiency of small–scale sugarcane growers through conducting separate focus group interviews involving cane growers and extension workers. This approach, which provided nuanced perspectives based on the lived experiences of the key informants has not been explored extensively in the South African agricultural sector compared to the quantitative techniques that estimate productive efficiency.

The thesis consisted of three research methodological approaches. The first was the input-oriented DEA that was bootstrapped with the Truncated Regression methodology to measure productive efficiency of small-scale sugarcane growers in the King Cetshwayo district and the socio-economic factors that affected technical efficiency. This approach also calculated efficiency estimates from the two regions i.e. Felixton and Amatikulu, and also investigated the determinants of technical, cost and allocative efficiency. Technical, cost and allocative efficiency reported different scores. The socio-economic determinants revealed positive and negative significant relationships to technical, cost and allocative efficiency. The results showed low cost and allocative efficiency predominated compared to technical and scale efficiency. The distribution of technical efficiency scores was very wide, with the majority of the small-scale sugarcane growers averaging 60%. The results also demonstrated a low-cost efficiency that revealed that small-scale sugarcane growers paid higher prices for a given level of output. The low-cost efficiency was accompanied by poor combination of inputs that was indicated by the low allocative efficiency results. This implies that encouraging proper allocation of inputs at the right price would yield desired output derived from optimal cost and allocative efficiency. The study also suggested a higher technical efficiency compared to chemical-use efficiency. This implies that small-scale sugarcane growers do not over-utilise the input chemicals in their production and therefore, growers to increase the application of chemicals inputs to optimise yield. However, regular soil samples must be taken to avoid degradation of the environment.

The determinants of technical efficiency were found to include education, off-farm income, experience, extension support and land size. The technical scores in both regions were almost equal, but exhibited significant difference in cost and allocative efficiency. This implies that growers ought to allocate available resources and adopt innovative technologies at a lower cost. Socio-economic factors such as experience, education, access to credit, and employment status of the small-scale sugarcane grower showed a positive relationship with technical, cost and allocative efficiency. The results imply that public and private initiatives aimed at training, development and subsidising input will create an appropriate environment to produce at low cost. Moreover, the mentioned socio-economic factors also suggest that the small-scale sugarcane grower is competent in the working world with a high-level skill set to manage finances and calculate the lowest cost combination production techniques.

The second quantitative approach, known as the Färe-Primont Index decomposed productivity and efficiency change of small-scale sugarcane growers, given the tough competition in the sugar industry and the dire climatic conditions. In the face of climate change the long-term sustainability of the small-scale grower based on their productivity and efficiency change components are of grave concern. However, drought resistant seedlings, crops risk diversification and water conservation farming techniques may serve to mitigate the concern. Furthermore, the study showed an increased input growth in both input mix and input scale mix efficiency, but input technical efficiency reported a negative input growth. This implies that small-scale sugarcane growers experience poor optimal combination of inputs. The sources of TFP were education, sustainability investment and education of the small-scale grower.

The last approach involved a qualitative TA of focus group interviews with cane-growers and extension workers and semi-structured interviews with small-scale sugarcane growers, respectively. The approach investigated barriers to technical efficiency of small-scale sugarcane growers. The small-scale sugarcane growers identified four barriers to technical efficiency, namely, structural change in market dynamics, environmental challenges, technical constraints and institutional barriers. Market dynamics were noted as being a critical challenge to cane growers for it was difficult to keep up with the complicated changes in the political, business, supply and demand, and global environments, hence they suggested that all stakeholders in the sugar industry create forums to address these issues. The qualitative approach also reported the severe distress small-scale sugarcane growers experienced because of drought, as one of the environmental challenges faced in the optimisation of technical efficiency. The results also indicated technical difficulties because of poor support from extension officers from the public sector. Lastly, the slow response of the contractors responsible for fetching sugarcane from the plots is a serious issue that affected the price of sugarcane and was identified as one of the institutional barriers.

8.2 Policy Recommendations

The thesis recommends the need for policy makers and stakeholders to put in place policies that would improve access to credit, educational training aimed at senior growers, and development since there factors can stimulate agricultural productive efficiency. Policies that would encourage financial and capital support would promote both allocative and cost efficiency. Due to lack of collateral, introducing policy that will enable regional micro-financing of the farm business will improve input allocation.

Agricultural policies aimed at providing land rights to the state and for small-scale growers to lease alone will not be enough to promote productivity and efficiency growth. Therefore, there is a need to direct policies towards agricultural research and development and educational development on key production scales. Policies focused on the adaptation of innovative technologies such as tractors, certified seeds, and chemicals would be helpful in promoting small-scale sugarcane efficiency change. The results also show poor combinations of inputs; therefore, it is important for small-scale sugarcane reforms to aim at promoting training on proper allocation of inputs and resources, especially in the context of climate change.

Further, policy measures should include interventions directed at enhancing extension support, farm level linkage between specialists, stakeholders, consultants and growers to enable sharing of knowledge as derived from the qualitative approach. Promoting government extension officers' involvement will help promote technical efficiency and reduce the burden on private extension officers to better manage the ratio with sugarcane growers. Other policies should include improved stakeholder involvement and regulation of the sugar industry to ease the plight of small-scale sugarcane growers. The reforms aimed at regulating the cheap imports of sugar can strengthen the livelihoods of small-scale growers and aid in promoting long-term efficiency and productivity.

Motivated by the quantitative findings which guided the qualitative analysis, which in turn generated results, the following recommendations aimed at promoting technical efficiency for small-scale sugarcane growers are proposed:

- There is a need for intervention that is directed at enhancing extension support and the understanding of how effectively this function should be used to guide growers.
- There should be a farm level support link between specialists, stakeholders and consultants to foster sharing of knowledge that will be available to the growers.
- There should be programmes aimed at revitalising the small-scale sugarcane growers' ability to manage performance and patterns of land ownership.
- Future research should interview governmental extension officers in the bid to discover their role in improving small-scale sugarcane production.
- Short courses on technical production, managerial, financial, climate change and institutional matters ought to be offered to farmers, perhaps with mills and NGOs working together with government.
- Given the vastness of the farming region, stakeholders ought to establish cost-effective strategies to communicate critical know-how and market dynamics to

small scale growers, for example through a dedicated local radio or television station as well as social media approaches.

- Methods should be devised whereby mills and or government authorities assist with screening and monitoring contractors who should be sanctioned for not fulfilling their contractual obligations to cane-growers.

8.3 Limitations and recommendations for further studies

This thesis came up with both quantitative and qualitative findings that were aimed at contributing to small-scale sugarcane farming efficiency and productivity. The study identified some of the limitations. The study was limited to two sugarcane-producing regions in the northern part of KwaZulu-Natal. The DEA approach focused on productive efficiency and its determinants in the King Cetshwayo district using cross-sectional data collected from 300 respondents by means of a questionnaire. The second part of this approach used a balanced sample of 160 small-scale sugarcane growers to estimate productive efficiency and its determinant in the Felixton and Amatikulu regions. Therefore, the results of this theme cannot be generalised to represent the entire population of small-scale sugarcane growers in the district. Furthermore, the analysis was computed using a form of DEA that can have measurement error because of its inability to handle statistical noise. Therefore, future studies might consider both the SFA and DEA approaches and compare their results.

The Färe-Primont index approach was conducted using farm-level data for the period of 2013–2016 for 38 small-scale growers. This aspect of the study was motivated by decreasing sugarcane output recorded by the extension departments in both mills. The study was constrained due to data limitations that arose due to poor record keeping giving rise to seasonal data uncertainty. The study only managed to compile a sample of 38 growers in the Amatikulu region who kept reasonable records. Future studies are encouraged to seek larger farm level data sets over longer time periods for more robust results to be achieved.

The Thematic Approach was motivated by low technical efficiency mean scores and production challenges, constraints and issues that affected the small-scale growers. This part of the study analysed qualitative data that was sourced using semi-formal interviews with small-scale sugarcane growers who were suggested by extension officers. Therefore, the DEA and TA approaches produced contradictory results concerning the helpfulness of extension workers. Part of the problem was that different approaches were used to analyse data that were gathered differently. The positive results concerning extension workers were achieved due to their having a long working relationship with the farmers concerned and the very same famers comprised the interview. Future studies ought to ensure such biases do not arise.

Future studies might consider including environmental- related variables and regional socio-economic dynamics to compare different estimates from regions and provinces that produce sugarcane. These studies may also investigate input-slack among different categories of growers in the sugar industry.

REFERENCES

Abatania, L. N., Hailu, A., and Mugera, A. W. (2012). Analysis of farm household technical efficiency in northern Ghana using bootstrap DEA. Paper presented at the *56th Annual Conference of the Australian Agricultural and Resource Economics Society, Fremantle, Australia.*

Abatania, L. N. (2013). *Identifying Performance Benchmarks in Ghanaian Agriculture through Efficiency Analysis. PhD thesis. University of Western Australia.*

Abdallah, A. (2016). Agricultural credit and technical efficiency in Ghana: Is there a nexus? *Agricultural Finance Review, 76*(2), 309-324.

Abdulai, A., and Eberlin, R. (2001). Technical efficiency during economic reform in Nicaragua: Evidence from farm household survey data. *Economic Systems, 25*(2), 113-125.

Abdulai, A., and Huffman, W. (2000). Structural adjustment and economic efficiency of rice farmers in northern Ghana. *Economic Development and Cultural Change, 48*(3), 503-520.

Abebe, G. G. (2014). Off-farm income and technical efficiency of smallholder farmers in Ethiopia.

Abedullah, Kouser, A., and Mushtaq,.K. (2007). Analysis of technical efficiency of rice production in Punjab (Pakistan): Implications for future investment strategies. *Pakistan Economic and Social Review*, 45(2), 231-244.

Addai, K. N., and Owusu, V. (2014). Technical efficiency of maize farmers across various Agro ecological zones of Ghana. *Journal of Agriculture and Environmental Sciences, 3*(1), 149-172.

Adelekan, Y. A., and Omotayo, A. O. (2017). Linkage between rural non-farm income and agricultural productivity in Nigeria: A Tobit-two-stage least square regression approach. *The Journal of Developing Areas, 51*(3), 317-333.

Afriat, S. N. (1972). Efficiency estimation of production functions. *International Economic Review,* 13(1), 568-598.

Aigner, D., Lovell, C. K., and Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37.

Akresh, R. (2005). Understanding pareto inefficient intrahousehold allocations.

Alchian, A. A., and Kessel, R. A. (1962). Competition, monopoly and the pursuit of money. *Aspects of Labour Economics, 14, (1)*, 157-183.

Alene, A. D. (2010). Productivity growth and the effects of R&D in African agriculture. *Agricultural Economics, 41*(3-4), 223-238.

Alene, A. D., Manyong, V. M., and Gockowski, J. (2006). The production efficiency of intercropping annual and perennial crops in southern Ethiopia: A comparison of distance functions and production frontiers. *Agricultural Systems, 91*(1), 51-70.

Alene, A. D., and Zeller, M. (2005). Technology adoption and farmer efficiency in multiple crops production in eastern Ethiopia: A comparison of parametric and non-parametric distance functions. *Agricultural Economics Review, 6*(1), 5.

Ali, M., and Flinn, J. C. (1989). Profit efficiency among basmati rice producers in Pakistan Punjab. *American Journal of Agricultural Economics, 71*(2), 303-310.

Allen, R., Athanassopoulos, A., Dyson, R. G., and Thanassoulis, E. (1997). Weights restrictions and value judgements in data envelopment analysis: Evolution, development and future directions. *Annals of Operations Research, 73*, 13-34.

Alston, J. M., Andersen, M. A., James, J. S., and Pardey, P. G. (2009). *Persistence pays: US agricultural productivity growth and the benefits from public R&D spending* Springer Science & Business Media.

Alston, J. M., Norton, G. W., and Pardey, P. G. (1995). *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting.* Cornell University Press.

Aly, H. Y., and Shields, M. P. (2010). Gender and agricultural productivity in a surplus labour, traditional economy: Empirical evidence from Nepal. *The Journal of Developing Areas,43(2)*, 111-124.

Amadhila, E., and Ikhide, S. (2016). Constraints to financing agriculture in Namibia. *African Review of Economics and Finance, 8*(2), 82-112.

Amos, T. T. (2007). An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. *Journal of Social Science, 15*(2), 127-133.

Anderson, B. D. (2018). Factors driving sugar cane production in the kingdom of Eswatini. Masters Dissertation, University of Arkansas.

Andrew, M., Shackleton, C., and Ainslie, A. (2003). Land use and rural livelihoods: Have they been enhanced through land reform?

Aparicio, J., Pastor, J. T., and Zofio, J. L. (2015). How to properly decompose economic efficiency using technical and allocative criteria with non-homothetic DEA technologies. *European Journal of Operational Research, 240*(3), 882-891.

Aravindakshan, S., Rossi, F. J., and Krupnik, T. J. (2015). What does Benchmarking of wheat farmers practicing conservation tillage in the eastern indo-gangetic plains tell us about energy use efficiency? An application of slack-based Data Envelopment Analysis. *Energy, 90(1)*, 483-493.

Asadullah, M. N., and Rahman, S. (2009). Farm productivity and efficiency in rural Bangladesh: The role of education revisited. *Applied Economics, 41*(1), 17-33.

Asfaw, S., Di Battista, F., and Lipper, L. (2016). Agricultural technology adoption under climate change in the Sahel: Micro-evidence from Niger. *Journal of African Economies, 25*(5), 637-669.

Atici, K. B., and Podinovski, V. V. (2015). Using data envelopment analysis for the assessment of technical efficiency of units with different specializations: An application to agriculture. *Omega, 54(1)*, 72-83.

Ayaz, S., and Hussain, Z. (2011). Impact of institutional credit on production efficiency of farming sector: A case study of district Faisalabad. *Pakistan Economic and Social Review, 49(2),* 149-162.

Aye, G. C., and Mungatana, E. D. (2011). Technological innovation and efficiency in the Nigerian maize sector: Parametric stochastic and non-parametric distance function approaches. *Agrekon, 50*(4), 1-24.

Babalola, D., Makinde, Y., Omonona, B., and Oyekanmi, M. (2010). Determinants of post-harvest losses in tomato production: A case study of Imeko-Afon local government area of Ogun state. *Acta Satech, 3*(2), 14-18.

Babatunde, R. O. (2013). On-farm and off-farm works: Complement or substitute? evidence from rural Nigeria. Paper presented at the *4th International Conference of the African Association of Agricultural Economists,* 22-25.

Babbie, E., and Mouton, J. (2001). The practice of social science research. *Belmont, CA: Wadsworth,*

Bäckman, S., Islam, K. Z., and Sumelius, J. (2011). Determinants of technical efficiency of rice farms in north-central and north-western regions in Bangladesh. *The Journal of Developing Areas, 45(1)*, 73-94.

Baloyi, R. T. (2011). *Technical Efficiency in Maize Production by Small-Scale Farmers in Ga-Mothiba, Limpopo Province, South Africa,*

Bamidele, F. S., Babatunde, R., and Rasheed, A. (2008). Productivity analysis of cassava-based production systems in the guinea savannah: Case study of Kwara state, Nigeria. *American-Eurasian Journal of Scientific Research, 3*(1), 33-39.

Banker, R. D., Charnes, A., and Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science, 30*(9), 1078-1092.

Bardhan, P. K. (1973). Size, productivity, and returns to scale: An analysis of farm-level data in Indian agriculture. *Journal of Political Economy, 81*(6), 1370-1386.

Barrett, C. B. (1996). On price risk and the inverse farm size-productivity relationship. *Journal of Development Economics, 51*(2), 193-215.

Barrett, C. B., Carter, M. R., and Timmer, C. P. (2010). A century-long perspective on agricultural development. *American Journal of Agricultural Economics, 92*(2), 447-468.

Bates, R., and Sokhela, P. (2003). The development of small-scale sugarcane growers: A success story. *The Challenge of Change: Agriculture, Land and the South African Economy. University of Natal Press, Pietermaritzburg, South Africa,* 105-118.

Battese, G. E., and Broca, S. S. (1997). Functional forms of stochastic frontier production functions and models for technical inefficiency effects: A comparative study for wheat farmers in Pakistan. *Journal of Productivity Analysis, 8*(4), 395-414.

Battese, G. E., and Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *International applications of productivity and efficiency analysis* (pp. 149-165) Springer.

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

Benicio, J., de Mello, João Carlos Soares, and Meza, L. A. (2015). Efficiency in increasing returns of scale frontier. *Operations research and big data* (pp. 15-22) Springer.

Besley, T. (1994). How do market failures justify interventions in rural credit markets? *The World Bank Research Observer, 9*(1), 27-47.

Beyene, A. D. (2008). Determinants of off-farm participation decision of farm households in Ethiopia. *Agrekon, 47*(1), 140-161.

Bhalla, S. (1977). Changes in acreage and tenure structure of land holdings in Haryana, 1962-72. *Economic and Political Weekly, Review of Agriculture*, A2-A15.

Bhattacharya, N., and Saini, G. (1972). Farm size and productivity: A fresh look. *Economic and Political Weekly, Review of Agriculture*, A63-A72.

Binswanger, H. P., and Deininger, K. (1993). South African land policy: The legacy of history and current options. *World Development, 21*(9), 1451-1475.

Birkhaeuser, D., Evenson, R. E., and Feder, G. (1991). The economic impact of agricultural extension: A review. *Economic Development and Cultural Change, 39*(3), 607-650.

Bjurek, H. (1996). The Malmquist total factor productivity index. *The Scandinavian Journal of Economics,98(2)*, 303-313.

Bojnec, S., and Swinnen, J. F. (1997). Agricultural privatisation and farm restructuring in Slovenia.

Bojnec, Š., and Fertő, I. (2013). Farm income sources, farm size and farm technical efficiency in Slovenia. *Post-Communist Economies, 25*(3), 343-356.

Bojnec, Š, and Latruffe, L. (2013). Farm size, agricultural subsidies and farm performance in Slovenia. *Land Use Policy, 32*(1), 207-217.

Boyle, G. (1987). *How technically efficient is Irish agriculture? Methods of measurement* Department of Agricultural Economics, Rural Economy Research Centre, An Foras Taluntais.

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Bravo-Ureta, B. E., and Pinheiro, A. E. (1997). Technical, economic, and allocative efficiency in peasant farming: Evidence from the Dominican Republic. *The Developing Economies, 35*(1), 48-67.

Briec, W., and Kerstens, K. (2011). The Hicks–Moorsteen productivity index satisfies the determinateness axiom. *The Manchester School, 79*(4), 765-775.

Brigatte, H., and Teixeira, E. (2010). Determinants of product and of total factor productivity in Brazilian agriculture. *Revista De Politica Agricola, 19*(2), 5-13.

Bunnin, F. O., Guo, Y., and Ren, Y. (2002). Option pricing under model and parameter uncertainty using predictive densities. *Statistics and Computing, 12*(1), 37-44.

Bureau, J., Färe, R., and Grosskopf, S. (1995). A comparison of three nonparametric measures of productivity growth in European and united states agriculture. *Journal of Agricultural Economics, 46*(3), 309-326.

Carter, M. R. (1984). Identification of the inverse relationship between farm size and productivity: An empirical analysis of peasant agricultural production. *Oxford Economic Papers, 36*(1), 131-145.

Caves, D. W., Christensen, L. R., and Diewert, W. E. (1982). Multilateral comparisons of output, input, and productivity using superlative index numbers. *The Economic Journal, 92*(365), 73-86.

Chaitip, P., Chaiboonsri, C., and Inluang, F. (2014). The production of Thailand's sugarcane: Using panel data envelopment analysis (panel DEA) based decision on bootstrapping method. *Procedia Economics and Finance, 14(1)*, 120-127.

Chang, H., and Mishra, A. (2008). Impact of off-farm labor supply on food expenditures of the farm household. *Food Policy, 33*(6), 657-664.

Chang, H., and Wen, F. (2011). Off-farm work, technical efficiency, and rice production risk in Taiwan. *Agricultural Economics, 42*(2), 269-278.

Chapman, A., Hadfield, M., and Chapman, C. (2015). Qualitative research in healthcare: An introduction to grounded theory using thematic analysis. *Journal of the Royal College of Physicians of Edinburgh, 45*(3), 201-205.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* Sage.

Charnes, A. C. (1961). *Management Models and Industrial Applications of Linear Programming,* Charnes, A., and Cooper, W. (1961). Multicopy traffic network models. *Theory of Traffic Flow, 85*, 85-96.

Charnes, A., Cooper, W. W., Lewin, A. Y., and Seiford, L. M. (1994). Extensions to DEA models. *Data envelopment analysis: Theory, methodology, and applications* (pp. 49-61) Springer.

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research, 2*(6), 429-444.

Charnes, A., Cooper, W. W., and Rhodes, E. (1981). Evaluating program and managerial efficiency: An application of data envelopment analysis to program follow through. *Management Science, 27*(6), 668-697.

Chaudhry, A. A. (2009). Total factor productivity growth in pakistan: An analysis of the agricultural and manufacturing sectors. *The Lahore Journal of Economics, 14(1)*, 1-16.

Chauke, P., and Anim, F. (2013). Predicting access to credit by smallholder irrigation farmers: A logistic regression approach. *Journal of Human Ecology, 42*(3), 195-202.

Chemak, F., Boussemart, J., and Jacquet, F. (2010). Farming system performance and water use efficiency in the Tunisian semi-arid region: Data envelopment analysis approach. *International Transactions in Operational Research, 17*(3), 381-396.

Christie, C., Todd, A., Hutchings, J., Langton, M., and Elliott, A. (2008). Energy requirements and perceived body discomfort of the various sub tasks of manual sugar cane harvesting: A pilot study. *Ergonomics SA: Journal of the Ergonomics Society of South Africa, 20*(2), 26-33.

Cockburn, J., Coetzee, H., Van den Berg, J., Conlong, D., and Witthöft, J. (2014). Exploring the role of sugarcane in small-scale farmers' livelihoods in the Noodsberg area, Kwazulu-Natal, South Africa. *South African Journal of Agricultural Extension, 42*(1), 80–97.

Coelli, T. J., and Rao, D. P. (2005). Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980–2000. *Agricultural Economics, 32(1)*, 115-134.

Coelli, T., Rahman, S., and Thirtle, C. (2002). Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: A non-parametric approach. *Journal of Agricultural Economics, 53*(3), 607-626.

Coelli, T., Rahman, S., and Thirtle, C. (2003). A stochastic frontier approach to total factor productivity measurement in Bangladesh crop agriculture, 1961–92. *Journal of International Development: The Journal of the Development Studies Association, 15*(3), 321-333.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., and Battese, G. E. (2005). *An introduction to efficiency and productivity analysis* Springer Science & Business Media.

Colombi, R., Kumbhakar, S. C., Martini, G., and Vittadini, G. (2014). Closed-skew normality in stochastic frontiers with individual effects and long/short-run efficiency. *Journal of Productivity Analysis, 42*(2), 123-136.

Conradie, B., Piesse, J., and Thirtle, C. (2009). District-level total factor productivity in agriculture: Western Cape Province, South Africa, 1952–2002. *Agricultural Economics, 40*(3), 265-280.

Cooper, W. W., Seiford, L. M., and Zhu, J. (2000). A unified additive model approach for evaluating inefficiency and congestion with associated measures in DEA. *Socio-Economic Planning Sciences, 34*(1), 1-25.

Cooper, W. W., Seiford, L. M., and Zhu, J. (2011). Data envelopment analysis: History, models, and interpretations. *Handbook on data envelopment analysis* (pp. 1-39) Springer.

Corbin, J. M., and Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology, 13*(1), 3-21.

Daraio, C., and Simar, L. (2007). The measurement of efficiency. *Advanced Robust* and Nonparametric Methods in Efficiency Analysis: Methodology and Applications. *Springer-Verlag New York Inc*, New York. USA.13-42.

Davidova, S., and Latruffe, L. (2007). Relationships between technical efficiency and financial management for Czech Republic farms. *Journal of Agricultural Economics, 58*(2), 269-288.

Dawson, P., and Lingard, J. (1989). Measuring farm efficiency over time on Philippine rice farms. *Journal of Agricultural Economics, 40*(2), 168-177.

Deb, U. K. (1995). Human capital and agricultural growth in Bangladesh. *Unpublished PhD Dissertation. University of the Philippines at Los Banos.*

Debreu, G. (1951). The coefficient of resource utilization. *Econometrica: Journal of the Econometric Society, 19(3)*, 273-292.

Department of Agriculture, Forestry and Fisheries. 2011. Trends in the Agricultural Sector. 2011. Pretoria. South Africa. Available online: https://www.nda.agric.za/docs/statsinfo/trends2011.pdf (Accessed on 02 November 2017)

Di Falco, S., and Veronesi, M. (2013). How can African agriculture adapt to climate change? A counterfactual analysis from Ethiopia. *Land Economics, 89*(4), 743-766.

Di Falco, S., Veronesi, M., and Yesuf, M. (2011). Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics, 93*(3), 829-846.

Diao, X., Headey, D., and Johnson, M. (2008). Toward a green revolution in Africa: What would it achieve, and what would it require? *Agricultural Economics, 39*, 539-550.

Dlamini, M. (2005). Experience with drip irrigation on smallholder sugarcane irrigation schemes in Swaziland. *Proceedings of South African Sugar Technology Association, 79*, 463-472.

Dlamini, S., Rugambisa, J., Masuku, M., & Belete, A. (2010). Technical efficiency of the small-scale sugarcane farmers in Swaziland: A case study of Vuvulane and Big bend farmers. *African Journal of Agricultural Research, 5*(9), 935-940.

Dobrowsky, D. W. (2013). *Technical and Allocative Efficiency in Determining Organizational Forms in Agriculture: A Case Study of Corporate Farming,*

Donkoh, S. A., Ayambila, S., and Abdulai, S. (2013). Technical efficiency of rice production at the Tono irrigation scheme in northern Ghana. *American Journal of Experimental Agriculture, 3*(1), 25.

Dubb, A. (2015). Dynamics of decline in small-scale sugarcane production in South Africa: Evidence from two 'rural'wards in the Umfolozi region. *Land use Policy, 48*, 362-376.

Duy, V. Q. (2012). The role of access to credit in rice production efficiency of rural households in the Mekong delta Vietnam. *Center for Asian Studies Discussion Paper,* (284)

Duy, V. Q., Neuberger, D., and Suwanaporn, C. (2012). Access to credit and rice production efficiency of rural households in the Mekong delta. *Journal of Accounting and Business Research, 3*(1), 33-48.

Duy, V. Q., Neuberger, D., and Suwanaporn, C. (2015). Access to credit and rice production efficiency of rural households in the Mekong delta. *Sociology and Anthropology, 3*(9), 425-433.

Etim, N. (2015). Adoption of inorganic fertilizer by urban crop farmers in Akwa Ibom state, Nigeria. American Journal of Experimental Agriculture, 5(5):466-474

Ezzy, D. (2002). Coding data and interpreting text: Methods of analysis. *Qualitative Analysis: Practice and Innovation.* Sydney: Allen and Unwin, 80-112.

Fafchamps, M., and Minten, B. (2002). Social capital and the firm: Evidence Irom agricultural traders in Madagascar. *The Role of Social Capital in Development: An Empirical Assessment,* 125.

Fare, R., Färe, R., Fèare, R., Grosskopf, S., and Lovell, C. K. (1994). *Production frontiers* Cambridge university press.

Färe, R., and Grosskopf, S. (1985). A nonparametric cost approach to scale efficiency. *The Scandinavian Journal of Economics, 87(4)*, 594-604.

Färe, R., Grosskopf, S., and Roos, P. (1996). On two definitions of productivity. *Economics Letters, 53*(3), 269-274.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society.Series A (General), 120*(3), 253-290.

Feng, S. (2008). Land rental, off-farm employment and technical efficiency of farm households in Jiangxi province, china. *NJAS-Wageningen Journal of Life Sciences, 55*(4), 363-378.

Fennell, K. M., Jarrett, C. E., Kettler, L. J., Dollman, J., and Turnbull, D. A. (2016). “Watching the bank balance build up then blow away and the rain clouds do the same”: A thematic analysis of South Australian farmers’ sources of stress during drought. *Journal of Rural Studies, 46*, 102-110.

Fernandez, C., Ley, E., and Steel, M. F. (2001). Model uncertainty in cross-country growth regressions. *Journal of Applied Econometrics, 16*(5), 563-576.

Fernandez-Cornejo, J., Mishra, A. K., Nehring, R. F., Hendricks, C., Southern, M., and Gregory, A. (2007). *Off-Farm Income, Technology Adoption, and Farm Economic Performance,*

Ferrier, G. D., and Hirschberg, J. G. (1997). Bootstrapping confidence intervals for linear programming efficiency scores: With an illustration using Italian banking data. *Journal of Productivity Analysis, 8*(1), 19-33.

Flick, U. (2004). Triangulation in qualitative research. *A Companion to Qualitative Research, 3*, 178-183.

Førsund, F. R., and Sarafoglou, N. (2002). On the origins of data envelopment analysis. *Journal of Productivity Analysis, 17*(1-2), 23-40.

Fraser, C., Smith, K. B., Judd, F., Humphreys, J. S., Fragar, L., and Henderson, A. (2005). Farming and mental health problems and mental illness. *International Journal of Social Psychiatry, 51*(4), 340-349.

Fried, H. O., Lovell, C. K., Schmidt, S. S., and Schmidt, S. S. (2008). *The measurement of productive efficiency and productivity growth* Oxford University Press.

Fuglie, K. O. (2008). Is a slowdown in agricultural productivity growth contributing to the rise in commodity prices? *Agricultural Economics, 39*, 431-441.

Fuglie, K., and Rada, N. (2013). *Research Raises Agricultural Productivity in Sub-Saharan Africa.*

Fuglie, K., and Rada, N. (2013). Resources, policies, and agricultural productivity in Sub-Saharan Africa. USDA, Economic Research Service, February 2013.

Gebrehiwot, K. G. (2017). The impact of agricultural extension on farmers' technical efficiencies in Ethiopia: A stochastic production frontier approach. *South African Journal of Economic and Management Sciences, 20*(1), 1-8.

Gelan, A., and Muriithi, B. W. (2012). Measuring and explaining technical efficiency of dairy farms: A case study of smallholder farms in East Africa. *Agrekon, 51*(2), 53-74.

Glaser, B. G. (1998). *Doing grounded theory: Issues and discussions* Sociology Press.

Glaser, B. G. (1999). The future of grounded theory. *Qualitative Health Research, 9*(6), 836-845.

Glaser, B. G., and Strauss, A. L. (1967). The discovery of grounded theory: Strategies for qualitative research. *Chicago: Aldire.*

Goldstein, M., and Udry, C. (2008). The profits of power: Land rights and agricultural investment in Ghana. *Journal of Political Economy, 116*(6), 981-1022.

Good, D. H., Nadiri, M. I., and Sickles, R. C. (1996). *Index Number and Factor Demand Approaches to the Estimation of Productivity,*

Goodwin, B. K., and Mishra, A. K. (2004). Farming efficiency and the determinants of multiple job holding by farm operators. *American Journal of Agricultural Economics, 86*(3), 722-729.

Graham, A. W., and Lyne, M. C. (1999). Land redistribution in KwaZulu-Natal: An analysis of farmland transactions in 1997. *Development Southern Africa, 16*(3), 435-445.

Hadley, D., Fleming, E., and Villano, R. (2013). Is input mix inefficiency neglected in agriculture? A case study of pig-based farming systems in England and Wales. *Journal of Agricultural Economics, 64*(2), 505-515.

Hadley, D., Shankar, B., Thirtle, C., and Coelli, T. (2001). Financial exposure and farm efficiency: Evidence from the England and Wales dairy sector. Paper presented at the *Annual Meetings of the American Agricultural Association, Chicago.*

Haji, J. (2007). Production efficiency of smallholders' vegetable-dominated mixed farming system in eastern Ethiopia: A non-parametric approach. *Journal of African Economies, 16*(1), 1-27.

Haji, J., and Andersson, H. (2006). Determinants of efficiency of vegetable production in smallholder farms: The case of Ethiopia. *Acta Agriculturae Scandinavica Section C, 3*(3-4), 125-137.

Harold O., Fried, Lovell, C. K., and Schmidt, S.S. (1993). *The measurement of productive efficiency: Techniques and applications* Oxford University Press.

Hasnah, F. E., and Coelli, T. (2004). Assessing the performance of a nucleus estate and smallholder scheme for oil palm production in west Sumatra: A stochastic frontier analysis. *Agricultural Systems, 79*(1), 17-30.

Hazarika, G., and Alwang, J. (2003). Access to credit, plot size and cost inefficiency among smallholder tobacco cultivators in Malawi. *Agricultural Economics, 29*(1), 99-109.

Headey, D., Alauddin, M., and Rao, D. P. (2010). Explaining agricultural productivity growth: An international perspective. *Agricultural Economics, 41*(1), 1-14.

Helfand, S. M., and Levine, E. S. (2004). Farm size and the determinants of productive efficiency in the Brazilian Center-West. *Agricultural Economics, 31*(2-3), 241-249.

Henderson, H. (2015). Considering technical and allocative efficiency in the inverse farm size–productivity relationship. *Journal of Agricultural Economics, 66*(2), 442-469.

Heriqbaldi, U., Purwono, R., Haryanto, T., and Primanthi, M. R. (2015). An analysis of technical efficiency of rice production in Indonesia. *Asian Social Science, 11*(3), 91.

Herrero, I. (2005). Different approaches to efficiency analysis. an application to the Spanish trawl fleet operating in Moroccan waters. *European Journal of Operational Research, 167*(1), 257-271.

Hicks, J. R. (1935). Annual survey of economic theory: The theory of monopoly. *Econometrica: Journal of the Econometric Society,3(1)*, 1-20.

Higgins, A. J., and Muchow, R. C. (2003). Assessing the potential benefits of alternative cane supply arrangements in the Australian sugar industry. *Agricultural Systems, 76*(2), 623-638.

Higgins, A., Antony, G., Sandell, G., Davies, I., Prestwidge, D., and Andrew, B. (2004). A framework for integrating a complex harvesting and transport system for sugar production. *Agricultural Systems, 82*(2), 99-115.

Higgins, A., Thorburn, P., Archer, A., and Jakku, E. (2007). Opportunities for value chain research in sugar industries. *Agricultural Systems, 94*(3), 611-621.

Hoang Linh, V. (2012). Efficiency of rice farming households in Vietnam. *International Journal of Development Issues, 11*(1), 60-73.

Huffman, W. E. (1980). Farm and off-farm work decisions: The role of human capital. *The Review of Economics and Statistics, 62(1)*, 14-23.

Iheke, O. R., Nwaru, J. C., and Onyenweaku, C. (2013). The impact of migrant remittances on the technical efficiency of arable crop farm households in south eastern Nigeria. Paper presented at the *Invited Paper Presented at the 4th International Conference of the African Association of Agricultural Economists,*

Iliyasu, A., and Mohamed, Z. A. (2016). Evaluating contextual factors affecting the technical efficiency of freshwater pond culture systems in peninsular Malaysia: A two-stage DEA approach. *Aquaculture Reports, 3*, 12-17.

Islam, K., Bäckman, S., and Sumelius, J. (2011). Technical, economic and allocative efficiency of microfinance borrowers and non-borrowers. *European Journal of Social Sciences,*

Jha, R., Chitkara, P., and Gupta, S. (2000). Productivity, technical and allocative efficiency and farm size in wheat farming in India: A DEA approach. *Applied Economics Letters, 7*(1), 1-5.

Jiang, N., and Sharp, B. (2014). Cost efficiency of dairy farming in New Zealand: A stochastic frontier analysis. *Agricultural and Resource Economics Review, 43*(3), 406-418.

Jin, S., Ma, H., Huang, J., Hu, R., and Rozelle, S. (2010). Productivity, efficiency and technical change: Measuring the performance of China's transforming agriculture. *Journal of Productivity Analysis, 33*(3), 191-207.

Jolliffe, D. (2004). The impact of education in rural Ghana: Examining household labour allocation and returns on and off the farm. *Journal of Development Economics, 73*(1), 287-314.

Jorgenson, D. W., and Griliches, Z. (1967). The explanation of productivity change. *The Review of Economic Studies, 34*(3), 249-283.

Juma, C. (2016). *Innovation and its enemies: Why people resist new technologies* Oxford University Press.

Kannan, E. (2011). *Total factor productivity growth and its determinants in Karnataka agriculture.* Institute for Social and Economic Change Bangalore. Working Paper 265.

Kassie, M., & Holden, S. (2007). Sharecropping efficiency in Ethiopia: Threats of eviction and kinship. *Agricultural Economics, 37*(2-3), 179-188.

Kellehear, A. (1993). *The unobtrusive researcher: A guide to methods* Allen & Unwin.

Kelly, E., Shalloo, L., Geary, U., Kinsella, A., Thorne, F., and Wallace, M. (2012). The associations of management and demographic factors with technical, allocative and economic efficiency of Irish dairy farms. *The Journal of Agricultural Science, 150*(6), 738-754.

Kelly, E., Shalloo, L., Geary, U., Kinsella, A., Thorne, F., and Wallace, M. (2013). An analysis of the factors associated with technical and scale efficiency of Irish dairy farms. *International Journal of Agricultural Management, 2*(3), 149-159.

Kerstens, K., and Van de Woestyne, I. (2014). Comparing Malmquist and Hicks–Moorsteen productivity indices: Exploring the impact of unbalanced vs. balanced panel data. *European Journal of Operational Research, 233*(3), 749-758.

Khan, F., Salim, R., and Bloch, H. (2015). Nonparametric estimates of productivity and efficiency change in Australian Broadacre Agriculture. *Australian Journal of Agricultural and Resource Economics, 59*(3), 393-411.

Khan, S.A., Mohd, N., Baten, M. A., Nawawi, M. K. M., and Murat, Rusdi I.B. (2016). Determining technical, allocative and cost efficiencies of rice farmers in Kedah, Malaysia using data envelopment analysis. Paper presented at the *AIP Conference Proceedings, , 1782*(1) 040008.

Khan, Z. R., Midega, C. A., Pittchar, J. O., Murage, A. W., Birkett, M. A., Bruce, T. J., and Pickett, J. A. (2014). Achieving food security for one million Sub-Saharan African poor through push-pull innovation by 2020. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 369*(1639), 20120284. doi:10.1098/rstb.2012.0284 [doi]

Kilic, T., Carletto, C., Miluka, J., and Savastano, S. (2009). Rural nonfarm income and its impact on agriculture: Evidence from Albania. *Agricultural Economics, 40*(2), 139-160.

Kinkingninhoun-Mêdagbé, F. M., Diagne, A., Simtowe, F., Agboh-Noameshie, A. R., and Adégbola, P. Y. (2010). Gender discrimination and its impact on income, productivity, and technical efficiency: Evidence from Benin. *Agriculture and Human Values, 27*(1), 57-69.

Kirsten, J., and Vink, N. (2003). Policy module South Africa. Paper presented at the *Presented Under the Roles of Agriculture Project in International Conference on the,* 20-22.

Koirala, K. H., Mishra, A. K., and Mohanty, S. (2013). (2013). Determinants of rice productivity and technical efficiency in the Philippines. Paper presented at the *Southern Agricultural Economics Association (SAEA) Annual Meeting,* 1-16.

Komicha, H. H., and Öhlmer, B. (2007). Influence of credit constraint on technical efficiency of farm households in South Eastern Ethiopia.

Koopmans, T. C. (1951). *Activity analysis of production and allocation* Wiley New York.

Kumbhakar, S. C., Lien, G., and Hardaker, J. B. (2014). Technical efficiency in competing panel data models: A study of Norwegian grain farming. *Journal of Productivity Analysis, 41*(2), 321-337.

Kwon, C., Orazem, P. F., and Otto, D. M. (2006). Off-farm labor supply responses to permanent and transitory farm income. *Agricultural Economics, 34*(1), 59-67.

Kwon, T., Yang, J., Song, J., and Chung, W. (2006). Efficiency improvement in Monte Carlo localization through topological information. Paper presented at the *2006 IEEE/RSJ International Conference on Intelligent Robots and Systems,* 424-429.

Laha, A. (2013). Technical efficiency in agricultural production and access to credit in west Bengal, India: A stochastic frontier approach. *International Journal of Food and Agricultural Economics, 1*(2), 53-64.

Laha, A., and Kuri, P. K. (2011). Measurement of allocative efficiency in agriculture and its determinants: Evidence from rural west Bengal, India. *International Journal of Agricultural Research, 6*(5), 377-388.

Lambert, D. K., and Bayda, V. V. (2005). The impacts of farm financial structure on production efficiency. *Journal of Agricultural and Applied Economics, 37*(1), 277-289.

Latruffe, L., and Desjeux, Y. (2016). Common agricultural policy support, technical efficiency and productivity change in French agriculture. *Review of Agricultural, Food and Environmental Studies, 97(1)*, 1-14.

Le Gal, P., Lyne, P. W., Meyer, E., and Soler, L. (2008). Impact of sugarcane supply scheduling on mill sugar production: A South African case study. *Agricultural Systems, 96*(1-3), 64-74.

Lefophane, M., Belete, A., and Jacobs, I. (2013). Technical efficiency in input use by credit and non-credit user emerging farmers in Maruleng municipality of Limpopo province, South Africa. *African Journal of Agricultural Research, 8*(17), 1719-1724.

Lejars, C., Auzoux, S., Siegmund, B., and Letourmy, P. (2010). Implementing sugarcane quality-based payment systems using a decision support system. *Computers and Electronics in Agriculture, 70*(1), 225-233.

Leontief, W. (1953). *Studies in the structure of the American economy* Oxford University Press New York.

Leontief, W. W. (1941). *The structure of American economy, 1919-1929. an empirical application of equilibrium analysis.* Harvard University Press.

Leontief, W. W. (1951). *Input-output economics* JSTOR.

Levin, J., and Milgrom, P. (2004). Introduction to choose theory. *Available from Internet: Http://web.Stanford.Edu/~ jdlevin/Econ, 20202*

Li, B., Sun, X., Leung, H., and Zhang, S. (2013). A survey of code-based change impact analysis techniques. *Software Testing, Verification and Reliability, 23*(8), 613-646.

Li, M., and Sicular, T. (2013). Aging of the labour force and technical efficiency in crop production: Evidence from Liaoning province, China. *China Agricultural Economic Review, 5*(3), 342-359.

Liebenberg, F., and Pardey, P. G. (2010). South African agricultural production and productivity patterns. *The Shifting Patterns of Agricultural Production and Productivity Worldwide,* 383-408. Iowa State University, Chapter 13, The Midwest Agribusiness Trade Research and Information Center (MATRIC).

Llewelyn, R. V., and Williams, J. R. (1996). Nonparametric analysis of technical, pure technical, and scale efficiencies for food crop production in East Java, Indonesia. *Agricultural Economics, 15*(2), 113-126.

López-Feldman, A., Pfeiffer, L., and Taylor, J. (2007). Is off-farm income reforming the farm? evidence from Mexico. *Agricultural Economics, 40*(2), 125-138.

Lovell, C. K., and Pastor, J. T. (1995). Units invariant and translation invariant DEA models. *Operations Research Letters, 18*(3), 147-151.

Lovo, S. (2010). Liquidity constraints and farm household technical efficiency. Evidence from South Africa. *Department of Economics, University of Sussex, UK.*

Lu, J. L. (2010). Gender analysis of women in the Philippine agriculture and their occupational issues. *Journal of International Women's Studies, 11*(4), 73-82.

Lubis, R., Daryanto, A., Tambunan, M., and Purwati, H. (2014). Technical, allocative and economic efficiency of Pineapple production in West Java Province, Indonesia: A DEA approach. *IOSR Journal of Agriculture and Veterinary Science, 7*(6), 18-23.

Luh, Y., Chang, C., and Huang, F. (2008). Efficiency change and productivity growth in agriculture: A comparative analysis for selected East Asian economies. *Journal of Asian Economics, 19*(4), 312-324.

Machethe, C. L. (2004). Agriculture and poverty in South Africa: Can agriculture reduce poverty. Paper presented at the *Paper Presented at the Overcoming Underdevelopment Conference Held in Pretoria, 28*-29. Pretoria, South Africa.

Madigan, D., and Raftery, A. E. (1994). Model selection and accounting for model uncertainty in graphical models using Occam's window. *Journal of the American Statistical Association, 89*(428), 1535-1546.

Maguire, M., and Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education, 9*(3)

Mahjoor, A. A. (2013). Technical, allocative and economic efficiencies of broiler farms in Fars province, Iran: A data envelopment analysis (DEA) approach. *World Applied Sciences Journal, 21*(10), 1427-1435.

Majiwa, E. B. O. (2017). *Productivity and Efficiency of the Agricultural Sector: Africa with a Special Focus on Rice Farming and Processing in Kenya. PhD Thesis, Queensland University of Technology.*

Majiwa, E. B. O., Lee, B., and Wilson, C. (2015). Multi-lateral multi-output measurement of productivity: The case of African agriculture. Paper presented at the *2015 Conference, August 9-14, 2015, Milan, Italy,* (212769)

Makhura, M. T. (2001). *Overcoming Transaction Costs Barriers to Market Participation of Smallholder Farmers in the Northern Province of South Africa,*

Malmquist, S. (1953). Index numbers and indifference surfaces. *Trabajos De Estadística, 4*(2), 209-242.

Maloa, M. B. (2001). Sugarcane: A case as development crop in South Africa. Paper presented at the *South African Regional Poverty Network (SARPN) Conference on Land Reform and Poverty Alleviation in Southern Africa,* 4-5.

Mandal, S. K., and Madheswaran, S. (2012). Productivity growth in Indian cement industry: A panel estimation of stochastic production frontier. *The Journal of Developing Areas,46(1)*, 287-303.

Mango, N., Makate, C., Hanyani-Mlambo, B., Siziba, S., and Lundy, M. (2015). A stochastic frontier analysis of technical efficiency in smallholder maize production in zimbabwe: The post-fast-track land reform outlook. *Cogent Economics & Finance, 3*(1), 1117189.

Mao, W., and Koo, W. W. (1997). Productivity growth, technological progress, and efficiency change in Chinese agriculture after rural economic reforms: A DEA approach. *China Economic Review, 8*(2), 157-174.

Martey, E., Wiredu, A. N., and Etwire, P. M. (2015). Impact of credit on technical efficiency of maize producing households in northern Ghana. Paper presented at the *Selected Paper Presented at the Centre for the Study of African Economies (CSAE) Conference,* 22-24.

Masterson, T. (2007). Productivity, technical efficiency, and farm size in Paraguayan agriculture. The Levy Economics Institute of Bard College, Annandale-on-Hudson, New York.

Masuku, M. B., Raufu, M., and Malinga, N. G. (2014). The impact of credit on technical efficiency among vegetable farmers in Swaziland. *Sustainable Agriculture Research, 4*(1), 114.

Matshe, I., and Young, T. (2004). Off-farm labour allocation decisions in small-scale rural households in Zimbabwe. *Agricultural Economics, 30*(3), 175-186.

Mbatha, N., and Antrobus, G. (2012). A cooperative benefits framework in South Africa's land redistribution process: The case of sugarcane farmland transfers. *Agrekon, 51*(4), 81-104.

Mbowa, S., and Nieuwoudt, L. W. (1998). Economies of size in sugar cane production in KwaZulu-Natal. *Development Southern Africa, 15*(3), 399-412.

McDonald, J. (2009). Using least squares and Tobit in second stage DEA efficiency analyses. *European Journal of Operational Research, 197*(2), 792-798.

Mdemu, M. V., Mziray, N., Bjornlund, H., and Kashaigili, J. J. (2017). Barriers to and opportunities for improving productivity and profitability of the Kiwere and Magozi irrigation schemes in Tanzania. *International Journal of Water Resources Development, 33*(5), 725-739.

Minviel, J. J., and Latruffe, L. (2014). Meta-regression analysis of the impact of agricultural subsidies on farm technical efficiency. Paper presented at the *Presentation at the EAAE 2014 Congress 'Agri-Food and Rural Innovations for Healthier Societies', August, 26-*29. Ljublijana, Slovenia, p 12.

Mishra, A. K., Mottaleb, K. A., Khanal, A. R., and Mohanty, S. (2015). Abiotic stress and its impact on production efficiency: The case of rice farming in Bangladesh. *Agriculture, Ecosystems & Environment, 199*, 146-153.

Mishra, K., Gallenstein, R., Miranda, M. J., and Sam, A. G. (2017). *Gender and Willingness to Pay for Insured Loans: Empirical Evidence from Ghana,*

Mkhabela, T. (2005). Technical efficiency in a vegetable based mixed-cropping sector in Tugela ferry, Msinga district, KwaZulu-Natal. *Agrekon, 44*(2), 187-204.

Mochebelele, M. T., and Winter-Nelson, A. (2000). Migrant labour and farm technical efficiency in Lesotho. *World Development, 28*(1), 143-153.

Mohamed, A. A., Rangkakulnuwat, P., and Paweenawat, S. W. (2016). Decomposition of agricultural productivity growth in Africa. *African Journal of Economic and Management Studies, 7*(4), 497-509.

Mokgalabone, M. (2015). Analyzing the Technical and Allocative Efficiency of Small-Scale Maize Farmers in Tzaneen Municipality of Mopani District: A Cobb-Douglas and Logistic Regression Approach, Masters Dissertation, University of Limpopo, South Africa.

Mote, N. N. (2015). Role of Small-Scale Sugarcane Farmers in Local Economic Development of the Darnall (KwaDukuza) Region, Masters Dissertation, University of KwaZulu-Natal. South Africa.

Msangi, H. A. (2017). Examining the Inverse Relationship between Farm Size and Efficiency in Tanzanian Agriculture, Masters Dissertation, Sokoine University of Agriculture. Tanzania.

Mugera, A. W., and Nyambane, G. G. (2015). Impact of debt structure on production efficiency and financial performance of broadacre farms in Western Australia. *Australian Journal of Agricultural and Resource Economics, 59*(2), 208-224.

Mullen, J. (2007). Productivity growth and the returns from public investment in R&D in Australian broadacre agriculture. *Australian Journal of Agricultural and Resource Economics, 51*(4), 359-384.

Murali, P., and Prathap, D. P. (2017). Technical efficiency of sugarcane farms: An econometric analysis. *Sugar Tech, 19*(2), 109-116.

Nadiri, M. I. (1970). Some approaches to the theory and measurement of total factor productivity: A survey. *Journal of Economic Literature, 8*(4), 1137-1177.

National Department of Agriculture, Forestry and Fisheries. Abstract of Agricultural Statistics. (2012). Pretoria. South Africa. Available online: https://www.nda.agric.za/docs/statsinfo/abstract_2012.pdf (Accessed: 22 November 2017)

National Planning Commission. (2011). Our future – make it work . National Development Plan 2030. Pretoria. South Africa.

Ndlovu, P. V., Mazvimavi, K., An, H., and Murendo, C. (2014). Productivity and efficiency analysis of Maize under conservation agriculture in Zimbabwe. *Agricultural Systems, 124*, 21-31.

Nin, A., Arndt, C., and Preckel, P. V. (2003). Is agricultural productivity in developing countries really shrinking? new evidence using a modified nonparametric approach. *Journal of Development Economics, 71*(2), 395-415.

Nkamleu, G. B. (2004). Productivity growth, technical progress and efficiency change in African agriculture. *African Development Review, 16*(1), 203-222.

Nkwinti, G. (2012). Speech by the minister of rural development and land reform, 2012 policy speech. *Pretoria: South Africa,*

Ntshangase, W., Ngiba, S., Van Niekerk, J., and Zwane, E. (2016). The impact of succession planning on the sustainability of cane production by small-scale cane growers in the north coast of Kwazulu-Natal, South Africa. *South African Journal of Agricultural Extension, 44*(1), 50-58.

O’Donnell, C. J. (2012). An aggregate quantity framework for measuring and decomposing productivity change. *Journal of Productivity Analysis, 38*(3), 255-272.

O’Donnell, C. J. (2008). An aggregate quantity-price framework for measuring and decomposing productivity and profitability change.

O’Donnell, C. J. (2010). Measuring and decomposing agricultural productivity and profitability change. *Australian Journal of Agricultural and Resource Economics, 54*(4), 527-560.

O’Donnell, C. J. (2014). Econometric estimation of distance functions and associated measures of productivity and efficiency change. *Journal of Productivity Analysis, 41*(2), 187-200.

O'Donnell, C. J. (2012). Nonparametric estimates of the components of productivity and profitability change in US agriculture. *American Journal of Agricultural Economics, 94*(4), 873-890.

O'Donnell, C. (2011). *The Sources of Productivity Change in the Manufacturing Sectors of the US Economy.*

Oehler, V. G., Yeung, K. Y., Choi, Y. E., Bumgarner, R. E., Raftery, A. E., and Radich, J. P. (2009). The derivation of diagnostic markers of chronic myeloid Leukaemia progression from microarray data. *Blood, 114*(15), 3292-3298. doi:10.1182/blood-2009-03-212969 [doi]

Olesen, O. B., and Petersen, N. C. (2016). Stochastic data envelopment Analysis—A review. *European Journal of Operational Research, 251*(1), 2-21.

Oni, K. C. (2013). Promoting agricultural mechanization in Nigeria through the intervention of Japanese government. *Agricultural Mechanization in Asia, Africa, and Latin America, 44*(4), 25-26.

Padilla-Fernandez, M. D., and Nuthall, P. L. (2009). Technical efficiency in the production of sugarcane in central Negros area, Philippines: An application of data envelopment analysis. *Journal of International Society for Southeast Asian Agricultural Sciences, 15(1)*, 77-90.

Pascual, U. (2005). Land use intensification potential in slash-and-burn farming through improvements in technical efficiency. *Ecological Economics, 52*(4), 497-511.

Pengfei, Y., and Bing, W. (2004). Technical efficiency, technical progress & productivity growth: An empirical analysis based on DEA [J]. *Economic Research Journal, 12*, 55-65.

Peyrache, A. (2014). Hicks-Moorsteen versus Malmquist: A connection by means of a radial productivity index. *Journal of Productivity Analysis, 41*(3), 435-442.

Pfeiffer, L., López-Feldman, A., and Taylor, J. E. (2009). Is off-farm income reforming the farm? evidence from Mexico. *Agricultural Economics, 40*(2), 125-138.

Piya, S., Kiminami, A., and Yagi, H. (2012). Comparing the technical efficiency of rice farms in urban and rural areas: A case study from Nepal. *Trends in Agricultural Economics, 5*(2), 48.

Poon, K., and Weersink, A. (2011). Factors affecting variability in farm and off-farm income. *Agricultural Finance Review, 71*(3), 379-397.

Pritchett, L. (2001). Where has all the education gone? *The World Bank Economic Review, 15*(3), 367-391.

Quisumbing, A. R. (1996). Male-female differences in agricultural productivity: Methodological issues and empirical evidence. *World Development, 24*(10), 1579-1595.

Quisumbing, A. R., Meinzen-Dick, R., Raney, T. L., Croppenstedt, A., Behrman, J. A., and Peterman, A. (2014). *Gender in agriculture: Closing the knowledge gap* Springer Science & Business.

Rahman, S. (2010). Women's labour contribution to productivity and efficiency in agriculture: Empirical evidence from Bangladesh. *Journal of Agricultural Economics, 61*(2), 318-342.

Rahman, S., and Salim, R. (2013). Six decades of total factor productivity change and sources of growth in Bangladesh agriculture (1948–2008). *Journal of Agricultural Economics, 64*(2), 275-294.

Ramanathan, R. (2003). *An introduction to data envelopment analysis: A tool for performance measurement* Sage.

Rezek, J. P., Campbell, R. C., and Rogers, K. E. (2011). Assessing total factor productivity growth in Sub-Saharan African agriculture. *Journal of Agricultural Economics, 62*(2), 357-374.

Rios, A. R., and Shively, G. E. (2016). Farm size and nonparametric efficiency measurements for coffee farms in Vietnam.

Rizov, M., Pokrivcak, J., and Ciaian, P. (2013). CAP subsidies and productivity of the EU farms. *Journal of Agricultural Economics, 64*(3), 537-557.

Rosegrant, M. W., and Evenson, R. E. (1992). Agricultural productivity and sources of growth in South Asia. *American Journal of Agricultural Economics, 74*(3), 757-761.

Russell, R. R. (1985). Measures of technical efficiency. *Journal of Economic Theory, 35*(1), 109-126.

Sanders, M. S., and McCormick, E. J. (1987). *Human factors in engineering and design* McGRAW-HILL book company.

Sarantakos, S. (2005). Social research methods.

Schirmer, J., Peel, D., and Mylek, M. (2015). Farmers and agriculture: The 2014 regional wellbeing survey. *The 2014 Regional Wellbeing Survey,*

Sen, A. K. (1962). An aspect of Indian agriculture. *Economic Weekly, 14*(4-6), 243-246.

Serasinghe, R., Mahipala, M., and Gunaratna, L. (2003). Comparison of stochastic frontier analysis (SFA) and Data Envelopment Analysis (DEA) to evaluate technical efficiency: Illustrated by efficiency analysis of cattle farming systems in up-country wet zone of Sri Lanka.

Serra, T., Zilberman, D., and Gil, J. M. (2008). Differential uncertainties and risk attitudes between conventional and organic producers: The case of Spanish arable crop farmers. *Agricultural Economics, 39*(2), 219-229.

Seyoum, E., Battese, G. E., and Fleming, E. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: A study of farmers within and outside the Sasakawa-global 2000 project. *Agricultural Economics, 19*(3), 341-348.

Sharma, K. R., and Leung, P. (2000). Technical efficiency of carp pond culture in South Asia: An application of a stochastic meta-production frontier model. *Aquaculture Economics & Management, 4*(3), 169-189.

Sheng, Y., Davidson, A., and Fuglie, K. (2014). Elasticity of substitution and farm heterogeneity in TFP and size: A theoretical framework and empirical application to Australian broadacre farms. Paper presented at the *58th AARES Annual Conference,* 5-7.

Shepard, R. W. (1953). Cost and production functions. *Princeton: Princeton University.*

Shepherd, R. (1970). Theory of cost and production functions (Princeton university press, Princeton, NJ).

Sherlund, S. M., Barrett, C. B., and Adesina, A. A. (2002). Smallholder technical efficiency controlling for environmental production conditions. *Journal of Development Economics, 69*(1), 85-101.

Shiferaw, B., Hellin, J., and Muricho, G. (2011). Improving market access and agricultural productivity growth in Africa: What role for producer organizations and collective action institutions? *Food Security, 3*(4), 475-489.

Simar, L., and Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics, 136*(1), 31-64.

Simar, L., and Wilson, P. W. (2000). A general methodology for bootstrapping in non-parametric frontier models. *Journal of Applied Statistics, 27*(6), 779-802.

Singh, S. (2016). Technical change and productivity growth in the indian sugar industry. *Procedia Economics and Finance, 39*, 131-139.

Smith, J. A., Jarman, M., and Osborn, M. (1999). Doing interpretative phenomenological analysis. *Qualitative Health Psychology: Theories and Methods,* 218-240.

Smith, K. R. (2002). Research and technology-does off-farm work hinder" smart" farming? *Agricultural Outlook,* (294), 28-30.

Sokhela, M. P. (1999). Enhancing the contribution of small-scale growers in the sugar industry.

Solís, D., Bravo-Ureta, B. E., and Quiroga, R. E. (2009). Technical efficiency among peasant farmers participating in natural resource management programmes in central America. *Journal of Agricultural Economics, 60*(1), 202-219.

Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics, 39*(3), 312-320.

Sossou, C. H., Noma, F., and Yabi, J. A. (2014). Rural credit and farms efficiency: Modelling farmers credit allocation decisions, evidences from Benin. *Economics Research International, 2014*.

South African Sugar Association. 2018. Industry Overview. 2017/2018. Mount Edgecombe: SASA. Available online: http://www.sasa.org.za/sugar_industry/IndustryOverview.aspx (accessed on 04 January 2018).

South African Sugar Industry Directory. 2017. Report of South African Sugar Association. 2016/2017. Mount Edgecombe: SASA. Available online: http://www.sasa.org.za/Files/Sugar%20Industry%20Directory%202016.pdf (accessed on 17 December 2017).

South African Sugar Industry Directory. 2016. Report of South African Sugar Association. 2015/2016. Mount Edgecombe: SASA. Available online: http://www.sasa.org.za/Files/Sugar%20Industry%20Directory%202016.pdf (accessed on 08 December 2017).

South African Sugar Industry Directory. 2014. Report of South African Sugar Association. 2013/2014. Mount Edgecombe: SASA. Available online: http://www.sasa.org.za/Files/Industry%20Directory%202013%20-%202014.pdf (accessed on 06 December 2017).

Speelman, S., Buysse, J., Farolfi, S., Frija, A., D'Haese, M., and D'Haese, L. (2009). Estimating the impacts of water pricing on smallholder irrigators in North West province, South Africa. *Agricultural Water Management, 96*(11), 1560-1566.

Speelman, S., D'Haese, M., Buysse, J., and D'Haese, L. (2008). A measure for the efficiency of water use and its determinants, a case study of small-scale irrigation schemes in North-West province, South Africa. *Agricultural Systems, 98*(1), 31-39.

Stanton, K. R. (2002). Trends in relationship lending and factors affecting relationship lending efficiency. *Journal of Banking and Finance, 26*(1), 127-152.

Stern, R. A., Shing, L., and Blouke, M. M. (1994). Quantum efficiency measurements and modeling of ion-implanted, laser-annealed charge-coupled devices: X-ray, extreme-ultraviolet, ultraviolet, and optical data. *Applied Optics, 33*(13), 2521-2533.

Strauss, A. L. (1987). *Qualitative analysis for social scientists* Cambridge university press.

Swaminathan, M., and Kesavan, P. (2012). Agricultural research in an era of climate change. *Agricultural Research, 1*(1), 3-11.

Tang, J., Folmer, H., and Xue, J. (2015). Technical and allocative efficiency of irrigation water use in the Guanzhong plain, China. *Food Policy, 50*, 43-52.

Taylor, T. G., Drummond, H. E., and Gomes, A. T. (1986). Agricultural credit programs and production efficiency: An analysis of traditional farming in South Eastern Minas Gerais, Brazil. *American Journal of Agricultural Economics, 68*(1), 110-119.

Temoso, O., Villano, R. A., and Hadley, D. (2015). Agricultural productivity, efficiency and growth in a semi-arid country: A case study of Botswana. *Journal of Agricultural and Resource Economics, 10*(3), 192-206.

Terin, M., Kulekci, M., and Yildirim, I. (2017). Measuring technical, allocative and economic efficiencies of dairy farms in Western Turkey. *Indian Journal of Animal Research, 51*(1), 165-169.

Tesfay, G., Ruben, R., Pender, J., and Kuyvenhoven, A. (2005). Resource use efficiency on own and sharecropped plots in Northern Ethiopia: Determinants and implications for sustainability.

Thabethe, L. S. (2013). *Estimation of Technical, Economic and Allocative Efficiencies in Sugarcane Production in South Africa: A Case Study of Mpumalanga Growers,*

Thabethe, L., Mungatana, E., and Labuschange, M. (2014). Estimation of technical, economic and allocative efficiencies in sugarcane production in South Africa: A case of Mpumalanga growers. *Journal of Economics and Sustainable Development, 5(16)*, 86-96.

Thamaga-Chitja, J. M., and Morojele, P. (2014). The context of smallholder farming in South Africa: Towards a livelihood asset building framework. *Journal of Human Ecology, 45*(2), 147-155.

Theriault, V., Serra, R., and Sterns, J. A. (2013). Prices, institutions, and determinants of supply in the Malian cotton sector. *Agricultural Economics, 44*(2), 161-174.

Thirtle, C., Piesse, J., and Gouse, M. (2005). Agricultural technology, productivity and employment: Policies for poverty reduction. *Agrekon, 44*(1), 37-59.

Thirtle, C., and Bottomley, P. (1992). Total factor productivity in UK agriculture, 1967-90. *Journal of Agricultural Economics, 43*(3), 381-400.

Thirtle, C., von Bach, H. S., and van Zyl, J. (1993). Total factor productivity in South African agriculture, 1947-91. *Development Southern Africa, 10*(3), 301-318.

Toma, E., Dobre, C., Dona, I., and Cofas, E. (2015). DEA applicability in assessment of agriculture efficiency on areas with similar geographically patterns. *Agriculture and Agricultural Science Procedia, 6*, 704-711.

Tone, K. (2001). A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research, 130*(3), 498-509.

Torgersen, A. M., Førsund, F. R., and Kittelsen, S. A. (1996). Slack-adjusted efficiency measures and ranking of efficient units. *Journal of Productivity Analysis, 7*(4), 379-398.

Törnqvist, L. (1936). The bank of Finland's consumption price index.

Townsend, R. F., Kirsten, J., and Vink, N. (1998). Farm size, productivity and returns to scale in agriculture revisited: A case study of wine producers in South Africa. *Agricultural Economics, 19*(1), 175-180.

Tozer, P. R., and Villano, R. (2013). Decomposing productivity and efficiency among Western Australian Grain producers. *Journal of Agricultural and Resource Economics, 38(3)*, 312-326.

Udry, C. (1996). Gender, agricultural production, and the theory of the household. *Journal of Political Economy, 104*(5), 1010-1046.

Udry, C., Hoddinott, J., Alderman, H., and Haddad, L. (1995). Gender differentials in farm productivity: Implications for household efficiency and agricultural policy. *Food Policy, 20*(5), 407-423.

Villano, R., Bravo-Ureta, B., Solís, D., and Fleming, E. (2015). Modern rice technologies and productivity in the Philippines: Disentangling technology from managerial gaps. *Journal of Agricultural Economics, 66*(1), 129-154.

Vink, N., and Kirsten, J. (2000). *Deregulation of agricultural marketing in South Africa.* Free Market Foundation.

Von Cramon-Taubadel, S., and Saldias, R. (2014). Access to credit and determinants of technical inefficiency of specialized smallholder farmers in Chile. *Chilean Journal of Agricultural Research, 74*(4), 413-420.

Wadud, A., and White, B. (2000). Farm household efficiency in bangladesh: A comparison of stochastic frontier and DEA methods. *Applied Economics, 32*(13), 1665-1673.

Watkins, K. B., Hristovska, T., Mazzanti, R., Wilson, C. E., and Schmidt, L. (2014). Measurement of technical, allocative, economic, and scale efficiency of rice production in Arkansas using data envelopment analysis. *Journal of Agricultural and Applied Economics, 46*(1), 89-106.

Watto, M. A., and Mugera, A. W. (2014). Measuring production and irrigation efficiencies of rice farms: Evidence from the Punjab Province, Pakistan. *Asian Economic Journal, 28*(3), 301-322.

Watto, M. A., and Mugera, A. W. (2015). Econometric estimation of groundwater irrigation efficiency of cotton cultivation farms in Pakistan. *Journal of Hydrology: Regional Studies, 4*, 193-211.

Weber, L. (1997). Some reflections on barriers to the efficient use of energy. *Energy Policy, 25*(10), 833-835.

Weiping, C., and Ying, D. (2007). Total factor productivity in Chinese agriculture: The role of infrastructure. *Frontiers of Economics in China, 2*(2), 212-223.

Wijesiri, M., Viganò, L., and Meoli, M. (2015). Efficiency of microfinance institutions in Sri Lanka: A two-stage double bootstrap DEA approach. *Economic Modelling, 47*, 74-83.

Wilson, P., Hadley, D., and Asby, C. (2001). The influence of management characteristics on the technical efficiency of wheat farmers in eastern England. *Agricultural Economics, 24*(3), 329-338.

Woldehanna, T. (2002). Rural farm/nonfarm income linkages in Northern Ethiopia. *Promoting farm/nonfarm Linkages for Rural Development: Case Studies from Africa and Latin America, Rome: FAO*, 121-144.

Xiaobing, W., Herzfeld, T., and Glauben, T. (2007). Labour allocation in transition: Evidence from Chinese rural households. *China Economic Review, 18*(3), 287-308.

Yeung, K. Y., Bumgarner, R. E., and Raftery, A. E. (2005). Bayesian model averaging: Development of an improved multi-class, gene selection and classification tool for microarray data. *Bioinformatics, 21*(10), 2394-2402.

Yilmaz, K. (2013). Comparison of quantitative and qualitative research traditions: Epistemological, theoretical, and methodological differences. *European Journal of Education, 48*(2), 311-325.

Yotopoulos, P. A., and Lau, L. J. (1973). A test for relative economic efficiency: Some further results. *The American Economic Review, 63*(1), 214-223.

Young, D., and Deng, H. (1999). The effects of education in early-stage agriculture: Some evidence from china. *Applied Economics, 31*(11), 1315-1323.

Yue, B., and Sonoda, T. (2012). *The Effect of Off-Farm Work on Farm Technical Efficiency in China.* Working Paper, Nagoya University. Furi-cho, Chikusa-ku, Nagoya, Japan.

Zhao, J., and J. Barry, P. (2014). Effects of credit constraints on rural household technical efficiency: Evidence from a city in Northern China. *China Agricultural Economic Review, 6*(4), 654-668.

Zhou, X., Li, K., and Li, Q. (2011). An analysis on technical efficiency in post-reform china. *China Economic Review, 22*(3), 357-372.

Ziervogel, G., Bharwani, S., and Downing, T. E. (2006). Adapting to climate variability: Pumpkins, people and policy. Paper presented at the *Natural Resources Forum, 30*(4) 294-305.

APPENDIX A1: STANDARDISED QUESTIONNAIRE

RESEARCH QUESTIONNAIRE FOR EFFICIENCY ANALYSIS OF SMALL–SCALE SUGARCANE GROWERS IN THE KING CETSWAYO DISTRICT OF KWAZULU-NATAL

Name of enumerator :

Date :

Name of Respondent	
Name of Household head	
How are you related to household head	
Village/Community	
Contact Details	

A. SOCIO-ECONOMICS CHARACTERISTICS

1. Gender of the farmer

1	2
Male	Female

2. Age of the farmer

1	2	3	4
Less than 25 years	25 – 49 years	50 – 60 years	Over 60 years

3. Marital status of the farmer

1	2	3	4
Single	Married	Widowed	Divorced

4. Level of education

1	2	3	4
No formal education	Primary level	Secondary level	Tertiary level

5. What is your total number of years of formal education? ……………………. Years

6. Employment status

1	2	3	4
Unemployed	Self employed	Employed	Pensioner

7. What is the size of your household? ……………………………..

8. What is the source of household income? ………………………………………

B. LAND AND LABOUR

1. How much land do you own? …………………………. (hectares)
2. What kind of land do you own?

   Tribal ………………

   Communal …………

   Private ………………

   Other ………………………. (Mention)
3. If lease, how much do you pay? ………………..
4. Do you use all the available land to grow sugarcane? Yes ☐ or No ☐
5. If No, how much land was used for sugarcane in the last season? ………………
6. Did you hire labour in any of the following season?

2013	2014	2015	2016

7. If the answer is yes, how many labourers did you hire? ……………… (number)
8. How much did you pay for labour? ……………………… (per day)
9. How many hours did they work? ……………….... (per day)
10. If not paid, how did you compensate them? ……………………………………….
11. How many family labourers did you use?

2013	2014	2015	2016

12. If paid, how much did they cost per hour? ………………………………………..
13. How many hours did family labourers contribute per day? ………………..

C. PRODUCTION INPUTS

1. Do you use any machinery and implements to produce sugarcane? Yes ☐ or No ☐
2. If yes what kind?

1	2	3	4	5	6	7
Tractor	Irrigation pump	Plough	Disc	Truck	Ripper	Other

Other: …………………………..

3. If you own any of these how did you acquire them?

1	2	3
Grant	Loan	Other

4. If other, please explain ……………………………

5. In case you do not own implements, how much does it cost you to hire them?

   Tractor ………………….. (Rands)

   Truck ……………………. (Rands)

   Other ……………………. (Rands)

Year	2013	2014	2015	2016
Tractor				
Truck				
Other				

6. Do you complement machinery with draft animals? Yes ☐ or No ☐

7. If yes, how much do you pay per day? …………………………. (Rands)

8. What inorganic production inputs do you use?

Input	Quantity (kg or L)				Costs	Source
	2013	2014	2015	2016		
Fertilisers						
Pesticides						
Herbicides						
Seeds						
Other						

Other: …………………………………

9. How do you finance your inputs? ……………………………………

10. Do you use any organic production inputs? Yes ☐ or No ☐

11. If yes, what kind?

Year	2013	2014	2015	2016
Manure (kg)				
Organic Pesticides (L)				
Hand Hoe (How many)				

D. FARM INCOME AND EXPENDITURE

1. What is the source of farm income?

   Sugarcane production ……………………. (Rands)

   Other crops ………………………………… (Rands)

Livestock …………………………………… (Rands)

Private ……………………………………… (Rands)

2. Do you have access to credit to fund sugarcane growing? Yes ☐ or No ☐
3. If yes, how much do you borrow per annum? …………………… (estimate)
4. Is the source private or funded through government? ………..

   1= Private   2 = Government

5. If government what is the name of the scheme? ……………………………………

E. ADDITIONAL INFORMATION

1. What were you doing before growing sugarcane? ………………………………..
2. How long have you been involved in farming in general? ………………….. (years)
3. Have you ever fallowed your land? Ye☐ or N☐
4. When did you start growing sugarcane? ………………………… (year)
5. What motivated you to grow sugarcane?

1	2	3	4	5
Income generation	Employment	Socialise	Subsistence	Grant funding

6. Do you intercrop sugarcane with any other crop? Yes ☐ or No ☐
7. If yes please output specify below.

Year	2013	2014	2015	2016
Beans				
Cabbage				
Maize				
Sweet potato				

8. Are you exposed to extension support? Yes ☐ or No ☐
9. If yes, who provides such support? Please tick the appropriate box

   Tongaat Hulett ☐

   South Africa Sugar Research Institute ☐

   South African Cane Growers Association ☐

   Department of Agriculture and Rural Development ☐

10. How often per season do you have extension visits?

………………………………..

11. Do you have any challenges in growing sugarcane?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………..

12. How do you think these challenges can be overcome?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

13. What are technical challenges do you face in producing sugarcane?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

14. Do you have enough money/capital to acquire inputs? Please elaborate.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

15. What key strategies do you use to minimise sugarcane production constraints?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. What key strategies did you use to maximise sugarcane yield in the drought season?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

17. Does mills support through different strategies satisfy your production needs, please explain?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

18. What government initiatives are available to small-scale sugarcane growers?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

19. What do you suggest government adopt to improve intervention strategies?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

20. Do you have anything to say about government support?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………