The Estimation of the Cobb- Douglas production functions for the South African agricultural sector and a seletion of its subsectors.

By

Lungani Hlongwa

Student No. 200955428

Submitted to the Faculty of Commerce, Administration and Law in Fulfillment of the Requirements for the M Com (Economics) Degree

University of Zululand

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Supervisor: Dr I Kaseeram

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Co-Supervisor: Professor E Contogiannis

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Declaration

I, the undersigned, hereby acknowledge that the contents of this dissertation is my own work, except where otherwise specified, and has not been submitted, in part or full, to any other University for the purpose of obtaining a degree.

Lungani Hlongwa

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Abstract

The main focus of this study is to apply a Cobb-Douglas production function to estimate agricultural production functions at both the aggregate and sub-sectoral levels in order to determine the productivity of land, labour and capital, while maintaining rainfall levels as a control variable for the South African economy over the period from 1975 to 2012. This task will be accomplished by applying cointegration techniques, Johansen's (1988) vector autoregression (VAR) methodologies and error correction mechanisms to capture short run disequilibrium between agricultural production function and its determinants. Specifically the main objective of this study is to derive plausible estimates of the marginal productivities of land, labour and capital. Moreover this study will attempt to establish the nature of the long and short run relationships between land, labour and capital in the aggregate sector and the maize and wheat subsectors. However before the empirical analysis is conducted the study will first attempt to explain the relevant theories of growth and, which will then serve as a basis for examining South African growth experiences and policy prescription more specifically in the agricultural sector, for the purposes of understanding the South African agricultural sector growth phenomenon and choosing appropriate determinates of agricultural production growth.

The fundings of the VECM, FMOLS, CCR and DOLS methods strongly suggest that the marginal productivities of capital and land were positive while that of labour was negative; all the coefficients were statistically significant except for capital. Additionally the marginal productrivity of land exceeded unity , thus implying that land productivity exhibits increasing returns to scale which confirms the trends that the number of farms have been decreasing but their land acreage have been increasing. While the negative marginal productivity of labour suggests that the South African aggregate agricultural sector is overwhelmed by severe diminishing marginal returns to labour, which explains the observed persistent decline in employment in the agricultural sector over the past three decades or more.

Acknowledgements

I would like to express my heart-felt gratitude to the following individuals, who have supported me spiritually, morally, financially or otherwise to enable me fulfill my dream of achieving a masters degree.

The Almighty God for promising me victory and walking by me to strengthen me by the day.

I thank my supervisors, Dr. Irrshad Kaseeram, with whom I began this journey with and Prof. Contogiannis who shaped and supported me to complete my degree.

My genuine thanks go to my family (Thulile (mum), Makhulu (uncle), Sakhile, Sphelele) whose constant love, prayer and blessings saw me through this difficult journey. To my late dad Mboniseni and my brother Langa Hlongwa, I hope you are proud of me were ever you are.

To my extended family and to all my friends, especially Mandla, Allie, Bongi, Mfanelo and the real boyfriends thank you for your moral support. May God bless you, I feel greatly indebted to you all.

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List of Acronyms Used

ALA – Agricultural Labour Act

ADF – Augmented Dickey Fuller Test

AgricBEE – Agricultural Black Economic Employment

ANC- African National Congress

ARDL- Autoregressive Distributed Lag

AsgiSA – Accelerated and Shared Growth Initiative of South Africa

BCEA – basic condition of Employment Act

BMA – Bayesian Model Avergaing

CCR- Canonical Cointegration Regressions

CRLS – Center for Rural and Legal Studies

CRP – Conversation Reserve Program

DAFF -Department of Agriculture, Foresty and Fisheries

DAFWA- Department of Agriculture and Food, Western Australia

DCs – Developed countries

DEA- Data Enveloping Analysis

DF – Dickey Fuller

DFGLS – DF with Generalized Least Squares Detrending

DFID- Development for International Development

DOLS- Dynamic Ordinary Least Squares

ECM – Error Correction Model (or Mechanism)

EAP- Economically Active Person

FMOLS- Fully Modified Ordinary Least Squares

FPMC – Food Pricing Monitoring Committe

GDP – Gross Domestic Product

GLS – Generalized Least Squares

Ha- Hacters

I(d) – Intergrated of the order d

IFAD- International Fund for Agricultural Development

ILO – International Labour Organasation

KPSS – Kwiakowski, Philips, Schmidt and Skin Test

LDCs -Less Developed Countries

LK- Lin Capital

LL- Lin Labour

LPs – Linear Programms

MTSF- Medium Term Strategic Framework

NDA- National Department of Agriculture

NDP - National Development Plan

NPC-National Development Commission

NEDLAC – National Economic Development and Labour Council

NGO- Nonprofit Organization

NSA- National Skills Authorities

OECD – Organisation for Economic Cooperation and Development.

OLS – Ordinary Least Squares

RJ - Reserve Jump

SSA- Sub-Saharan Africa

Stata SA- Statitics South Africa

TFP- Total Factor Productivity

TT – Terms of Trade

UIA – Unemployement Insurance Act

UK – United Kingdom

UN- United Nations

US – United States

USAID – United states Agency of International Development

VAR – Vector Autoregression (model)

VECM – Vector Error Correction Model

WFP – Women of Farm Projects

CHAPTER ONE

1.0 Introduction

Since 1994, the main challenge for South Africa has been the marginalisation of the poor, especially the rural poor. Combating this social inequity requires changes in access to both natural resources and public goods which include: land, water, education, health services, skills training, improved rural infrastructure and other government services. The agricultural sector is of vital importance in solving the crisis faced by the South African economy as it has major implications for job creation, rural development, food security and foreign exchange generation. According to the National Development Plan (NDP) the agricultural sector has the potential to create close to a million new jobs by 2030, a significant contribution to the overall employment target. The agricultural sector includes all activities relating to actual farming, the supply of inputs such as fertilizer and the processing and distribution aspects that add value to farm products (National Treasury, 2003). This can only be achieved by supporting agricultural sub-sectors with potential for long-term, sustainable expansion in production and value adding processes. The Agricultural sector is like any other business sector for it attempts to maximize profit through the choice of an optimal input mix given the market price.

Agriculture contributes to both income growth and poverty reduction in South Africa, by generating income and employment in rural areas and providing food at reasonable prices in urban areas .The agricultural sector also offers seasonal employment to a significant number of households. However, with the introduction of democracy in 1994, and the appointment of the first African National Congress (ANC) Minister of Agriculture in 1996, the South African economy started to undergo significant changes with the government implementing various policies aimed at addressing the injustices of the past. These policies included: land redistribution, minimum wage legislation in the agricultural sector, expansion of the welfare system and improving competitiveness as South Africa becomes increasingly open to the global economy. These policies have, directly or indirectly, impacted on the production processes under the agricultural sector.

The United Nations (2013) has warned that severe weather in the United States and other food-exporting countries such as South Africa could trigger a major hunger crisis in the next few years. According to the Department of Agriculture (2013) historically, agriculture accounted for approximately 15.2% of Gross Domestic Product (GDP) in the 1950s and 10% in the 1960s and now accounts for less

than 5% of GDP. Services and manufacturing have overtaken agriculture in terms of its contribution to GDP. However, though the relative size of the agricultural sector has been declining, the value added by the agricultural sector showed an annual average growth rate of 1.7% over the past 10 years. It is widely known that increased food production will ensure that the growing population is food secure. Therefore, the role of the agricultural sector in alleviating poverty and ensuring food security for all take precedence over all the other roles it has from a food security point of view. According to Yanggen et al., (1998), to increase rural incomes and meet growing food demands Sub-Saharan Africa (SSA) must improve agricultural productivity, SSA is the only developing region where per capita food production has been declining; the region now has the largest cereal deficits in the world. If there is no change in productivity, deficits will more than triple by 2020. Fertilizer is a powerful productivity-enhancing input, but Sub-Saharan Africa uses very little.

1.1. Motivation of the study

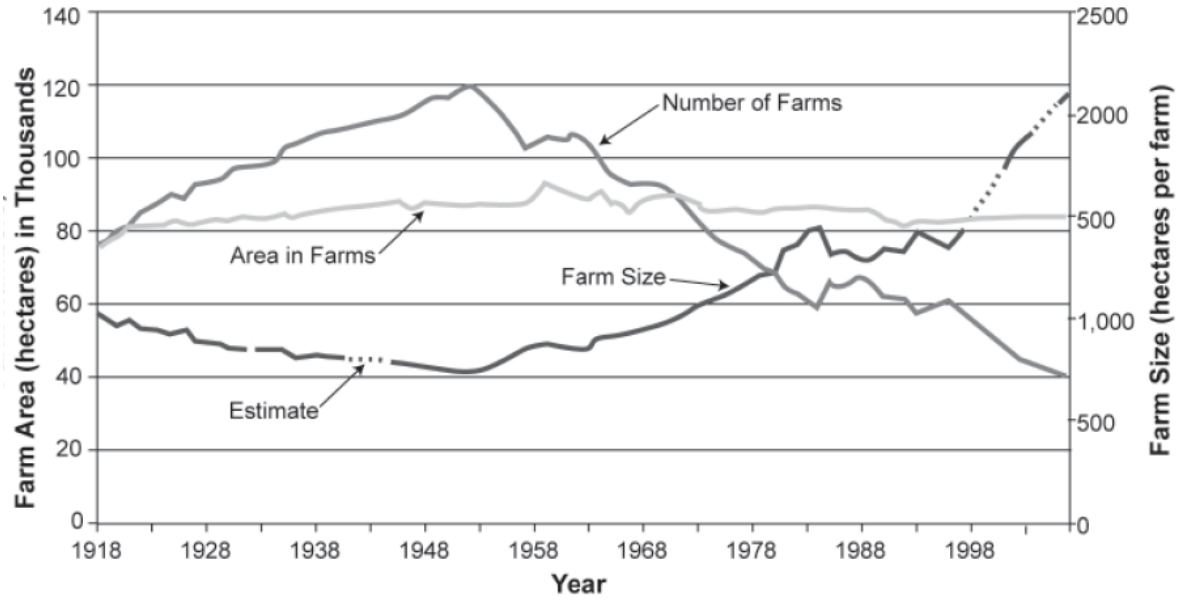


Figure 2 Farm numbers, farm area (hectares) and farm size

Source: Liebenberg and Praday, 2010

Agricultural inputs, in general, varied in terms of growth. From the above graph one can trace the impact of structural changes in farmland usage since 1918. Farmland grew by 91.8 million hectares in 1960, declining in 1996 to 82.2 million hectares. Between 2000 and 2007 it constantly remained within the range of 83.7 million hectares (Conradie et al, 2009). Black farmers' share of area farmed in 1918 and 1991 was 15% and in 2000 it doubled to 30%. The twenty-first century saw a declining number of farmers and a steady growth of average farm size. In 1918 farm numbers and average farm size were estimated at 76,622 and 1,006 hectares respectively whilst in 2007 these were 44,575 and 1,400 respectively (Statstistic South Africa , 2011).

On the other hand intermediate inputs have increased since 1947/48; their share of total costs in 1947/48 was around 30% compared to 50% in 2006/2007. That being the case capital costs has increased within the same period whilst labour costs have reduced from 36% in 1947/48 to 15.1% in 2006/07. Land costs saw a fluctuation over this period. In 1947/48 these were 6.6% and it grew to 15.55% and later declined to 3.0% of the total costs. The reason for this change was the introduction of

tractors in the mid 70s compared to the use of oxen in the 40s. In the twenty-first century the drastic decline in area planted was due to increasing costs of operation which therefore led to a reduction in the number of farmers and thus the amount of land planted (Liebenberg and Praday, 2010).

In the light of the above scenario it is important for policy and planning purposes to assess the productivity of land, labour and capital at both the aggregate and sectoral levels-more especially since no studies have been conducted using the Cobb-Douglas production function framework to undertake such analyses, within the South African context. Studies by Liebenberg and Praday (2010) and studies commissioned by the Agriculture and Fisheries Department mainly focus on broad trends in the data without engaging in any rigorous quantitative estimation analyses, using the latest time series methodological approaches.

1.2 Problem statement

Due to changing economic climate and policy reforms that have been implemented over the years, have largely impacted on agricultural input costs, thus resulting in the number of commercial farms declining from 90 422 in 1971 to 39 982 in 2007. Moreover commercial farms have become larger and more capital intensive. Over this period, the average number of employees per farm remained largely the same, but while average farm sizes has increased, the number of workers per hectare has declined (National Planning Commission, 2009).

Information about productivity of land, capital and labour can provide valuable predictions on outcomes should more land, capital and labor be released into the mainstream economy, for example via the land restitution programs. Some qualitative research has been conducted by Edor (2007) with regards to agricultural production. However, his study failed to provide indications of the magnitude of the marginal the elasticities of land, labour and capital, knowledge of which is critical for any policy interventions by government or investments allocations by the private sector.

No South African studies, to date, have estimated a Cobb-Douglas production function for the South African economy or the agricultural sector or any of its subsectors. Such insights are critical for the understanding of the sector and subsectors so that appropriate policy interventions can be introduced. Moreover estimates of the marginal production function of land, labour and capital derived from the

estimated Cobb-Douglas functions can assist both policy makers and potential investors in making effective decisions.

1.3 Objectives of the study

To estimate agricultural production functions at both the aggregate and subsectoral levels in order to determine the productivity of land, labour and capital, while maintaining rainfall levels as a control variable. The second objective is to derive plausible estimates of the marginal productivities of land, labor and capital through the use of the Cobb-Douglas methodology. The third objective of this study is to establish the nature of the long and short run relationships between land, labour and capital in the aggregate sector and the maize and wheat subsectors.

1.5 Intended contribution

This will be the first South Africa study to estimate Cobb-Douglas production functions at both the aggregate and the sectoral levels. This analysis will shed light on the contribution of labour, land and capital to agricultural output at aggregate and the maize and wheat sub-sectoral levels. Knowledge of such quantitative estimates is critical for policy planning and agri-business investment purposes.

1.6 Hypotheses

H1= There is a long run co-integration relationship between capital, land, labour, rainfall and aggregate agricultural output in the South African economy.

H2= There is a significant positive relationship between the long-run behavior of sub-sectoral agricultural output, land, capital, labour and rainfall for South Africa.

H3= The number of farms has indeed declined due to larger farmers being more capital intensive resulting in huge increases in the marginal productivities of land and capital.

H4= Land and capital have become more productive than labour inputs over the years at both the aggregate and the sub-sectoral levels

1.7 Organisation of the Study

The dissertation consists of six chapters. Chapter two presents and discusses the theoretical background that will assist in exploring critical determinants of economic growth and the role played by different variables that affect national output growth, in general and agricultural output growth, in particular. Moreover, the chapter gives an account of the conceptual literature behind agricultural linkages to economic growth and a historic overview of the South African agricultural sector.

Chapter three conducts a literature review on the empirical literature on agricultural production in both the local and global contexts. The chapter first presents the profile of the South African agricultural sector and reviews the productivity growth studies in South Africa .Thereafter; the chapter undertakes a review of the literature on agricultural productivity growth studies. Moreover, the chapter gives a brief account of the literature that employs the various methods in estimating productivity growth and points out that they have yielded different results due to different assumptions and methodological characteristics. Additionally, the literature review endeavours to identify the general findings on the subject matter and gaps that this study may address. Lastly, the empirical review will be used to identify appropriate variables and models to estimate in order to quantify the relationship between critical input variables and production output in the South African context.

Chapter four explains all relevant statistical estimation concepts, techniques and the econometric specification of the models to be estimated in chapter five. The chapter is divided into sections that cover time series statistical estimation methodology and model specification. Under the first section, the concepts of stationarity, cointegration and their designated tests are presented, followed by Vector Autoregressive (VAR), Vector Error Correction model (VECM), fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS) and canonical cointegrating regressions (CCR) modelling frameworks and functionalities. The second section covers the theoretical model to be estimated and a description of the chosen variables that enter the study's econometric model.

Chapter five discusses the empirical analysis, gives detailed explanations of the various phases of the estimation procedure and discusses the results of this study. The analysis begins with preliminary examinations to determine the basic properties of the data used for econometric analysis and to guide the investigator in the selection of appropriate estimation techniques to employ. The short- and- long

run interactions of the study's growth model are examined through the use of the VAR and VECM frameworks. Single equation estimation methods, which include the FMOLS, DOLS and CCR.

Chapter six concludes the study by conducting a succinct summary of the empirical findings and outlines their relevance to policy prescriptions pertaining to the general agricultural sector and the two subsectors that were investigated. Accordingly, policy recommendations, strengths and weaknesses and future research directions of the study are provided.

CHAPTER TWO

THEORITICAL BACKGROUND

2.0 INTRODUCTION

As this research paper will be looking at fundamental factors contributing to South African agricultural growth and the level of productivity for different factors of production, it will be of critical value to look at the different scholars involved in the development of different growth theories and the gaps that were identified within these growth theories. Firstly the researcher will look at the well-known growth theories which offer a much broader perspective of the micro and macro aspects of the overall theory. Thereafter the theory will specifically focus on the growth theories involving the agricultural sector.lastly discussing the challenges and proposed instruments under the sector aligned with the theories discussed in this chapter.

2.1 The Harod Domar Model

The first wave of interest in growth theory was associated with the contributions of Harrod and Domar which came into existence as a by-product of John Maynard Keynes's General Theory. This model extended the Keynes's analysis into the long-run by considering under what conditions a growing economy could realize full capacity utilization and full employment. The Harod Domar Model suggested that economic growth rates of any economy depend on two things which are the level of Savings (higher savings enable higher investment) and Capital Output Ratio (efficiency of investment).

Formula for Harod Domar

$g=s/c$ (1)

Where

g= is the economic growth rate, s= S/Y is the ratio of saving to income, c= is the marginal capital-output ratio. It is argued that in developing countries saving rates are often low, if left to the free market. Therefore, there is a need for governments to increase the savings rate in an economy. Alternatively, developed countries could step in and transfer capital stock to the developing countries, which would increase the productive capacity. This model within the scope of the agricultural sector explains the intervention of government in the agricultural sector through providing cheap loans, land redistribution and polices to support small farms in an aim to maintain efficiency and boost growth which can only be done if our government has enough savings to maintain the capital output ratio or turn to the developed world for assistance.

2.2 Solow Growth Model

The second wave of interest in growth theory was launched by the development of the neoclassical model by Robert Solow (1956), where he investigated the long run development of the economy under the influence of population growth, technical progress and capital formation and used a linear-homogenous Cobb-Douglas function with a geometric trend factor for technological development. This model employs similar variables that are employed in the Cobb-Douglas production that this study will attempt to estimate, but the Solow growth model converts capital as an exogenous to an endogenous variable and capital accumulation is taken as the engine of the long run economic growth. The Solow-tradition growth theory is based on the following production function:

$$Y(t) = F[K(t),A(t),L(t)]$$

where Y is output, K is physical capital, A is an index of overall productivity, and L is the labour force; there are constant returns to scale and decreasing returns to capital. With these assumptions, income growth can come from the increased efficiency of productive inputs, i.e. an increase in A, or the augmentation of such inputs, i.e. an increase in K and/or L. Positive growth rates can be sustained if, and only if the decreasing returns to the accumulation of capital are offset by population growth, or if the marginal productivity of capital is constantly shifted upwards by technical progress.

The Solow growth model is directly relevant to this study because it mostly focuses to the factors of production that influences economic growth. The Solow model focuses on the factors like capital and labour, Ehrenberg and Smith (2009). Which is also the main focuse of this study but looking at the agricultural sector and its subsectors, capital and labour are important control variables in the econometric modelling as covered in chapter 4.

2.3 Kaldor Model of Economic Growth

The Kaldor growth model was designed to replace the conventional Solow growth model, with its exogenous trend of technical progress, by more realistic models that generate increasing returns (to labor, capital and/or scale) as a result of endogenous technical progress. In contrast to the Solow model, the new model suggested that policy interventions can affect the long-run rate of economic growth. The rates of change in capital intensity and per-capita-output represent the dependent variables of the model. Growth is determined by three functions according to this model which include a saving function, an investment function and a technical progress function, all of which are crucial and relevant to the agricultural sector growth, especially since agriculture production in South Africa and elsewhere is becoming increasingly mechanized and fertilizer driven.

2.4 Cobb-Douglas production function

The Cobb-Douglas functional form of production functions is commonly used to represent the relationship of an output to inputs. It was proposed by Knut Wicksell (1851 - 1926), and tested against statistical evidence by Charles Cobb and Paul Douglas in 1928. In 1928 Charles Cobb and Paul Douglas published a study in which they modelled the growth of the American economy during the period 1899 – 1922 using aggregate time series data from the US manufacturing sector on labor, capital, and physical output, with the goal of understanding the relationship between the level of output and the quantities of inputs employed in production. They considered a simplified view of the economy in which production output is determined by the amount of labor involved and the amount of capital invested. While there are many other factors affecting economic performance, their model proved to be remarkably accurate. . The function they used to model production was of the form: P (L, K) = $\mathbf{bL^{\alpha}K^{\beta}}$

where:

P = total production (the monetary value of all goods produced in a year)

L = labor input (the total number of person-hours worked in a year)

K = capital input (the monetary worth of all machinery, equipment, and buildings)

b = total factor productivity

α and β are the output elasticities of labor and capital, respectively. These values are constants determined by available technology. Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production, ceteris paribus. There are extensions to the Cobb-Douglas models for translog and constant elasticity of substitution models. However, for the purpose of this study they are not essential. Moreover, they employ the same variables as that of the Cobb-Douglas model.

2.5 Agricultural sector contribution

In most poor countries, agriculture is a major employer and source of national income and export earnings. Growth in agriculture tends to be pro-poor – it harnesses poor people's key assets of land and labour, and creates a vibrant economy in rural areas where the majority of poor people live. Agriculture connects economic growth and the rural poor, increasing their productivity and incomes. The importance of agriculture for poverty reduction, however, goes well beyond its direct impact on rural incomes. Agricultural growth, particularly through increased agricultural sector productivity, also

reduces poverty by lowering and stabilising food prices; improving employment for poor rural people; increasing demand for consumer goods and services, and stimulating growth in the nonfarm economy. A positive process of economic transformation and diversification of both livelihoods and national economies is the key to sustained poverty reduction. But it is agricultural growth that enables poor countries, poor regions and ultimately poor households to take the first steps in this process (World Bank, 2003).

2.6 Modeling Agricultural Growth

In this section the researcher examine some of the models used to analyze economic and agricultural growth. The researcher will argue that recent advances in the "New Growth Theory" have great potential value for aiding our understanding of the place of agriculture in economic development. Its promise however is currently limited by the failure to capture the diversity of agricultural conditions. One of the fundamental insights of modern economics has been to emphasize the importance of technological and institutional changes (along with human capital formation) in the growth process. The induced innovation hypothesis and the threshold model have been the dominant paradigms used for analyzing the invention and diffusion of new agricultural technologies (and in the case of the induced innovation model, the linkages between the agricultural and nonagricultural sectors) (Ruttan and Hayami 1971).The agricultural sector, more in particular ,in the south African economy, has changed over the years, moving more to capital intensive production processes which have resulted in fewer large farms in the sector being more productive employing more capital less and labour to raise production.

2.7 The New Growth Theory

Macroeconomic theorist laureate Robert Lucas, Jr. over the last two decades has helped revive research on macroeconomic growth under the label of the "New Growth Theory." Adopting a dynamic optimization framework incorporating individual preferences, this literature initially focused on generating endogenous growth along the steady-state equilibrium path of aggregative or single-sector models(Lucas, 2004)). Agriculture fits uneasily into such models because it employs non-reproducible inputs, such as land, that are subject to diminishing marginal returns. The operation of Engel's law, leading agriculture's share of consumption spending to fall as income rises, further undermines the standard application of steady-state analysis (where in equilibrium every per capita growth rate is equal). To better understand the classical issue of the role of agriculture in economic development, a small stream of the new growth literature has begun analyzing the asymptotic transition path of dual-sector models. Such an approach allows for structural shifts including the possibility that the share of

the agricultural sector declines toward zero over the long run. Yet the potential of the "New Growth Theory" to aid our understanding of the transition is hindered by a failure to come to grips with the diversity of agricultural environments and institutions.

The New Growth literature is increasingly focusing on another relationship, long-understood by economic historians, showing the inverse correlation between the share of the national labour force in agriculture and its level of per capita income. This pattern, was reported in the standard Kuznets findings in recent years which , strongly suggests that growth inherently involves structural change, specifically, a movement out of low-productivity agriculture into higher productivity sectors such as manufacturing and services. Studies of the contemporary cross-country growth experience, based on the Penn World data, confirm the standard Kuznets findings that labor productivity is higher outside than inside agriculture. But the studies go two steps further, showing that (1) labour productivity inside agriculture varies much more across developed and developing economies than labour productivity outside agriculture, and (2) the gap between agricultural and nonagricultural productivity closes at higher incomes/lower shares of the labor force in agriculture. This perspective helps to explain the observation that fewer capital intensive farms are employing less skilled labour. By the end of the nineteenth century, productivity in the two sectors in the United States was virtually equal. This perspective helps to explain the observation that capital intensive farmers are employing fewer skilled employees.

2.8 Agriculture and poverty reduction

Earlier literature stressed the direct impact on poverty reduction that comes from rising rural wages and incomes. Most of the world's poor live in rural areas, or migrated from them in search of better opportunities. It seems that growth in agricultural productivity is the surest way to end poverty. The historical evidence confirms this logic. Growth in agricultural productivity not only can increase farm incomes, it also stimulates linkages to the non-farm rural economy, causing economic growth and rapid poverty reduction, with overall growth multipliers almost always significantly greater than one (Hazell and Haggblade, 1993).

Nonfarm linkages generated by technical change in agriculture can enhance both growth and its poverty-reducing effect. A growing agricultural sector demands nonfarm production inputs, and supplies raw materials to transport, processing, and marketing firms. Likewise, increases in farm incomes lead to greater demand for consumer goods and services. Besides stimulating national economic growth, these production and consumption linkages affect poverty and spatial growth patterns, particularly when

agricultural growth is concentrated on small and medium-size farms (Johnston and Kilby, 1975; Mellor, 1976; and Mellor and Johnston, 1984). (Hazell and Haggblade, 1993). However, in the South African case, greater farm incomes has meant the employment of fewer skilled labourers to operate high tech equipment (Bhorat, 2004)

2.9 Rural diversification as the conceptual framework

A sequence of progressively broader diversification steps defines a successful agricultural transformation (Timmer, 1988). In countries where farm sizes are small and likely to remain that way for decades because of population pressures and insecure property rights, diversification from production of staple grains to higher-valued commodities will be the first step in this process. The next step will be to move beyond basic commodity production in order to access value-added supply chains for the modern retail sector, especially supermarkets, where the value-added comes in the form of quality, timeliness, food safety, and labor standards in production. These are highly management-intensive factors and may well contribute to economies of scale in production that are not seen in commodity production alone (Timmer, 2004; Reardon and Timmer, 2006).

The next step is the diversification of the rural economy itself, from being primarily driven by its agricultural base to depending more on industrial and service sectors as the base for rural economic growth. This step seem feasible only when population densities permit substantial clusters of activities that feed on themselves for inputs and demand for output (Hayami and Kawagoe, 1993; Lanjouw and Lanjouw, 2001). Thus the effectiveness of the model proposed by Mellor (1976, 2000) of demand for labor-intensive, rural non-tradables as the vehicle for pro-poor growth, driven by agricultural profitability and wages from labor-intensive exports, would seem to be conditional on good rural infrastructure and human capital, and hence seems to be limited to Asia, parts of coastal and highland Africa, and several countries in Latin America and the Caribbean. At the same time, good rural infrastructure reduces the relative importance of non-tradables in local economies and increases competitive pressures from world markets. It is precisely this tension that raises doubts about the future potential for agriculture to be an important driver in poverty reduction, even in rural areas (Development for International Development, 2004).

Where rural diversification is not economically feasible, the alternative to diversification out of agricultural commodity production will be the transition of economic activity from rural to urban areas. In this transition, the importance of migration (and remittances) will be critical. It is really quite astonishing how little attention is paid to facilitating the migration of rural workers to urban jobs when

investments in the rural economy have low payoffs. One of the main justifications for investing in rural schools and public health facilities is to improve the competitiveness of rural migrants to urban areas.

Whatever the stage or dimension of rural diversification, it must be driven by market demand. Since the 1970s, the development profession has identified "market demand" with border prices and international trade, on the assumption that domestic markets are saturated, politically manipulated, or not remunerative for producers of higher quality products. This focus on international trade has allowed a revolution in food marketing in developing countries to go virtually unnoticed until several years ago, the extensive consolidation of the food retail sector and the rapid rise of supermarkets. The revolution has already created a challenge to higher rural incomes because the process has a tendency to have such high standards for quality, safety, hygiene and farm labor practices that many of a country's own farmers are excluded from the supply chains that provision their consumers, even poor consumers (Reardon et al., 2003; Timmer, 2004).

In the ultimate stage of rural diversification, globalization permits procurement officers to source food supplies from anywhere in the world, so local farmers compete not just against each other for local consumers; they compete against the global market. But farmers increasingly also have access to the global market if they are the low-cost producer meeting global standards. The future of agricultural development will depend on putting productive new technologies in the hands of farmers and creating an open market environment to make the resulting production as profitable to farmers as employment opportunities in other sectors. Where that development is not possible, and there will be many environments where it is not, rural poverty will only be solved by migration to alternative opportunities, usually in urban areas.

Where the strategy does work, diversifying the rural economy will be the key to increasing income opportunities. Placing rural diversification at the center of agricultural and rural development means there are two quite different tasks that need to be managed simultaneously: (a) raising the productivity of staple food crops for those farmers who continue to grow them; and (b) using the low costs of these staple foods as "fuel" for the agricultural diversification effort, including as the wage good for workers and as feed for livestock. In low-income Asia, diversification will depend on continued availability of low-cost rice, especially in rural markets. In Africa and Latin America, having cheap corn, wheat and rice available in rural markets will be important if diversification is to be successful. Low-cost staple foods are also important to the poor directly, because they devote such a large share of their budget to them, and indirectly, because low real wages, made possible by cheap food staples, make labor-intensive

activities more profitable. Making substantial progress on both of these “rural” tasks will be among the most “propoor” things the development community can hope to accomplish between now and the target date for the Millennium Development Goals

2.10 Agricultural growth models

The following are the main fundamental growth models that have been developed by different scholars over the years in an attempt to understand the agricultural sector and have a standard framework for agricultural growth and which will help explain the increase in agricultural productivity the simultaneous decline in the number of farm workers employed.

2.10.1 The Conservation Model

The conservation model emphasized the evolution of a sequence of increasingly complex land- and labour-intensive cropping systems, the production and use of organic manures, and labour-intensive capital formation in the form of physical facilities to more effectively utilize land and water resources (New standard 1992).

2.10.2 The Location Model

According to this model industrial development stimulated agricultural development by expanding the demand for farm products, supplying the industrial inputs needed to improve agricultural productivity, and drawing away surplus labour from agriculture. The empirical tests of the location model have confirmed repeatedly that a strong nonfarm labour market is a prerequisite for labour productivity in agriculture and improved incomes for rural people. The policy implications of the location model appear to be most relevant for less developed regions of highly industrialized countries or lagging regions of the more rapidly growing less developed countries e.g. South Africa and other emerging countries (Ruttan and Hayami 1971)

2.10.3 The Diffusion Model

The diffusion approach to agricultural development rests on the empirical observation of substantial differences in land and labour productivity among farmers and regions. According to this model the route to agricultural development is through more effective dissemination of technical knowledge and a narrowing of the dispersion of productivity among farmers and among regions) (Ruttan and Hayami 1971). The diffusion model of agricultural development has provided the major intellectual foundation for much of the research and extension effort in farm management and production economics, the diffusion model has led to the establishment of active programmes of farm management research to improve on agricultural productivity growth. A further contribution to the effective diffusion of known

technology was provided by the research of rural sociologists on the diffusion process. Models were developed emphasizing the relationship between diffusion rates and the personality characteristics and educational accomplishments of farm operators. The model emphasized the need for research and training of farmers and farm workers, the use of modern management systems and technology to boost growth. These are similar to polices the South African government is advocating.

2.10.4 The High Payoff Input Model

The inadequacy of policies based on the conservation, urban-industrial impact, and diffusion models led, in the 1960s, to a new perspective that the key to transforming a traditional agricultural sector into a productive source of economic growth is investment designed to make modern high payoff inputs available to farmers in poor countries. Peasants, in traditional agricultural systems, were viewed as rational, efficient resource allocators. They remained poor because, in most poor countries, there were only limited technical and economic opportunities to which they could respond. The new, high payoff inputs can be classified into three categories: (a) the capacity of public and private sector research institutions to produce new technical knowledge; (b) the capacity of the industrial sector to develop, produce, and market new technical inputs; and (c) the capacity of farmers to acquire new knowledge and use new inputs effectively. The enthusiasm with which the high payoff input model has been accepted and translated into an economic doctrine has been due in substantial part to the Success of efforts to develop new high-productivity grain varieties suitable for the tropics (. New high-yielding wheat and corn varieties were developed in Mexico, beginning in the 1950s, and new high-yielding rice varieties in the Philippines in the 1960s (Ruttan and Hayami 1971). These varieties were highly responsive to industrial inputs, such as fertilizer and other chemicals, and to more effective soil and water management. The high returns associated with the adoption of the new varieties and the associated technical inputs and management practices have led to rapid diffusion of the new varieties among farmers in several countries in Asia, Africa, and Latin America. The impact on farm production and income has been sufficiently dramatic to be heralded as a "green revolution." The significance of the high payoff input model is that policies based on the model appear capable of generating a sufficiently high rate of agricultural growth to provide a basis for overall economic development consistent with modern population and income growth requirements. As interpreted generally, the model is sufficiently inclusive to embrace the central concepts of the conservation, urban-industrial impact, and diffusion models of agricultural development. The unique implications of the model for agricultural development policy are the emphasis placed on accelerating the process of development and propagation of new inputs or techniques through public investment in scientific research and education.

2.10.5 Induced Innovation

The induced innovation hypothesis is essentially a long-run version of the factor substitution argument that treats the evolution of technology and institutions as endogenous responses to the forces of factor supply and product demand. In terms of its simplicity, intuitive appeal, and number of adherents, it has no close competitor. The model is most closely associated with the works of Hayami and Ruttan

2.10.6 Threshold Models

While the induced innovation hypothesis is the leading model for explaining the creation of new technologies, the threshold model is the standard tool for analyzing the timing and extent of technological diffusion. Whereas induced innovation models grapple with the dynamics of long-run factor substitution, threshold models are more modest in concentrating on short-run cost calculations. These simple models generally depict individual farmers as choosing between a traditional method of production with high variable cost and new mechanical methods which are fixed cost intensive. On small farms the high fixed costs of machines cannot be spread over a large enough acreage, and thus mechanisation is not profitable.

2.11 The Reasons for Agricultural Success and Failure

In the 1960s, Theodore W. Schultz was concerned with understanding the nuts and bolts of agricultural progress.He argued that to a significant extent agricultural failure had much more to do with misguided government policies than to bad weather, irrational farmers, and the like.

"To the minds of many who shape agricultural policy...farmers are ever so perverse. When a national economic plan calls for more agricultural production, farmers fail to respond; when instructions are issued to shift from wheat to corn, they fail to produce enough of either crop; when given the command to make a big leap forward, they step backward; and when they are heavily subsidized to reduce the acreage of particular crops, they proceed to increase the yield to produce more than offset the reduction in acreage. Farmers, especially in poor countries, are then looked on as loafers who prefer leisure to doing the extra work to increase production, as squanderers when it comes to savings for investment to increase agricultural production, and as ever so inefficient in using the resources at their disposal(Schultz, 1968)."

"After criticizing both W. Arthur Lewis and Ester Boserup for overplaying the shortcomings of individual farmers, Schultz noted that "there is a long shelf of empirical evidence ... which shows that in Africa, when the export price of cocoa, cotton, peanuts, or palm fruit becomes profitable, the supply response of farmers is highly elastic."

2.12 Five different rural worlds in South Africa: the agricultural sector is divided into five worlds (Organisation for Economic Cooperation and Development, 2003)

2.12.1 Rural World 1 – large-scale commercial agricultural households and enterprises

Rural World 1 households and enterprises engaged in high-value, export-oriented agriculture, make up a very small minority of rural households and firms in the developing world. In addition to their land and other holdings, producers and firms in this category have direct access to finance, risk management instruments, information and infrastructure necessary to remain competitive in their business operations. Most have an influential voice in national policies and institutions affecting their enterprises and, perhaps even more important, close ties to buyer-driven value chains associated with global agriculture. Rural World 1 producers and firms are considered to be important sources of employment because they depend on inexpensive labor and reliable contract farming agreements to ensure a timely supply of quality produce. The economic power of this group enables them to influence the political affairs of their country. They often use this influence to shape public policies that favour their interests and to steer public expenditures to investment priorities that meet their needs. They are well positioned to meet the strict new regulations imposed by importing nations and by retail buyers expanding operations in regional and national markets.

2.12.2 Rural World 2 – traditional landholders and enterprises, not internationally competitive

Rural World 2 accounts for a substantial number of rural households and agricultural firms in the South African economy. The one word that most aptly characterises them is “traditional”. They are frequently part of the local elite but have little influence at the national level. They have sizable landholdings often devoted to both commercial and subsistence agriculture. They previously had access to basic services, such as finance, but with the advent of liberalisation and the consequent withdrawal of the state from a direct role in agriculture, the availability of these services declined rapidly. Access to formal risk management instruments is limited. Rural World 2 producers have few ties (if any) to the important agribusiness supply chains. Their traditional orientation, embedded in local networks, is becoming less appropriate as national and international interdependencies reshape rural societies throughout the developing world. Some researchers argue that with better access to improved technologies and infrastructure services, Rural World 2 producers could regain some of their competitiveness, particularly in food staples. The more entrepreneurial members of this group are learning from their Rural World 1 neighbours and becoming more commercial. They are also benefiting from investments in services directed primarily at Rural World 1, such as improved transport systems.

2.12.3 Rural World 3 – subsistence agricultural households and micro-enterprises

Rural World 3 households – fisherman, pastoralists, smallholders and associated micro-enterprises – are survivalist. Food security is their main concern, and their small production units are almost totally dedicated to home consumption. Their assets are poorly developed, and they have very limited access to services (credit) that would enable them to increase the returns to their assets. Their ability to manage risk and associated vulnerability is limited to informal means, thus severely constraining their ability to take on higher risk, higher return livelihood opportunities. Many live in fragile ecosystems or less favoured regions and depend on off-farm employment for a significant percentage of their livelihood. This group embraces many women and female-headed households, who are among the poorest and most exposed in rural areas. The social sphere of Rural World 3 rarely extends beyond local communities, and their voice is almost unheard in the broader socioeconomic and political affairs shaping their lives. The economic fortunes of Rural Worlds 1 and 2 greatly affect Rural World 3's employment and income-earning opportunities, and sustained periods of growth give some the option of leaving subsistence production altogether.

2.12.4 Rural World 4 – landless rural households and micro-enterprises

Rural World 4 households are landless, frequently headed by women, with little access to productive resources other than their own labour. Sharecropping or working as agricultural labourers for better-off households in their communities is perhaps the most secure livelihood option for many of them. For others, migrating to economic centres on a daily, seasonal or even permanent basis is their best hope for survival. But their low education levels are a major barrier to migrating out of poverty. Community ties, the glue in this group's socioeconomic sphere, can be an important asset in seeking out alternative livelihood options. But participation in more influential economic and political networks is not common. As for Rural World 3, the fortunes of Rural World 4 rely on Rural Worlds 1 and 2 for employment and income-earning opportunities.

2.12.5 Rural World 5 – chronically poor rural households, many no longer economically active

Rural World 5 households are chronically poor. Most have sold off or been stripped of their asset holdings during periods of crisis. Remittances from relatives, community safety nets and government transfers are vital to their sustenance. As a result of the HIV/AIDS pandemic, many more households are facing this precarious situation. Entrenched gender inequalities exacerbate this problem. Social exclusion often typifies the relationship of Rural World 5 to the larger community. Cash and in-kind transfer schemes will be critical for this group for some time.

2.13 Framing agriculture's contribution to pro-poor growth in the new context

Agricultural sector productivity gains and market access lie at the core of a more robust agricultural economy and of pro-poor growth. Endeavours to increase sector productivity and expand market access must recognise from the outset, however, that the challenges facing today's rural households are much different from those confronted bythe Green Revolution producers who recorded rapid and sustained gains only two or three decades ago. Many of today's poorest producers live in less favoured or fragile regions, whose agricultural potential is being jeopardised by degradation of the natural resource base and constrained by inadequate attention to infrastructure needs (World Bank, 2003).

In sub-Saharan Africa, where many of the poorest rural households are located, there is no dominant food-production system. Instead, a wide variety of production systems serve as the livelihood foundation for agricultural communities. The demography of these and many other rural communities is also changing rapidly, as agriculture is increasingly becoming feminised through the effects of migration and the impacts of HIV/AIDS. Many producers lack access to key inputs and services, including credit and extension. Moreover, many small producers now compete in markets that are much more demanding in quality and food safety and distorted by OECD agricultural subsidies and the trade barriers of developing countries (OECD, 2011a).

In many developing countries, especially in South Africa, there still is excellent growth potential for small producers in the food staples sector. For Africa as a whole, the consumption of these foods accounts for the lion's share of agricultural output and is projected to double by 2015. This will add another USD 50 billion to demand (in 1996-2000 prices). Moreover, with more commercialisation and urbanisation, much of this added demand will translate into market transactions, not just additional household consumption (wolrd bank, 2012a).

No other agricultural markets offer growth potential on this scale to reach huge numbers of Africa's rural poor. Many small producers could double or triple their incomes if they could capture a large share of this market growth. Simulations with economy-wide models at the International Food Policy Research Institute confirm this conjecture. For Ethiopia (a poor and food-deficit country) the fastest way to reduce poverty by 2015 is through productivity growth in food staples. This strategy outperforms a strategy built around increasing the production of high-value products (Hazell, 2004). If small producers are to capture a fair share of this growth in food staples, particularly in Africa, they will have to become more competitive, especially against cheap food imports from abroad. In many middle and higher income countries in Asia and Latin America, food staple market opportunities are more constrained,

with demand growth linked more to growth in livestock feed or export opportunities than to domestic human consumption. In these cases small producers need urgently to diversify into higher value products that face much better demand prospects. A challenge for this "new" high-value agriculture is to make it pro-poor. Left to market forces alone, the major beneficiaries of the new high-value agriculture will mostly be the larger and commercially oriented producers and producers well connected to roads and markets. The majority of small producers are likely to get left behind (World Bank 2012c). Fortunately, there is great opportunity to guide the new high-value agriculture so that small producers and even many backward regions can participate

Influence in society, both in official organisations and informal village associations, is distributed along gender lines. Hence policy needs to consider women's access to, and interaction with, informal and formal networks, marketing organisations and administrations – as well as training for women producers and entrepreneurs to learn about and adapt to new economic structures and marketing (OECD, 2012a).

2.14 Increasing the agricultural sector's productivity

The productive potential of agriculture is highly varied and depends on the natural endowment, geographical location, links to the rest of the economy and social dimensions of the population. But the general failure in recent decades to achieve sustained rates of agricultural sector productivity and the pro-poor growth linked to it, especially in sub- Saharan Africa, can be put down to inappropriate policies, inadequate institutions and services, failures to invest in appropriate infrastructure, and failures to invest in the development of the human, social and natural capital that agricultural households need to achieve higher productivity (OECD, 2010a).

Governments need to make choices in allocating resources for the support of agriculture. There is a strong argument to prioritise such support to producers and enterprises of Rural Worlds 2 and 3, where the stage of economic development of a country and the availability and relative cost of labour mean that there would be a greater impact on poverty from government support. For developing countries such as South Africa the attraction of small production units lies in their economic efficiency relative to larger units. They can create large amounts of productive employment, reduce rural poverty, support a more vibrant rural economy and help reduce rural-urban migration (OECD, 2012e).

The very limited capacity of the vast majority of poor rural households to access, analyse and utilise new knowledge on improved practices is a binding constraint to enhanced productivity. Research, development and information services that address this constraint have been weakened by years of

under-funding and by failures of institutions to respond in relevant ways to the needs of agricultural producers, especially those in Rural Worlds 2 and 3 (International Fund for Agricultural Development, 2004). As a result, producers who lack the resources to obtain it on their own have not had access to the information and technologies that would enable them to adopt improved production strategies and increase the income and well-being of their households. Pro-poor strategies for agricultural research and its dissemination need to be tailored to the needs of the rural worlds and be aware of the broad range of factors affecting their adoption of new technology. Research strategies need to incorporate knowledge from local actors, and an institutional framework based on much greater participation of a wide range of stakeholders needs to be developed. Innovative approaches to the delivery of associated information services, including public, private and civil society actors, also need to be developed (Timmer, 2009).

In identifying the constraints to productivity enhancement in the different rural worlds it is important to recognise that both land and labour productivity are central to pro-poor growth. In the early stages of development, land productivity is most critical in order to create additional employment opportunities in agricultural production. In the later stages, labour productivity increases in importance as off farm wage rates rise but demands for agricultural workers remain high. Three broad categories of technology are available to increase the productivity of agricultural households: intensifying input-based production, managing natural resources better, and diversifying outputs in primary production or household post-harvest processing to capture more value added.

2.15 Small-scale agriculture

The efficiency of smaller production units in most developing countries is demonstrated by an impressive body of empirical studies showing an inverse relationship between unit size and land productivity (Heltberg, 1998). Moreover, small producers often achieve higher land productivity with lower capital intensities than large units. These are important efficiency advantages in many poor countries where land and capital are scarce relative to labour.

The greater land productivity of small units stems from their greater abundance of household labour per hectare cultivated. Household workers are typically more motivated than hired workers are, and they provide higher quality and self-supervising labour. They also tend to think in terms of whole jobs or livelihoods rather than hours worked, and are less driven by wage rates at the margin than hired workers. Small producers exploit labour using technologies that increase yields (hence land productivity), and they use labour intensive methods rather than capital-intensive machines. As a result,

their land and capital productivities are higher and their labour productivity is typically lower than that of large production units. This is strength in labour-surplus economies such as South Africa, but it becomes a weakness for the long-term viability of small-scale production as countries get richer and labour becomes more expensive (Bhoart, 2000).

In poor, labour-abundant economies, small producers are not only more efficient but they also account for large shares of the rural and total poor, so small production unit development can be win-win for growth and poverty reduction. Asia's Green Revolution showed how agricultural growth that reaches large numbers of small units could transform rural economies and raise enormous numbers of people out of poverty (Rosegrant and Hazell, 2000). Recent studies show that a more egalitarian distribution of land not only leads to higher economic growth but also helps ensure that the growth achieved is more beneficial to the poor (Deininger and Squire, 1998; Ravallion and Datt, 2002). Small producers also contribute to greater food security, particularly in subsistence agriculture and in backward areas where locally produced foods avoid the high transport and marketing costs associated with many purchased foods. Small producer households have more favourable expenditure patterns for promoting growth of the local rural economy, including rural towns. They spend higher shares of incremental income on rural non-tradables than large production units (Mellor, 1976; Hazell and Roell, 1983), thereby creating additional demand for the many labour-intensive goods and services that are produced in local villages and towns. These demand-driven growth links provide greater income-earning opportunities for small producers and landless workers.

2.16 Intensifying input-based production

Intensifying input-based production, centred on seed varieties with higher productive potential and the fertilisers and pesticides to realise these potentials, was the focal point of the Green Revolution in Asia. Similar efforts, expanded to include livestock breeds and associated veterinary drugs and compound feeds, hold great potential for rural households in Rural Worlds 1, 2 or 3. This is particularly true in areas with good agro-ecological resources, low climatic risks, and good access to input suppliers and to markets.

Most of the opportunities for intensifying input-based production have already been exploited, however, and new opportunities will require much improved dissemination of existing intensification technologies, significant investments in infrastructure programmes and functioning input markets. Input-based production intensification can also degrade land, which over time limits the yield responses. Furthermore, in Africa far fewer producers have irrigation, resource endowments are often too poor,

and risks are too high for input-based intensification to be relevant to more than a few producers in Rural Worlds 1 and 2.

Producers and processors in Rural World 1, also in some cases in Rural World 2, already benefit from advanced technologies based on the recent discoveries of molecular biology and genetic manipulation. However, much of this technology remains primarily aimed at users in developed countries and has been financed by multinational companies. For the originators of the technology, research and development geared to the needs of the rural poor in developing countries are not considered high return investments. Application of some of the principles of these advanced technologies to the needs of poorer producers in Rural Worlds 2, 3 and 4 could nevertheless do much to raise their productivity and reduce risks. For instance, tissue culture can generate virus-free, and hence more productive, stocks of perennial crops that are important to the survival strategies of poor households.

2.17 Managing natural resources better

Natural resource management practices typically raise the productivity of household labour through changes in agricultural practices, such as managing water, soils and crop residues to augment in situ capture and retention of rainfall and raise land productivity or controlling pests and weeds by exploiting natural biological processes. Approaches such as dry-land cultivation, water harvesting and flood recession farming as well as dissemination of demand management techniques such as irrigation water conservation and waste water reuse can help address the needs of poor agricultural households while promoting sustainable use of water. Genetic improvements can play an important part in these efforts, but often do more to reduce risks by stabilising and diversifying production rather than maximising yield (World Bank, 2007).

This category of technology is knowledge-intensive and often location-specific. With less stress on maximising yields, it seeks to lower risks and unit costs of output. It can be a first technology for many agricultural households in Rural World 3 that retain some usable land and labour but have no financial reserves, as well as for the financially vulnerable in Rural World 2. It can help women, the old and households with labour forces depleted by migration or HIV/AIDS to increase household food production on the small parcels of land they have retained. Developing the needed natural resource management technologies will require investments in science and technology, and disseminating existing technology will require widely distributed and skilled technical support on the ground all over the country (World Bank, 2007).

Integrated water resource management can support the sustainable and equitable use of water. An integrated water policy relies on improved planning and legal frameworks, analysis of supply and demand, improved education and sector co-ordination. Co-ordination and arbitration are essential in conflicts arising due to increasing water scarcity, especially for cross-border resources where only supra-national or external bodies can provide a structure for dialogue. Co-ordination also improves water governance by enhancing decision makers' accountability for resource development and management (OECD, 2011a).

Policy must be tailored to increase the efficiency of natural resource management by incorporating knowledge from women and promoting greater participation of women stakeholders. Erosion, drought, floods, desertification and pollution mean that women find it harder to collect food, fuel and water. Poor sanitation has implications for health and the schooling of girls and women. In addition, women often have more knowledge about the ecosystems, but are often not included in natural resource management and environmental protection (OECD, 2011c).

2.18 Diversifying outputs

The diversification of outputs involves a change in primary production or household post-harvest processing to capture more value added. This category spans a wide range of technological options from household processing of cassava roots – to making milk products to sell to passers by – to organic farming and the production of fruits or poultry to supply global supermarket chains. Often market demands make this category of technology better suited to well resourced producers in Rural Worlds 1 and 2, who can more easily meet demands for volume, quality and timeliness of deliveries. Others in Rural World 2 as well as in Rural World 3 are likely to need finance and extensive institutional support to diversify, organise marketing and maintain technical quality. Risks and financing needs for diversification will tend to be higher than those for merely upgrading production technology for existing staples. Careful prior assessments of markets and their needs, good information systems and ready rural access are other prerequisites for successful diversification. But for many small producers for whom the returns from staple crop production are no longer sufficient to earn a living, diversifying outputs may be the only technical strategy that will allow them to stay on the land (OECD, 2011a).

2.20 Improving market access

Productivity gains can mean little without expanded access to markets. Market structures in many rural regions of the developing world are very weak, so the allocative efficiencies that markets achieve in fast-growing sectors of their economies do not materialise. Instead, undeveloped market demand for outputs discourages producers from raising production, while the consequent failures of incomes to rise in rural areas deter private traders and rural enterprises from entering and doing business. A vicious cycle. In the absence of functioning markets, rural areas remain trapped in a subsistence economy in which neither the narrow agricultural production sector nor the wider rural economy (both of which generate off-farm employment opportunities) can grow. In the past many governments tried to address agricultural market failures in rural areas by creating state-managed organisations, such as marketing boards. Most of these interventions proved to be costly failures, often enabling widespread corruption to take hold in rural economies, and are becoming less and less common. The problems associated with weak markets remain, however, and new efforts are required if the agricultural sector is to spark sustained and rapid growth in poor countries. These efforts should focus on creating effective markets through improving the enabling conditions for wider private sector participation. Removing restrictions on the movement, sale and purchase of agricultural products is one example where changes are needed. Insecure property rights, weak financial services and poor infrastructure are three of the most common barriers to more efficient rural markets, often to the notable disadvantage of women. There is mounting evidence for attention to all three areas to transform stagnating rural areas (World Bank, 2000a).

2.21Secure property rights

For most of the rural poor in developing countries, land is the primary means for generating a livelihood and a main vehicle for investing, accumulating wealth and transferring it between generations. Because land makes up such a large share of the asset portfolio of the poor, giving secure property rights to land they already possess can greatly increase the wealth of poor people who, unlike the rich, cannot afford the (official and unofficial) fees needed to deal with the formal system.

Unequal ownership of land is also a critical factor that creates and maintains differences between women and men in the Africa but, to be more specific, in South Africa it has been between racial groups, with consequences for the coming generations. In Kenya, for example, only 5% of the landowners are women, despite the fact that African women produce 60%-80% of the continent's food (Kameri-Mbote and Mubuu, 2002). A World Bank policy research report, "Land Policies for Growth and Poverty

Reduction", concludes that the increased control by women over land titles could have "a strong and immediate effect on the welfare of the next generation and on the level and pace at which human and physical capital are accumulated" (World Bank, 2003). Ensuring that women have secure rights to land is thus critical in many respects, including the challenges arising in the context of the HIV/AIDS epidemic, where the absence of secure land tenure for women who have lost their husbands has been shown to be a key reason for costly conflict and additional hardship.

Secure title to land not only promotes wealth creation but can also enhance security. China illustrates that broad-based land access can provide a basic social safety net at a cost much below alternative government programmes, allowing government to spend scarce resources on productive infrastructure instead of safety nets. Having their basic subsistence ensured is likely to have allowed Chinese households to take on greater risks in non-agricultural businesses. With policies to foster lease markets for land, this also contributed significantly to a vibrant rural economy.

2.22 Opening access to rural land by outside investors

Despite evidence on the productive efficiency of small producers, policy makers in many developing countries specifically South Africa prefer large-scale production, often an excuse to give very generous land concessions at conditions very favourable to the awardees. There is a real issue, however, on how to provide access to the links, for marketing and processing, necessary for small producers to make the optimum use of their land and to choose a model for the organisation of production that helps to maximise economic efficiency, especially in very land-abundant settings. Models to do that exist but need to be developed further (Deininger, 2001).

2.23 Increasing access to finance

One of the critical reasons that well functioning land institutions and markets improve the environment for private sector investment is that the ability to use easily transferable land titles as collateral reduces the cost of credit for entrepreneurs and increases opportunities for gainful employment. It has the added advantage of developing rural financial systems.

Deepening rural financial markets is a high priority in an improved incentive framework that enables the agricultural sector to serve as a key driver for pro-poor growth. For the past two decades, however, most donors in South Africa have and government institutions provided very little funding for rural finance, and as part of structural adjustment programmes many partner countries have ended their substantial involvement in this area of activity. That has left a vacuum in the supply of seasonal credit for small producers. While private banks may still service the needs of large commercial enterprises,

small producers and firms who want to finance the purchase of productivity-enhancing technologies, or access new markets, often have to rely on self-financing or household financing, sell livestock and other assets, borrow from local money lenders or use remittances from household members(world bank, 2000c).

A return to the previous subsidised government credit schemes, with their artificially low interest rates and high rates of delinquency, is neither feasible nor desirable. Earlier government involvement in the management and implementation of rural financial systems was expensive and inefficient. The programmes were plagued by a poor repayment culture and the financial instability of the lending institutions. In much of the developing world today, the inability of poor rural households, particularly female members, and enterprises to access credit on competitive terms to invest in new economic opportunities means that their incomes are lower than they need be. Moreover, without adequate access to risk-reduction instruments (such as weather based crops or insurance for commodity market prices), rural households and enterprises may even retreat from profitable projects for which they have adequate liquidity. The absence of savings instruments also leads to less productive forms of savings, further reducing the scarce liquidity of poor rural households (Deininger, 2001).

A number of factors thwart the development of vibrant financial markets in rural areas. The high transaction costs associated with dispersed populations and poor physical infrastructure, along with the particular needs and higher risk factors inherent in agriculture; result in the under-provision of financial services (United States Agency for International Development, 2003). It is critical that strategies for rural financial market development be put in place and that rural households have equitable access to financial services for their business and domestic needs. Giving micro credits to poor women in rural areas has proved to be a strong concept. Taking into account the vulnerable livelihood situation of many women and, for the most part favourable results of, for example Grameen Bank, more micro credit facilities for women producers should be actively promoted.

2.24 Improving infrastructure

Improved infrastructure, including rural roads, rural electrification, irrigation and storage facilities links small producers to markets and reduces their risks and transaction costs. It saves time in transporting water, crops, wood and other products rural households produce. It increases the volume of marketable goods and reduces costs for inputs needed to produce these costs. And it gives them much greater access to social services, including health and education, which can provide them with new livelihood opportunities. It is important to encourage the participation of beneficiaries in planning, construction

and operation, and maintenance of the infrastructure in order to strengthen their ownership and sustainability (World Bank, 1994).

Several recent studies highlight the link between weak infrastructure and rural poverty. Jalan and Ravallion (2002) find that road density has a significant positive effect on consumption expenditure in agricultural households in poor regions of China. Research in Vietnam indicates that poor households have a much greater probability of escaping poverty if they live in communities with access to paved roads (Glewwe et al., 2000). Fan (2004) has also demonstrated that investments in rural infrastructure significantly contribute to agriculture growth and to poverty reduction. Improved infrastructure not only expands opportunities for growth but also ensures that growth is more diffused and equitable.

Despite infrastructure's recognised importance, many governments and donors have slashed their infrastructure investments in rural areas in recent years. Many developing countries, especially in Africa, still have inadequate infrastructure. Achieving pro-poor growth through agriculture will require much greater attention to this critical area of investment.

2.25 Improving institutions for higher productivity and greater market access

The challenge for many developing countries is to find more effective ways to pay for additional public investments, and to develop suitable institutional arrangements for their delivery. Effective public institutions require an adequate supply of trained people, including policy advisors, agricultural researchers and extension workers, business managers and financial and computer experts. Past investments in training did increase the supply of some types of key personnel, despite the fact that many did not return from overseas training. But HIV/AIDS, ageing, and low salaries and morale within public institutions have contributed to chronic staff shortages in many countries. Strengthening public institutions that provide public goods and services can reduce costs while improving the quality of services. New innovations may be needed for this. Increased donor support of key public sector investments could be provided through new financing arrangements (vouchers, user fees and some co-financing mechanisms) that empower the users of public services and through appropriate institutional reforms to improve mandates and performance. And new partnerships need to be formed by the public, private and non profit organization (NGO) sectors for the provision of public services (World Bank, 2007).

Even though government must pay for many goods and services, it does not have to deliver them. Recent years have seen considerable success in using non-governmental and community-based organisations to deliver targeted assistance to the poor, and private firms can be contracted to build and

maintain schools, health centres, roads and the like. Contracting arrangements can be very cost-effective and may offer better possibilities for involving local people and communities. The types of partnerships desired will vary by sector and function, with many more opportunities to diversify supply arrangements for education and health services than for rural roads and market regulation.

2.26 Small producers for marketing

Small producers have always been at a disadvantage in the marketplace, and in some places these disadvantages are increasing. Small producers typically trade only in small volumes, often have variable and sub-standard quality products to sell and lack market information and links with buyers in the marketing chain. These inefficiencies can all too easily offset the efficiency advantages of small production units.

Many small producers must now also compete in ever more integrated and consumer driven markets where quality and price are everything. In the new and rapidly expanding global value chains, the private sector is emerging as a key player in linking larger-scale commercial producers with markets (contract farming and supermarkets), but they have less interest and ability in dealing with small-scale producers on an individual basis. Those small-scale producers will need to organise themselves to overcome these problems and to exploit the new opportunities that these market changes offer. Otherwise, they risk losing market access (Vorley and Fox, 2004).

Widespread and pervasive market failures, particularly in countries at the earliest stages of economic development, may provide some justification for a more direct role for the state, through using subsidies to create or build markets aimed to kick-start productivity gains. Fertiliser and irrigation subsidies had a powerful effect on development during the Green Revolution in Asia. But they can also distort markets and deliver decreasing returns as productivity and overall levels of development rise; they demand levels of state capacity and governance that may be lacking. Furthermore, subsidy systems are highly politicised and can be difficult to dismantle once set up – as current experience in India shows. Thus subsidies present governments with dilemmas when it comes to justifying their use to overcome initial perceptions of commercial risk or the high costs of working in thin and weak markets.

Subsidies or guarantees should generally be temporary measures to tackle specific barriers to private participation in markets. Persistent use may add to rather than solve underlying problems. Subsidies should not be used to provide a market for all producers or to provide general support to producers' incomes, since this will tend to benefit disproportionately the larger and more successful producers.

Many now believe that improved market access for small producers can best be promoted as one plank in the platform of well-structured producer federations that can defend the interests of the small producers in a range of policy and programme negotiations and ensure that the necessary services are put into place. Unlike former state co-operatives, widely discredited because of their poor performance and high cost, the new producer organisations should be voluntary, economically viable, self-sustaining, self-governed, transparent and responsive to their members. The functions of these associations should include establishing information systems and connections to domestic and global markets, creating good governance practices, and creating the infrastructure to connect small holders to finance and input supply systems. The associations can also have a role in establishing new forms of production insurance, hedging price "fluctuations" and developing new forms of public and private partnerships.

2.27 The Role of Agriculture in Economic Development

The role of agriculture in economic development is complicated and controversial, despite a long historical literature examining the topic (Johnston and Mellor, 1961; Hayami and Ruttan, 1985; Timmer, 2002). Part of the controversy stems from the structural transformation itself, which is a general equilibrium proc ess not easily understood from within the agricultural sector (Timmer, 1988). Over long historical periods, agriculture's role seems to evolve through four basic stages: the early "Mosher" stage when "getting agriculture moving" is the main policy objective (Mosher, 1966); the "Johnston-Mellor" stage when agriculture contributes to economic growth through a variety of linkages (Johnston and Mellor, 1961); the "T.W. Schultz" stage when rising agricultural incomes still fall behind those in a rapidly growing non-agricultural economy, inducing serious political tensions (Schultz, 1978); and the "D. Gale Johnson" stage where labor and financial markets fully integrate the agricultural economy into the rest of the economy (Johnson, 1997; Gardner, 2002). These stages were first proposed in Timmer (1988) and are developed in the context of more recent experience in the World Bank's latest treatment of the role of agriculture in poverty reduction (World Bank, 2004d). Efforts to "skip" the early stages and jump directly to a modern industrial economy have generally been a disaster.

Another reason for controversy over the role of agriculture stems from the heterogeneity of agricultural endowments and the vastly different cropping systems seen in Latin America, Africa and Asia (not to mention the diversity within these regions). It is unrealistic to expect much of a common role in such diverse settings. When coupled with the enormous differences in stages of development around the world, and hence the vastly different roles that agriculture plays in economies at different levels of economic maturity, it is easy to understand why there is so little common ground in academia or the

donor community on the role of agriculture in economic development. Bravo-Ortega and Lederman (2004) document clearly the different contributions of agriculture to national welfare across these various categories.

There does seem to be widespread agreement in the literature on the basic linkages connecting agriculture and overall economic growth that was first articulated to a general economics audience by Lewis (1954) and Johnston-Mellor (1961). At a conceptual level, these linkages have long been part of the core of modern development theory and practice (Timmer, 1988; 2002). Establishing the empirical value of these linkages in different settings has been a cottage industry since the early 1970s (Byerlee, 1973; Hazell and Roell, 1983; Haggblade; Fan, Hazell and Thorat; Fan, Thorat and Rao, 2004).

Virtually all of these studies conclude that the "agriculture multiplier" is significantly greater than one, especially in relatively closed, "non-tradable" economies of the sort found in rural Africa, where the multiplier is often between 2 and 3. But even in the more open economies of Asia, where rice was more tradable than most African staple foods and local prices more easily reflected border prices, the agriculture multiplier is close to 2 in the early stages of agricultural modernization when productivity gains are the fastest. Because economic growth usually has a direct impact on poverty, any contribution agriculture makes to speeding overall economic growth through these large multipliers will, in most circumstances, also directly contribute to reducing poverty (Dollar and Kraay, 2002; World Bank, 2004a).

Despite the potential impact of these large multipliers, a combination of market failures and political biases led to a systematic undervaluation of output from rural economies. Correcting these biases can have economy-wide benefits. The historic bias against the rural sector in developing countries left them starved of resources and discriminated against by macro economic and trade policies (Lipton, 1977; Timmer, 1993). Failures in rural credit and labor markets – some of which can cause "poverty traps" – have provided the analytical context for much of modern neoclassical development economics (Dasgupta, 1993). But even global commodity markets for many products from developing countries "fail" in the sense that agricultural surpluses from rich countries are dumped there, depressing world market prices below long-run costs of production.

A final set of linkages makes growth originating in the agricultural sector tend to be more "pro-poor" than it would be if the source of growth came from the industrial or service sectors (Mellor, 1976; Ravallion and Datt, 1996; Ravallion and Chen, 2004; Timmer, 1997, 2002). New agricultural technologies that improve farm productivity strengthen this connection. Separate reviews by Thirtle, et al. (2004) and

by Majid (2004) confirm the strong empirical link between higher agricultural productivity and poverty reduction.

2.28 Direct contribution to economic growth via Lewis linkages

The "Lewis Linkages" between agriculture and economic growth provide the non-agricultural sector with labor and capital freed up by higher productivity in the agricultural sector. These linkages work primarily through factor markets, but there is no suggestion that these markets work perfectly in the dualistic setting analyzed by Lewis (1954). It tries to explain how a developing economy moves from a traditional agricultural base to a modern manufacturing led economy. The model assumes that a developing economy has a surplus of unproductive labour in the agricultural sector. These workers are attracted to the growing manufacturing sector where higher wages are on offer. It is also assumed that the wage on offer in the manufacturing sector is fixed. Entrepreneurs in the manufacturing sector will make a profit because they charge a price above the fixed wage rate. The model then assumes that these profits will be reinvested in the business in the form of more fixed capital. Firms productive capacity is thus increased and entrepreneurs will demand a greater amount of labour. More workers will be employed from the surplus found in the agricultural sector. The process continues until all surplus labour from the agricultural sector has been employed. The manufacturing sector has grown and the economy has moved from a traditional to industrialized one. Chenery and Syrquin (1975) argue that a major source of economic growth is the transfer of low-productivity labour from the rural to the urban sector. If labor markets worked perfectly, there would be few productivity gains from this structural transfer. This has been much the case over the years in the South African economy with a rapidly growing manufacturing sector and a shrinking agricultural sector in size.

2.29 Indirect contributions to economic growth via Johnston-Mellor linkages

The "Johnston-Mellor Linkages" allow market-mediated, input-output interactions between the two sectors so that agriculture can contribute to economic development. These linkages are based on the agricultural sector supplying raw materials to industry, food for industrial workers, markets for industrial output, and the exports to earn foreign exchange needed to import capital goods (Johnston and Mellor, 1961). Mellor explained that "the faster agriculture grows, the faster its relative size declines." Others have dubbed this "Mellor's Law." Mellor's observation stems from the possibility that technological changes can overcome the effects of a growing population, and following Engel's Law, as per capita income increases, the percentage of income spent on food will decline leading to a relative decline in the size of the agricultural sector. Where agriculture represents a large share of total output, structural transformation requires increases in agricultural productivity. In the process, agriculture becomes

relatively less important while paving the way for the development of the nonagricultural sector. Even today leaders in the international development community still hold that this notion "captures the essence of agricultural growth and its causal relationship to the structural transformation and aggregate growth of an economy." Mellor further notes that the relationship described in the above statement "can be illustrated by comparing the agricultural and nonagricultural growth rates of countries in each of the world's three major geographical regions [meaning Asia, Africa, and Latin America]."Again, for the Johnston-Mellor linkages as with the Lewis linkages, it is difficult to see any significance for policy or economic growth unless some of the markets that serve these linkages are operating imperfectly (or, as with many risk markets, are missing altogether). That is, resource allocations must be out of equilibrium and face constraints and bottlenecks not immediately reflected in market prices if increases in agricultural output are to stimulate the rest of the economy at a rate that causes the "contribution" from agriculture to be greater than the market value of the output, i.e. the agricultural income multiplier is greater than one (Timmer, 1995).

2.30 Roundabout contributions from agriculture to economic growth

Writing in the mid-1960s, Mosher was able to assume that "getting agriculture moving" would have a high priority in national plans because of its "obvious" importance in feeding people and providing a spur to industrialization (Mosher, 1966). That assumption has held only in parts of East and Southeast Asia, and has been badly off the mark in much of Africa and Latin America. In the latter regions, a historically prolonged and deep urban bias led to a distorted pattern of investment. Too much public and private capital was invested in urban areas and too little in rural areas. Too much capital was held as liquid and non-productive investments that rural households use to manage risk. Too little capital was invested in raising rural productivity.

Such distortions have resulted in strikingly different marginal productivities of capital in urban and rural areas. New growth strategies--such as those pursued in Indonesia after 1966, China after 1978, and Vietnam after 1989--altered investment priorities in favor of rural growth and benefited from this disequilibrium in rates of return, at least initially. For example, in Indonesia from the mid-1960s to the mid-1990s, farm GDP per capita increased by nearly half, whereas it had declined from 1900 to the mid-1960s. In China, the increase from 1978 to 1994 was nearly 70 percent, whereas this measure had dropped by 20 percent between 1935 and 1978 (Prasada Rao, Maddison and Lee, 2002). A switch in investment strategy and improved rates of return on capital increase factor productivity (and farm income) because efficiency in resource allocation is improved.

One explanation for more rapid and pro-poor economic growth as urban bias is reduced is provided by Mellor's model of agricultural growth, rural employment and poverty reduction that emphasizes the role of the rural non-tradables sector in pulling underemployed workers out of agriculture and into the non-agricultural rural economy. The Mellor model explicitly integrates manufactured export performance (the source of much dynamism in East Asia's economies since the 1960s) and the non-tradables sector in the rural economy (which includes a wide array of local agro-processing) to explain subsequent reductions in poverty. This model, drawing on Mellor's earlier work in India (Mellor, 1976) and more recently in Egypt (Mellor, 2000), explains why countries with substantial agricultural sectors that experienced rapid growth from labor-intensive manufactured exports had such good records of overall economic growth and poverty reduction.

An additional set of linkages focuses on more nebulous and hard-to-measure connections between growth in agricultural productivity and growth in the rest of the economy. These linkages grow explicitly out of market failures, and, if they are quantitatively important, government interventions are required for the growth process to proceed as rapidly as possible. The contribution of agricultural growth to productivity growth in the non-agricultural economy stems from several sources: greater efficiency in decision making as rural enterprises claim a larger share of output and higher productivity of industrial capital as urban bias is reduced; higher productivity of labor as nutritional standards are improved; and a link between agricultural profitability (as distinct from agricultural productivity) and household investments in rural human capital, which raises labor productivity as well as facilitates rural-urban migration.

Several of these mechanisms stand out as likely to be important (and potentially measurable) because they draw on the efficiency of decision making in rural households, the low opportunity cost of their labor resources, the opportunity for farm investment without financial intermediaries, and the potential to earn high rates of return on public investments that correct for urban bias. Each of these factors alone, as public investments and favorable policy stimulate growth in the agricultural sector, should cause an increase in the efficiency of resource allocation. In combination, these mechanisms should translate faster agricultural growth into measurably faster economic growth in aggregate, after controlling for the direct contribution of the agricultural sector to growth in GDP itself.

One of the most visible determinants of poverty is hunger and malnutrition. The development profession continues to argue over the causation—whether hunger causes poverty or vice versa--but hunger as a measure of poverty is widely established. Most poverty lines have an explicit or implicit food

component. The evidence for nutritional poverty traps, where workers are too malnourished to work hard enough to feed themselves and their families, has strong historical roots (Fogel, 1991, 1994; Bliss and Stern, 1978; Strauss, 1986; Strauss and Thomas, 1998). But simple energy shortages cannot account for very much of the chronic poverty observed over the past several decades because the cost of raw calories, in the form of staple foods, has fallen too sharply relative to wages for unskilled labor (Johnson, 1997; Fox, 2002). If inadequate food intake is the primary cause of poverty, the solution would be in sight (and food aid could be an important part of the answer). If, however, poverty is the main cause of inadequate food intake, hunger will be much harder to end. In most countries, the domestic agricultural sector is likely to play a key role in ending hunger (and ready availability of food aid may well be part of the problem).

2.31 Connecting Agriculture to Poverty Reduction

In current strategies used by countries and donor agencies to cope with poverty, the role of agriculture has been limited, largely because of failure to recognize the importance of direct links between agricultural development, food availability, caloricfic intake by the poor, and reduction in poverty. Part of the reduction in poverty is definitional because the poverty line is often measured in caloricfic terms. But raising caloricfic intake of the poor has a positive effect on their well-being, work productivity, and investment in human capital. Empirical evidence provided by Paul Schultz (1993) and Fogel (1991) illustrates this importance, but a more general case can also be made.

The case builds on three empirical relationships: between agricultural growth and poverty alleviation; between increases in domestic food production and improvements in nutrient intake; and between agricultural productivity and productivity growth in the rest of the economy. It has long been established that, for a given level of income per capita, a higher share of GDP originating in agriculture contributes to a more equal distribution of income (Kuznets, 1955; Chenery and Syrquin, 1975). An agriculture-driven growth strategy, if it does not sacrifice aggregate growth, directs a greater share of income to the poor, i.e. it is more pro-poor. This is the essential first step in breaking the cycle of poverty.

Next, increases in domestically produced food supplies contribute directly to increases in average caloric intake per capita, after controlling for changes in income per capita, income distribution, and food prices (Timmer, 1996). Countries with rapidly increasing food production have much better records of poverty alleviation, perhaps because of changes in the local economics of access to food, changes that are not captured by aggregate statistics on incomes and prices. The most recent confirmation of this

relationship is in Majid (2004). With the $1 per day headcount poverty rate from the International Labour Organisation (ILO) data set as the dependent variable, both the log of agricultural output per worker and the per capita food production index have a large and statistically significant impact on reducing poverty (controlling for per capita income and other standard variables).

Whatever the mechanisms, intensive campaigns to raise domestic food production through rural investments and rapid technical change, can be expected to have positive spillover effects on nutrient intake among the poor. This is the second step in breaking the cycle of poverty.

The third step is to ensure that these sectoral gains can be sustained without distorting the economy or destroying the environment. These dual goals can be achieved only if factor productivity increases for the entire economy. Eventually, growth in factor productivity must provide a substantial share of total growth in income per capita. When using its resource base efficiently, agriculture has a key role to play at this stage as well (Sarris, 2001; Timmer, 2005c).

2.31 Valuing the poverty-reducing role of agriculture

Agriculture has been seriously undervalued by both the public and private sectors in those societies in which poverty has remained untouched or even deepened. In addition to an urban bias in domestic policies, the root cause of this undervaluation is a set of market failures. Commodity prices, by not valuing reduced hunger or progress against poverty, often do not send signals with appropriate incentives to decision makers. These inappropriate signals cause several problems, in addition to those noted above.

First, low values for agricultural commodities in the marketplace are reflected in low political commitments. But political commitments to rural growth are needed to generate a more balanced political economy, with less urban bias than has been seen in most developing countries historically (Lipton, 1977; Timmer, 1993). The developing world has already seen a notable reduction in the macroeconomic biases against agriculture, such as overvalued currencies, repression of financial systems, and exploitive terms of trade (Westphal and Robinson, 2002). Further progress might be expected as democracy spreads and empowers the rural population in poor countries (although agricultural policies in most democracies make economists cringe).

The second problem with low valuation of agricultural commodities is that rural labor is also undervalued. This weakens the link between urban and rural labor markets, which is often manifested in the form of seasonal migration and remittances. There is no hope of reducing rural poverty without

rising real wages for rural workers. Rising wages have a demand and a supply dimension, and migration can affect both in ways that support higher living standards in both parts of the economy. Migration of workers from rural to urban areas raises other issues, of course, but those issues depend fundamentally on whether this migration is driven by the push of rural poverty or the pull of urban jobs (Larson and Mundlak, 1997).

Either way, the food security dimensions of rural-urban migration are clear. Urban markets become relatively more important in supplying food needs for the population. Whether the country's own rural economy or the world market is the best source of this supply will be one of the prime strategic issues facing economic policy makers and negotiators for the Doha Round of trade deliberations (Naylor and Falcon, 1995; Tabor, 2002; Elliott, 2004). It is no accident that China, through its commitments upon entering the WTO, has decided to use world markets to provision a significant share of its basic food supply. The intent is to keep food costs low and stable and thus to provide a competitive advantage to its labor-intensive industries and producers of high-value agricultural commodities.

2.32 Conclusion

Once all these elements are in place as the basis for profitable farming, policy attention and budget priorities should turn to the rural non-tradables sector. Part of the profitability for this sector will come from a labor-intensive export sector that is successfully linked into the global economy, and in many countries this will include the agri-business sector. Rapid growth in this export sector creates demand for labor directly as well as for the goods and services of the rural economy that raise demand for labor indirectly for the South African economy.

The rural non-farm sector is usually the bridge between commodity-based agriculture—which is often on a "treadmill" between rising productivity and falling prices (Gardner, 2002)—and livelihoods earned in the modern industrial and service sectors in urban centers. Throughout South Africa most rural households earn half or more of their incomes from non-farm sources, and often this sector is the "ladder" from underemployment at farm tasks to regular wage employment in the local economy and from there to jobs in the formal sector (bhoat, 1999). The following chapter takes an historical review on literature around agriculture productivity while focusing on the various methodologies used and discussing the important findings.

CHAPTHER THREE

EMPIRICAL LITERATURE

3.0 INTRODUCTION

Over the years numerous studies have contributed to the field of agricultural productivity. This chapter takes an historical and comprehensive look at the literature on agriculture productivity while focusing on the various methodologies used and discussing the important findings. The document consists of two sections. Section 1 presents the profile of the South African agricultural sector and reviews the productivity growth studies in South Africa. Section 2 reviews the agricultural productivity growth studies. The last section of this document provides the summary and concluding comments.

For each era, I identify common elements regarding methodology used, research questions analyzed, and the research findings. I also determine how theoretical and empirical research in a given period influences those of the subsequent period(s). This allows us to identify the evolution of research methods used in the analysis of agricultural productivity growth as well as the evolution of different research directions or emphasis. Most importantly, assessing the productivity growth literature provides us with great insights into this important research area.

Agricultural productivity is a key driver for the well-being of the farmers, the agro-based industry and mankind at large. It is linked to food security, prices, and poverty alleviation in developing countries (Darku & Malla, 2010). Moreover, food supplies have to be geared to meet the challenges of increasing global population, changes in income, and the resultant changes in diet (Bruinsma, 2009). Hence, research on agricultural productivity is of paramount importance. Studies reviewed here have used a number of different methods/approaches to measure productivity as well as different concepts/types of productivity. Various methods of estimating productivity growth have yielded different results due to different assumptions and methodological characteristics. In terms of concepts, productivity growth is classified into three components: technical change, scale effects, and changes in the degree of technical efficiency (Coelli *et al* 2005).

Technological progress captures the idea that production function can shift over time. It refers to the situation in which a firm can achieve more output from a given combination of inputs or equivalently, the same amount of output from fewer inputs. Technical change refers to technological progress in its broadest sense, including advances in physical technologies and innovations in the knowledge base, while, scale effects occur when additional output requires less than proportionate increase in inputs. Finally, technical inefficiency indicates the amount by which actual output falls short of the maximum

possible output. Technical efficiency occurs when resources are used more efficiently by applying practices from the present stock of knowledge. In terms of this approach, productivity measures are broadly divided into partial and total measures. The most common partial productivity measures for the agriculture sector are crop yield and labor productivity, which refer to the amount of output per unit of a particular input. Specifically, crop yield is a measure of output per unit of land, and normally is used to access the success of new production practices or technology. Similarly, labor productivity measures the output per economically active person (EAP). The partial productivity measures could be misleading because they reflect the joint effect of a host of factors and might not give any clear indication of why they change over time. For example, land and labor productivities may rise due to increased use of other inputs such as tractors or fertilizers, or to a move to high value crops. The methodology used in determining total productivity could be grouped into index numbers or growth accounting techniques; econometric estimation of production relationship; and non-parametric approaches (Data Enveloping Analysis-DEA). Index numbers or growth accounting techniques aggregate all inputs and outputs into input and output indices to calculate total factor productivity (TFP) index, while imposing several strong assumptions about technology. The non-parametric approaches (Data Enveloping Analysis-DEA) use lineal programming technique, and since the model is not statistical, it cannot be statistically tested or evaluated. Finally, the different methods should not be viewed as competitors; there could be important synergies of methods to generate comprehensive results for policy analysis. For example, econometric methods are used to analyze the determinants of TFP obtained by the index method.

SECTION A

3.1 Economic contribution

South Africa has a dual agricultural economy: a well-developed commercial sector and a predominantly subsistence sector. About 12% of the country can be used for crop production. High-potential arable land comprises only 22% of total arable land. Some 1.3 million hectares (ha) are under irrigation. Agricultural activities range from intensive crop production and mixed farming to cattle ranching in the bushveld, and sheep farming in the more arid regions (Department of Agriculture, Forestry and Fisheries, 2012).

Primary agriculture contributes about 4% to the GDP of South Africa and about 10% to formal employment. However, there are strong linkages into the economy, so that the agro-industrial sector comprises about 12% of GDP. Although South Africa has the ability to be self-sufficient in virtually all major agricultural products, the rate of growth in exports has been slower than that of imports. The only

increase in agricultural export volumes occurred during the period of exchange-rate depreciation in 2002 and came to about nine million tons (mt). Major import products include wheat, rice, vegetable oils and poultry meat (Department of Agriculture, Forestry and Fisheries, 2012).

The agricultural sector is of vital importance in the South African economy as it has major implications for job creation, rural development, food security and foreign exchange. The agricultural sector includes all activities relating to actual farming, the supply of inputs such as fertiliser and the processing and distribution aspects that add value to farm products. Commercial farming is the dominant performer in the agricultural sector, but small, subsistence and emergent farming also play a critical role. These farmers have a strong impact on poverty reduction, job creation and food security in rural areas (National Treasury, 2003).

South Africa is a country lacking sufficient water supplies. It is also characterised by a shortage of high potential agricultural land. The non-agricultural demand for both these resources is escalating (Department of Agriculture, Forestry and Fisheries, 1995).

3.2 Water deficit

Southern Africa is the second region in the world to be confronted by a debilitating water deficit (the first is the Middle East and North Africa) .Within the region, South Africa stands out as one of the most water-scarce countries. The country is also characterised by extremely variable rainfall, both geographically and over time. In 12% of the country that is suitable for the production of rain-fed crops, productivity tracks rainfall, making farming a challenging business. Climate change predictions are that rainfall will be more infrequent but more intense. This will shrink the country's arable land and increase agricultural unpredictability. Farmers will find it increasingly difficult to increase productivity to meet the growing demand for food. This highlights the need for sound cropping and rangeland production practices to retain soil integrity despite these predicted intense rainfall events (Turton,2000).

3.3 Droughts and food security

Droughts have major and long-term effects on the agricultural sector of South Africa. Food security is one of the main concerns resulting from drought in line with the view that hunger of the world is related to highly variable rainfall, especially in rural areas (UNDP-BCPR, 2005). Maize, for example, is highly sensitive to variations in rainfall as an extended dry period can result in lower grain formation and a decline in maize output (Clay et al., 2003).

Droughts may trigger adverse outcomes, for example the price of staple foods such as maize may escalate drastically wilth negative consequences to the poor. The price of basic foods tends to increase during droughts as supplies become scarcer. Larger farmers are also able to exacerbate rising prices as they release less stock to drive the price up to increase profits, but at the same time hurting the consumer who has to pay more for their food (Food Pricing Monitoring Committee, 2003).

3.4 Irrigation

Irrigation is an age-old method of increasing agricultural productivity. It expands the arable area, improves yield and increases cropping frequency (sometimes enabling two or even three crops a year). In South Africa only 1,5% of the land is under irrigation, producing 30% of the country's crops (South African Yearbook, 2008/9). At first glance, expanding irrigation seems the obvious means of increasing productivity, but all of South Africa's irrigable land (estimated at 1,2% of the country) is already cultivated, with irrigation now rapidly expanding into unsuitable areas and negatively impacting the environment.

Of particular concern is that irrigation is already by far the biggest water use in South Africa. Year 2000 data showed irrigation extracting 63% of the country's available surface water (Water Accounts for South Africa, 2000). With 98% of the available water resources allocated, there is little room for increased extraction, particularly as other sectors compete for the surplus (which is itself dependent on rainfall). South Africa has few exploitable aquifers and extracts groundwater for only 13% of its supply. There is some room for increased groundwater extraction in the south-east of the country, but in other areas groundwater is already overexploited, with water tables falling at an alarming rate (South African Yearbook, 2008/9).

The first non-racial democratic government in South Africa inherited a stagnant economy with high levels of unemployment (Hodge, 2009). Kgafela (2009) indicates that during the first year of non-racial democratic government, South Africa's unemployment rate was 20% according to the strict definition and 31,5% according to the broad definition. Burger and Von Fintel (2009) argue that the country has, since then, witnessed an acceleration of its already high unemployment rate. The South African Institute of Race Relations (2008) indicates that this increase in the unemployment rate peaked in 2003 at 25,5% and 38,3% according to the strict and the expanded definitions respectively. In 2007, Statistics South Africa showed that the unemployment rate decreased to reach 22,7% in September 2007. However, as a result of the economic recession, the unemployment rate again increased to reach 25,2% during the first

quarter of 2010. Burger and Von Fintel (2009) point out that South Africa currently has one of the highest unemployment rates globally.

Stats SA (2010) shows that most economic sectors, including the agriculture sector, have shed a substantial number of jobs between 2008 and 2010 as a result of the recession. Apart from job losses that the agriculture sector experienced as a result of the recession, it had already experienced substantial job losses between 2001 and 2007 (Stats SA, 2007). These job losses in the sector came as no surprise since Kirsten and Vink (2001) and Aliber et *al.* (2007), using regression analysis2 and base scenario estimates, forecast that the number of jobs in the formal agriculture and agro-processing sectors would decline over time.

Kingdon and Knight (2001) argue that the high level of unemployment is potentially a matter of serious concern, and may have potentially negative effects on economic welfare, production, erosion of human capital, social exclusion, crime, and social instability. On the other hand, Simbi and Aliber (2000) argue that trends in agricultural employment threaten to deepen the poverty crisis in South Africa's rural areas, in which the incidence of absolute poverty is much higher, because as Armstrong *et al* (2008) show, the poverty rates of households and individuals in the rural areas were 54,2% and 67,7% respectively.

While increasing agriculture unemployment arguably deepens poverty in the rural areas, some authors do not see agriculture employment being effective in helping farm workers to secure a minimum living standard. For example, Jacobs (2009) argues that the low agricultural wages are inadequate to lift wage-dependent rural households permanently above a socially acceptable deprivation threshold, because the largest share of it is spent on staple agro-foods, which means that their food security status is very sensitive to food price shocks. According to the Department of Labour (2001) and Pekeur (2010), the farm workers earn the lowest wages among those formally employed in the country.

The government has committed itself to dealing with the unemployment crisis in South Africa through its plans to create decent work (Mohamed, 2009). The Department of Economic Development et al. (2010) indicate that the creation of decent jobs is one of the government's top five priorities for the current Medium Term Strategic Framework (MTSF).

Previous studies have not researched the issue of decent employment in the agriculture sector and as such, it becomes justifiable to understand the position of agriculture, forestry and fisheries with regard to its contribution to decent employment by answering the following questions: (i) Is the agriculture,

forestry and fisheries sector contributing substantially to reducing the level of unemployment in the country? (ii) How "decent" is the work in the sector? (iii) Can the sector be one of the priority sectors for creating decent employment?

According to the Presidency (2010), creating decent employment, through inclusive economic growth, is possible through a focus on improving income levels, labour absorption, improving equality, and GDP growth. This issue of decent employment is not only important to South Africa, but it is also one of the key aims of the International Labour Organisation (ILO).

3.5 Historical background of the agricultural sector employment in South Africa

In 1992 there were 1,1 million people employed in commercial agriculture, and they supported approximately four million dependents (Newman *et al*., 1997). By 1996, the number of people employed in commercial agriculture decreased to 914 000 employees, of which 67% were employed on a regular basis while 33% were engaged as casual/seasonal workers. The number of employees engaged in regular work on commercial farms decreased by 15,7% from 724 000 in 1988 to 610 000 in 1996. Of the 2,2 million employed people in the former homelands, 37% reported that they were engaged in subsistence farming (Statistics South Africa and National Department of Agriculture, 2000).

Statistics South Africa and the National Department of Agriculture (2000) show that in 1996, full-time employment in the agriculture and hunting subsectors was the highest among white men and the lowest among African and coloured women. Among white men employed in the agriculture and hunting subsectors, 97% had full-time jobs compared with 83% among African women and 75% among coloured women. Among the relatively few coloured people employed in agriculture, 82% were found in elementary jobs such as fruit picking and weeding. Among the preponderant group of Africans employed in the agriculture and hunting subsectors, 58% were in jobs classified as elementary compared with 22% among Indians and only 12% among whites. At the higher end of the occupation hierarchy, 15% of Indians and an equivalent proportion of whites (15%) were employed as managers, professionals or technicians compared with only 1% of either Africans or coloureds.

Simbi and Aliber (2000) argue that the commercial farming sector shed a staggering 140 000 regular jobs during the 11-year period from 1988 to 1998, a decline of roughly 20%. The authors further spot a trend away from employment of regular, permanent workers, and a simultaneous increase in the use of casual labour. According to them, this would mean jobs of less security and consistency, and if the decline in the sector employment continues in this fashion, then the already grave problem of rural unemployment will become graver still.

Many authors provide different reasons for declining employment in the agriculture sector. Newman *et al*. (1997) argue that higher labour costs could lead to the substitution of personally owned machinery, contract machinery or contract labour for permanent labour. Simbi and Aliber (2000) argue that the adoption of labour-saving technologies does not appear to be motivated by the relative increase in the cost of labour, but rather it represents cost savings that farmers find practical and attractive. The authors further indicate that seasonal workers are being made redundant by the agricultural machinery and chemicals that are affecting aspects of the production cycles.

Townsend *et al*. (1997) states that large machinery-using biases in technology have been developed with minimal labour-using biases and these biases have not contributed to alleviating the unemployment problem currently facing the labour-surplus economy of South Africa. According to the authors, the biases have largely been caused by policies favouring the large-scale capital-intensive production model. However, during the first year of non-racial democratic government, the African National Congress (1994) indicated it would change the situation by prioritising investment in the labour-intensive agricultural sector including investment in infrastructural projects such as the creation of roads and irrigation systems using labour.

According to Vink and Kirsten (1999), the decline in the number of people employed in the agricultural sector over the past decades has been exacerbated by bad policies that inhibited export opportunities, discouraged the development of labour-saving technology, and actively encouraged the adoption of capital-intensive farming practices. Another important issue to consider when looking at employment in the sector is the wages and livelihoods that farm workers derive from agriculture. According to Newman et *al.* (1997), the farm workers are not only remunerated with cash payments. The aggregate remuneration package normally includes cash wages, rations, housing, grazing and cultivation rights, clothing and other benefits. The cash wage would usually be paid on a weekly or monthly basis and often includes a bonus at the end of the year. The perquisites would be offered differently depending on farm types. For example, on livestock farms labourers generally receive milk and may be assigned rights to graze a limited number of animals on the farm. Cultivation rights allow a worker to cultivate a certain area of land; the farmer may also provide seed and fertiliser. Rations generally include maize meal, meat, tinned foodstuffs and vegetables. Housing may be provided by farmers, or they may allocate an area for their labourers to build their own dwellings.

The findings of the Women on Farms Project (WFP) and the Centre for Rural and Legal Studies (CRLS) (2009) show that female workers receive lower wages and fewer benefits and are less likely to be

permanent workers than are male workers. The average wage was found to be R667 per month for men, while the average wage paid to women was about R458 per month. The authors indicate that these are not absolute remunerations, as a quarter of the wages paid to farm workers are “in-kind”.

According to Statistics South Africa and the National Department of Agriculture (NDA)(2000) the average monthly remuneration of employees in the commercial farming sector more than tripled, in nominal terms, over the period 1988–1996, from R142 in 1988 to R524 in 1996. The remuneration levels among casual workers in 1996 were still substantially lower than among regular workers. By 1996, the remuneration received by casual workers in the commercial farming sector was only around a quarter (26%) of that received by regular employees (up from 19% in 1990). The level of remuneration among Africans was barely 12% of the level among whites, even though over the period 1994–1996 their remuneration increased by 28,9% compared to 14,9% among white employees (Statistics South Africa and National Department of Agriculture, 2000).

According to Newman *et al.* (1997), minimum wages have been advocated as a way of improving farm workers’ remuneration. However, Brown-Luthango (2006) argues that the minimum wage is completely inadequate to afford farm workers and their children a decent standard of living as they cannot even afford the basics such as housing, clothing and education for their children. When the minimum wage policy was introduced in 2003, many people feared that it would result in job losses. For example, Simbi and Aliber (2000) argue that the perceived impact of legislation on the total wage bill and hence on the demand for labour has resulted in fears that extending minimum wage regulations to the agricultural sector will aggravate the employment crisis already prevalent in rural areas. The authors further quote Bhorat (1999) arguing that the minimum wage will impact negatively on this is the latest, most comprehensive study on employment trends by the NDA and Stats SA. Employment in the sector. On the other hand, Newman et al. (1997) argue that the respondents in their study mentioned that labour would be replaced with machinery and contractors if the minimum wage was set above the wages paid during the time of study (1997).

Apart from the legislation on minimum wages, a number of statutes (labour laws) exist and apply to the agriculture sector. Newman *et al.* (1997) indicate that, from 1993, labour legislation was extended to agriculture with the expectation that it would have a significant effect on labour transaction and wage costs in South Africa’s commercial farming sector. During the same year (1993), the Basic Conditions of Employment Act No. 3 of 1983 (BCEA) and the Unemployment Insurance Act No. 30 of 1966 (UIA) were extended to agriculture, with some amendments. These Acts were followed by the Agricultural Labour

Act No. 147 of 1993 (ALA). The BCEA provides for minimum conditions governing working hours, leave, overtime, etc., the UIA provides for contributions to the Unemployment Insurance Fund and the ALA provides for for the application of the Labour Relations Act (1956) and the further application of the Basic Conditions of Employment Act (1983) to farming activities and employers and employees engaged therein. According to Newman *et al.* (1997), the vast majority of the respondents to their study perceived the present legislation to be time-consuming and costly, and wanted the legislation to be less ambiguous and more flexible and to have reduced powers.

3.6 Drivers of employment in the agricultural sector

The role played by agriculture in employment contribution drew the attention of a number of authors from the 1980s, 1990s and the 2000s. In the 1980s, the debate on unemployment in the agriculture sector focused mainly on the impact of mechanisation in the agricultural sector (Van Zyl et al., 1987 cited in Kirsten and Vink, 2001). During the 1990s and the 2000s most studies (Vink and Kirsten, 2001, Vink, 2003; Aliber *et al.,* 2007) looked at, inter alia, the impact of labour policies on agricultural employment. The debate on employment and employment statistics focused mainly on the adoption of the narrow definition of the term by the South African government in the late 1990s (Kingdon and Knight, 2000). This was arguably attributed to the fact that, as the apartheid era was coming to an end, new legislation was introduced and enforced. This legislation includes the Labour Relations Act, the Basic Conditions of Employment Act and legislation pertaining to the minimum wages introduced by the Department of Labour early in the 2000s.

At the turn of the millennium, the agriculture sector contributed about 10% to total employment in South Africa as compared to the current 5%. It is also clear from the long term trends identified in Kirsten and Vink (2001), Aliber *et al*. (2007) and Aliber and Simbi (2000) that there is an absolute decline in employment in the agriculture sector. This section explores the drivers of employment in the agricultural sector and the findings will be used for drawing future recommendations on job creation in the sector. A non-exhaustive list of drivers of employment in the agricultural sector is discussed below, and it will be followed by an assessment of the decency of farm work.

3.7 Regulatory environment

Bhorat (2000) argued that the regulatory environment and therefore the cost of doing business in South Africa were relatively unfavourable compared to other countries with more or less the same development status. In line with this, Vink (2003) observed that the introduction of new labour laws and minimum wage rates were the main causes of reduction of employment in the agricultural sector hence

an increased trend toward casual workers in the sector during the early 2000s. According to Simbi and Aliber (2000), the casualization trend is attributed mainly to the fact that seasonal employees are not able to make demands and are not represented by the labour unions. The authors highlight the fact that more or less at the same time when mechanisation was changing from a complement to labour to a substitute for it, government policy on agricultural labour switched from assisting farmers through the old labour-repressive strategies, to assisting them with labour replacement.

Factors such as income tax provisions to allow for the accelerated write-off of agricultural equipment, the encouragement of large-scale farming through the Subdivision of Agricultural Land Act of 1970, and negative real interest rates on agricultural loans were all measures designed to promote the development of a modern, labour-lean agricultural sector. Hartwig (2004) concludes that together with broader labour legislation changes and a changing economic environment (including technological advancement), among other things, legislation emphasising security of tenure has contributed to misemployment, eviction and urbanisation for a large proportion of agricultural labour in the Free State Province.

Simbi and Aliber (2000) argued that labour shedding in agriculture in the late 1990s was a result of (i) the fear of losing control of one's land to resident farm workers owing to new and possible future legislation and (ii) the sense that farm workers are more difficult to manage than they were prior to 1994.

3.8 Adoption of new production methods/technology

Bhorat and Hodge (1999) measured, through a simple decomposing technique, the extent to which the adoption of new production methods have an impact on labour demand by race and found that Asians and whites benefited from the change and that such change had a negative impact on Africans and coloureds. They argue that these disparities were chiefly because of skills and occupational differentials that exist between these two cohorts of individuals. This is in line with the findings by Siegel (1998), who found that technological change leads to a shift in labour composition and compensation for workers with a higher level of education. A study by Aliber et al. (2007) forecasts that the adoption of labour-using technologies such as animal traction rather than mechanical traction can result in a 30% increase in employment in the formal agriculture sector in 2026. However, the authors project that under the same scenario there will not be any percentage change in the number of large-scale black farmers, black smallholders, semi-subsistence farmers and smallholder employees. The main reason as argued by

Aliber *et al*. (2007) is that small-scale farmers tend to attempt to reduce poverty through project-based enterprises, requiring effective management which is in short supply.

According to Simbi and Aliber (2000), mechanisation and modernisation in the agriculture sector have large repercussions for employment in the sector. The incremental improvements in agriculture chemicals and the means of applying them are also diminishing the role of labour, especially unskilled labour, in agriculture. The use of long-lasting herbicides and more efficient harvesters (harvesters for potatoes and peanuts) also has reduced the need for seasonal farm workers who are traditionally employed for harvesting and weeding. The authors argue that the relatively skilled permanent workers who operate the agricultural machinery are ever more important to the farmer while the demand for the casual labour has declined.

As stated before, Townsend *et al.* (1997) found that large machinery-using biases in technology have been developed with minimal labour-using biases. According to the authors these biases have not contributed to alleviating the unemployment problem currently faced n South Africa and they argue that the biases were largely caused by policies favouring the large-scale capital-intensive production model.Thirtle *et al*. (1995), as cited by Simbi and Alber (2000), finds evidence that the labour-saving, capital-using nature of technological change in South African agriculture is largely due to the relative increase in the cost of labour.

3.9 Promoting innovation and entrepreneurship (new business formation)

Programmes such the Accelerated and Shared Growth Initiative of South Africa (AsgiSA) and Agricultural Black Economic Empowerment (AgriBEE) are aimed at promoting entrepreneurship. AgriBEE's purpose, for instance, is to achieve broad-based economic empowerment for black people throughout the entire value chain in the sector. The impact of these programmes in terms of the creation of sustainable and decent jobs may not be felt in the short run mainly because, as Baptista et al. (2008) argue, new firms are unlikely to lead to significant employment growth unless the new firms generate significant positive, indirect supply-side effects. These, according to Fritsch and Mueller (2004) as cited in Baptista *et al.* (2007), include greater efficiency due to increased competition, greater productivity due to faster structural change, increased innovation and greater product variety and quality brought about by new entrants.

Various recent studies, including Baptista et al. (2008) and Van Stel and Storey, (2004), despite using very different methodologies and selection of dependent and independent variables, found a negative

relationship between the formation of new firms and job creation implying that new firms did not necessarily translate into job creation. In contrast to this,

Fritsch and Mueller (2004) investigated the time lags using the Almon model and found that new firms can have both positive and negative effects on regional employment. The new view, clarified by Fritsch (2008), is that if the establishment of a new firm result in increased productivity then there will be a subsequent decline in employment and that employment may occur because of increased competitiveness. These studies show that the empirical evidence concerning the effects of new firms on job creation is not very clear (see also Fritsch, 2008).

Baptista *et al.* (2008) found that the indirect effects of new firms on subsequent employment growth are stronger than the direct effects and concluded that employment growth is probably dependent on the types and qualities of start-ups. The notation of the type of startups in the agricultural sector is of particular importance as it can also determine the economic viability and long-term sustainability of agricultural projects. Machethe and Kirsten

(2005) found that, among the reasons why agricultural development projects were failing in the North West Province, was that there was a large number of beneficiaries, which resulted in conflicts and the subsequent abandonment of projects.The success of agricultural development projects can stimulate employment growth in the agriculture sector. Fritsch (2008) argues that new firms can stimulate employment growth by (i) securing efficiency and stimulating productivity increase, (ii) accelerating structural change, (iii) amplifying innovation, especially with the creation of new markets and (iv) providing a greater variety of products and problem solutions.

Smonly (1998) studied the impact of product and process innovation on output, capacity utilisation, prices and employment and found that innovative firms showed higher employment growth than did non-innovative firms.

Although there is a considerable number of international studies which investigated the relationship between the formation of new firms and job creation, such studies have not conducted an in-depth, sector-specific analysis of this relationship, especially in agriculture.However, it seems rather plausible that new business formation will result in job creation in the agricultural sector given the type and labour-intensity requirements of agricultural projects.

3.10 Policy

The commercial agricultural sector adjusted well to policy reforms and liberalisation efforts. However, economic and financial pressure on commercial agriculture is substantial, and as with other sectors, farmers must adapt their production and investment decisions to the market situation and overall economic developments. The ability of the commercial sector to respond to increased market opportunities will ultimately determine any gains from global trade liberalisation. Farming policies need to be conducive to quality and productivity improvements for this sector to further improve its international competitiveness and exploit its export potential (Department of Agriculture, Forestry and Fisheries, 2006).

Sustainable production and value-added systems are based on the utilisation of available resources. In South Africa labor is an under-utilised resource. It was ill-conceived to try and circumvent labor problems by means of costly large-scale mechanisation in the 1970s. It is of the utmost importance that ways should be found to optimise the utilisation of labor in agriculture. It will require, amongst others, effective labor organisations, good labour relations, the appropriate training of farm workers and finding a balance between labor and mechanisation by means of appropriate technology (Department of Agriculture, Forestry and Fisheries, 1995).

Mechanisation does not always increase farm profits and economic viability. Labour is a relatively freely available production resource which can be fully utilised in the production system, provided that better training is given. This could create employment opportunities, reduce capital input in agriculture, stabilise rural communities and lead to a better quality of life (Department of Agriculture, Forestry and Fisheries, 1995).

Agricultural inputs in general varied in terms of growth. There was a structural change in farmland use since 1910. Farmland grew by 91.8 million hectares in 1960, declining in 1996 to 82.2 million hectares and between 2000 and 2007 it has constantly remained within the range of 83.7 million hectares (Conradie *et al*, 2009). Black farmers' share of area farmed in 1918 and 1991 was 15% and in 2000 it doubled to 30% (Department of Agriculture, Forestry and Fisheries, 2006). The reason the share of black farmland area was small compared to that of commercial farmland was due to discriminatory policies in particular Land Act of 1913 which confined land ownership by black farmers to native reserves comprising 15% of the total agricultural land area in the country. The twenty-first century saw a declining number of farmers and a steady growth of average farm size. In 1910 farm numbers and

average farm size were estimated at 76,622 and 1,006 hectares respectively whilst in 2007 these were 44,575 and 1,400 respectively (Department of Agriculture, Forestry and Fisheries, 2006).

Over the last 15 years, South Africa has undergone immense social and economic changes, with fundamental structural reforms resulting in an open, market-oriented economy. Some of these changes were intended, while others are the result of the country's integration into the global economy following the end of apartheid-era sanctions. The changes in policy were intended to remove the socialist control of agriculture prevalent under the Nationalist Government, improve the lot of farm labourers, and redress land inequalities. Closing agricultural marketing boards, phasing out certain import and export controls and introducing certain import tariffs all converted a stagnant and state-controlled sector into a vibrant market economy. Dismantling state support to farmers combined with low import tariffs did, however, leave many South African farmers unable to compete in certain areas, such as wheat and milk, against farmers from developed countries who receive generous state subsidies and dump their products in South Africa. On the other hand, government led initiatives to increase irrigated farmland has enabled other farmers to successfully grow high-value export crops such as deciduous fruit, grapes and citrus. The volume of agricultural exports increased dramatically, and the rand value of exports increased from 5% of agricultural production in 1988 to 51% in 2008 (SA Yearbook 2008/9). The net result has been a decrease in the area under production for staple low-value crops such as wheat and maize, and a dramatic increase in the export of high-value crops.

3.11 Land reform

An important share of public financial resources has been devoted to land reform and agricultural support programmes for disadvantaged farming communities. New programmes were introduced in 2005 to support the development of market-oriented family farms emerging from the land reform process, mainly through investment grants and provision of microcredit and retail financial services in rural areas. The Land Reform Programme has doubtless reduced social tensions in certain areas and has redressed previous wrongs, but progress has been slow and projects have shown a 90% failure rate, reducing agricultural output in certain areas. Uncertainty around land tenure has also proved to be a disincentive for white farmers to farm responsibly (MEGA Report, 2009). A key challenge is to develop a sound understanding of the sociology of emerging agriculture to determine how to better support sustainable land reform initiatives.

3.12 Growth

Overall the growth rate of productivity of land grew by 2.49% per year slightly lower than the labour productivity that grew at 2.83% per year between 1911 and 2008. Even so, the productivity of both these inputs fluctuated over the years. Between 1911 and 1940 both labour and land productivity grew at a very slow pace of 0.89% and 1.89% per year (Liebenberg, 2008). The rate of growth of both land and labor productivity then peaked between 1947-1981 at an impressive 4.91% per year for labour productivity and 4.17% per year for land productivity. Since then it declined by 2.67% per year for labour and 1.46% per year for land.

Although land and labour productivity in South Africa has remained at 1.46% and 2.67% per year, this level remains high compared to other African countries. This is because the value of output per labour is considerably high in South Africa estimated at $5,663 per worker since 2007. The rapid labor productivity is seen through an increase in agricultural output in South Africa of 1.35% per year from 1961-2007 (Wiebe, 1998).

Overall the productivity of field crops and livestock production has increased slightly lower than horticultural output productivity. According to Liebenberg (2010) the productivity of field crops has been fluctuating over the years due to rainfall variation and recurring droughts. However, around 1910 corn yields increased more than 4-fold, wheat yields by 4.4-fold and sorghum yield by 7-fold. These yields decreased significantly in the 30s, 80s and 90s due to frequent droughts in the country. In the twenty-first century the growth of yields of all these grains picked up due to increased mechanization, use of improved seeds, fertilizer, herbicides and pesticides.

SECTION B

3.13 Empirical evidence (International)

Agricultural economists rely on aggregated data at various levels depending on data availability and the econometric techniques employed. However, the implication of aggregation on economic relationships remains an open question.

To the best of my knowledge there are no published South African studies involving the use of the Cobb-Dougals model or other econometrics techniques involving aggregated or sectoral data are in existence. However there are many international studies covering these issues.

Bhattacharjee (1955) used data from 1948 to 1950 to study agricultural productivity in the world for twenty-two countries. The main focus of the study was to estimate, to some degree, the efficiency of the resources used in agricultural production. The study used data from the United Nations database and a single Cobb-Douglas equation to estimate the agriculture production function. The main result obtained by Bhattacharjee was that overall agricultural growth during the period 1948 to 1950 was 2.26 % per year. This was similar to the FAO's finding of slightly over 2 % per year (FAO 1953). Among the inputs land had the highest elasticity of production at 0.425, followed by material (0.287) and human resources (0.277). Productive livestock, work-stock, and tractors did not increase the predictive value of the model and the values of their coefficients were statistically insignificant. The coefficients for all the inputs showed diminishing returns, corresponding with general economic thoughts about the nature of returns in agriculture. In addition, the sum of the coefficients was close to 1, implying constant returns to scale.

Griliches (1963) criticized the use of unexplained residual changes as a measure for technical change. Therefore, he put forward an alternative to the conventional production function approach to measuring total factor productivity. This alternate approach was illustrated using a meta-analysis of agricultural productivity growth studies on the United States. The study used a Cobb-Douglas production function and covered the period of 1940 to 1960 for 68 regions of the United States. The focus of this study was on the inputs such as labour, education, machinery, and fertilizer, though the studies included other variables (buildings, other current expenses, and livestock expenses). The author then made adjustments to the measure of variables and compared the results of the two approaches.

The author used a Cobb-Douglas estimated production function with the adjusted series and presented the results in a geometric index base. It was found that using these adjusted series reduced the original estimated productivity increased by one-half (or slightly more). If an economy of scale at the cross-sectional estimated rate was allowed for, then all or somewhat more of the original estimated productivity increase was accounted for.

Evenson (1967) studied agricultural productivity with the objective of estimating the impact of research on agricultural production, and estimating the time lag between research expenditure and its impact. Econometric method (iterative nonlinear least-squares estimating procedure) was used to estimate an aggregate Cobb-Douglas production function. The results indicated that the effect of research expenditure had a time lag of 6 to 7.5 years on production. The best estimate for the magnitude of the effect of research expenditure on agricultural production was 0.21 with a lag of 6 years.

Hayami and Ruttan (1970) studied agricultural productivity with the objective to understand the causes of the agricultural productivity difference between developed countries (DCs) and less developed countries (LDCs). In all, thirty-eight countries 3 were studied, over the periods 1952 to 1966. Three individual output series were created by aggregating agricultural commodities with the import prices of the United States, Japan, and India. These were then combined into a single output series using a geometric average. The overall results showed that 95% of the differences in productivity between DCs and LDCs were explained by resource endowment (represented by land and livestock), technology (fertilizer and tractor horsepower) and human capital (represented by education and technical manpower). These three factors were stated to be of roughly equivalent importance. Another result indicated that it was within reach of the LDCs, (with the present land-labour ratios), to enhance their labor productivity four times, attaining similar levels of the older DCs and over half - of recent DCs.

The results compared with earlier studies. Estimated production elasticity's for land and fertilizer was smaller than the results obtained by Bhatacharjee (1955), However, the authors indicated that their model may be better specified due to the fact that they obtained statistically significant coefficients for livestock and machinery where Bhatacharjee (1955) did not. It was also noted that the resulting aggregate production elasticities in this study were similar to those of Griliches (1964) despite the different nature of the data used.

Koebel (2002) described the microeconomic implications of aggregated production functions questioning whether the same optimization framework used for disaggregated production function can

be used for their aggregated counterparts. The theoretical model outlined provided support for the notion that the use of aggregated goods and prices will not conflict with orthodox microeconomic theory, though a loss of information does occur in the aggregation process. A possible consequence of this includes biased estimates. Walter (2006) experiments indicate that the error terms from an aggregated sample were significantly different from zero. This result conflicts with one of the basic Gauss- Markov assumptions, namely that the error terms have an expected value of zero, and hence indicates biased results.

But the empirical results presented in Koebel (2002) are less optimistic than the theoretical model. Using panel data from 1978-1990 of 27 German industries, the author estimates the input demand system and profit function. He finds that not all microeconomic properties apply to the estimated aggregated function, such as convexity and homogeneity of degree one.

Lu and Liu (1978) used data from 1939 to 1972 to study agricultural productivity growth in the U. S. and evaluated the impact of public research and extension expenditures it. They also estimated the rate of return to Research and Education investment and benefit to cost ratios. The study covered U.S. agriculture with 1974 to 76 as the base years and projected productivity indexes for 1985, 1990, 1995 and 2000. Regarding econometrics methods, the Almon distributed lag method and Durbin's two-stage procedure were combined to estimate the relevant parameters. The results of Almon distributed lag and Durbin's two-stage procedure indicated that a 1% increase in R&E expenditure increases productivity gradually at the rate of 0.0037%, reaching a peak in 6 to 7 years. It was also estimated that a 1% change in the weather index changes agricultural productivity by 0.2% in the same direction, and a 1% increase in education index increases productivity by 0.78%.

Luh and Stefanou (1991) used indexing and econometric techniques to study agricultural productivity growth in the US during the period 1948 to 1982. They included a varying factor demand and output supply response in the model to imitate dynamic optimization framework. Two output categories were used, crop output and animal products. The translog quantity indices and the implicit prices of the five crop output subgroups were used to calculate the implicit price for the aggregated crop variable.

The results of econometric estimation indicated that, the dynamically measured TFP grew at 1.50% per annum. Scale, quality-adjusted input growth, and long-run disequilibrium input use contributed 3.44% of TFP growth. While technical change contributed the most to the growth in TFP. It was also found that the studies by Capalbo (1988) and Ball (1985), which assumed longrun equilibrium, underestimated the

contribution of technical change to TFP growth. Finally, they found that both capital and labour adjusted sluggishly toward long run equilibrium levels in response to relative price changes. Physical capital adjusted at the rate of -0.15, which meant it took nearly 7 years to adjust to the long run equilibrium level. Labour adjusted at the rate of -0.11, meaning that it took 9 years to adjust to the equilibrium level.

Thirtle and Bottomley (1992) used the chained productivity indexing method to study U.Kb agricultural productivity during the 1967 -1990 period. The output variable used comprised of crops, horticulture, livestock, and livestock products. These four outputs were aggregated together using a moving average of their respective shares in total revenue as a weight.

The results indicated that TFP grew at an annual average rate of 1.88% over the period. The increase in growth appeared to be due to increased aggregate output at a rate of 1.71% per year plus a declining growth in aggregated inputs at a rate of 0.17% per year. The average annual TFP growth rate increased from 1% per year (1967-74) to over 3% per year (1975-84) after U.K. joined the European Community, then dropping to just over 1.5% after 1985. The chained productivity indexes, annual average growth rate (numerical and graphical), and average revenue shares and average annual growth rates of outputs and inputs. In terms of the various output components there was a rapid growth in the crop output index (5% per year), including a 10% increase after 1974. This was in contrast with the 1% per year, or less, growth in the other three outputs (horticulture, livestock, and livestock products). This was explained to be the result of switch over to arable agriculture under the common agricultural practices (CAP) program.

Huffman and Evenson (1992) provided econometric evidence on the contribution of public and private research to U.S. agricultural productivity during 1950-82. The paper focused on four distinct objectives. Firstly, it examined pre-technology and applied public agricultural research from the perspective of their competitiveness and complementary nature. The paper examines the impact of private agricultural research and public research.

The divisia index was used for productivity decomposition and the seemingly unrelated regression method was used for the econometric analysis. The results indicated that in the case of public livestock research, the pre-technology science and applied research coefficient was negative. In other words they substitute one another in affecting productivity (they were not complementary).

McCunn and Huffman (2000) studied the nature of the convergence in state agricultural TFP growth rates and investigated the contributions of public and private research and development to this

convergence. The study was based on the agricultural production of forty-two U.S. states during the period 1950 to 1982 (the New England states, Alaska and Hawaii were excluded as they accounted for a small portion of US farm output). The study adopted indexing (Törnqvist-Theil quantity indexes for input and output) and econometric modeling (OLS and maximum likelihood regression). The results indicated that state agricultural TFP levels were not converging across all states of the U.S. However, there was some evidence of -convergence (single TFP level) among the crop subsector in the southern plains and northeast regions. It was found that -convergence (steady state rate of growth) existed, although not constant across states. The speed of convergence was 2.1% per year, 0.3% per year, and 1.7% per year, respectively, for the crop, livestock and aggregate sectors.

Acquaye et al (2003) studied agricultural productivity growth in the U.S. using data on forty-eight states over the period 1949-1991. Fisher's ideal indices were used following Divisia indexing procedures in order to reduce bias in the index numbers. The study used disaggregated data that distinguished among 58 types for inputs (classified into land, labour, capital, and purchased (Electricity, purchased feed, fuel, hired machines, pesticides, nitrogen, phosphorous, potash, repairs, seeds, and miscellaneous purchases) and 55 types for outputs (classified into crops, livestock, machines rented out, and returns from conservation reserve program – CRP). The results indicated that the U.S. agricultural productivity grew by 1.90% per annum between 1949 and 1991. Output growth contributed 1.71% while input reduction contributed 0.19%.

Pfeiffer (2003) examined agricultural productivity growth in the Andean Community. Focusing on the Andean Community (a homogeneous geographic area) helps identify characteristics of the negative productivity growth in agriculture in developing countries specific to geographical, social or political circumstances. The scope of the study was Bolivia, Colombia, Ecuador, Peru and Venezuela during the period 1972 to 2000. The study adopted econometric (GLS and maximum likelihood procedures for regression) and non-parametric alternatives. A meta-production function was used to assess productivity change.

The output was measured as the total value of agricultural production. The input comprised of labor (thousands of participants in the economically active population in agriculture), land (thousands of hectares of arable and permanent cropland), fertilizers (thousands of metric tons of nutrient units), tractors (the number of tractors in use), and livestock (thousands of cow-equivalent livestock units as defined by Hayami and Ruttan (1985)). Three inefficiency variables: an estimate of land quality obtained from the USDA, an estimate of wars and violence, and an estimate of civil freedoms, were also included

in the estimations in order to explain the differences in performance between countries. The results obtained across various methods were consistent indicating that, unlike previous studies productivity growth in the Andean Community was positive and increased over time. The TFP growth rates estimated (1.52 % per annum) were comparable to that of the growth rates in developed countries. The growth rate ranged from the highest of 2.11percent for Ecuador to the lowest of 1.08 percent for Venezuela. Finally, technical progress, rather than increases in efficiency, was the main reason behind agricultural productivity growth in the Andean Community.

Coelli and Rao (2003) estimated agricultural TFP during the period 1980-2000, for the 93 largest agricultural producers in the world. The study used the Malmquist index and Data Envelopment Analysis (DEA) methods to construct a piece-wise linear production frontier for each year in the sample. The study used crops and livestock output, derived by aggregating detailed output quantity data on 185 agricultural commodities. The results showed that, firstly, an annual growth in TFP growth of 2.1 %, with efficiency change (or catch-up) contributing 0.9 % per year and technical change (or frontiershift) explaining the other 1.2 %. Asia posted the highest TFP growth (2.9 %), the main factor being the efficiency change growth of 1.9 %. South America posted the lowest growth rate of 0.6 %. Secondly, a productivity reversal (during1980-2000 period) was observed in the phenomenon of negative productivity trends and technological regression reported in some of the earlier studies for the period 1961-1985. It was observed that regions with the lowest mean technical efficiency scores in 1980 (Asia and Africa) achieved the highest increases in mean technical efficiency over the sample period.

Huffman and Evenson (2006) studied the impact of federal formula or competitive grant funding of agricultural research on state agricultural productivity. The study used an econometric model of total factor productivity using pooled cross-section time-series data over the period 1970-1999. They estimated the parameters using the Prais–Winsten estimator of regression coefficients, and the standard errors were corrected for heteroscedasticity and contemporaneous correlation across states. The results indicated that public agricultural research and extension had a significant positive impact on state agricultural TFP. Furthermore, program funding, like federal formula funding, had a larger impact on agricultural productivity than federal competitive grants and contracts. This observation was in contradiction to President Bush's proposal to convert the Hatch Act funding into a competitive grant program. It was also found that the social marginal annualized real rate of return on investment of public resources in agricultural research range between 49 and 62%. The rate of return was even higher for public agricultural extension.

Stewart et al (2009) estimated the growth rates of agricultural output, aggregate input use and total factor productivity (TFP) in crops and livestock production and analyze variations in TFP growth between Canadian Provinces and over time. The study used data on the three Prairie Provinces during the period 1940 to 2004. Superlative indexing method (Törnqvist-Theil index, a discrete approximation of the Divisia index) was first used to construct the TFP and econometric methods were applied on a translog cost function, to decompose the productivity growth.

The results indicated that there were strong productivity growth rates in Prairie agriculture during 1940 to 2004, at 1.56 % per annum. The productivity growth explained 64% of the output growth rate of 2.43% per annum. Productivity growth rates were found to be higher during the last 25 years (1980–2004) at 1.80% per annum. During this period output growth remained at 2.38% per annum. Thus 76% of output growth was attributed to productivity growth. Of the three Prairie Provinces; Manitoba showed the highest productivity growth, followed by Saskatchewan, and Alberta with the lowest productivity growth which fell during the last 25 years.

It was also found that growth in crops (2.85%) was faster than in livestock (1.56%). During the 25 years from 1980 to 2004, the livestock output growth rate increased while the output growth rate for crops slightly decreased. Technical change contributed the largest in the estimated productivity growth in crops (Alberta 94.7%, Saskatchewan 84.5%, and Manitoba (80.4%). The scale effect on crops was 16.9% for Manitoba, 16.5% for Saskatchewan, and 4.9% for Alberta. Scale effect on livestock was 51.0% for Alberta, and 62.4% for Saskatchewan. Manitoba's livestock productivity growth consisted mainly of technical change (53.2%), while scale effect was 36.0%. The authors highlighted that the removal of the Crow rate in 1995, which resulted in the lower prices for feed, may have contributed to increase in livestock productivity. The authors also highlighted that despite geo-climatic similarities there was disparity in the productivity growth rates between Alberta and Saskatchewan, which may be due to Alberta's oil and gas resources. The study recommended the strengthening of data management and use of superlative indexing methodology to measure TFP.

O'Donnell (2010) used the data envelopment analysis (DEA) methodology for estimating and decomposing the multiplicatively complete Hicks–Moorsteen TFP index. The study covered eighty-eight developed and developing countries during the period 1970 to 2001. The study adopted non-parametric method, using DEA with multiple linear programs (LPs) to decompose the Hicks-Moorsteen index to understand the causes of changes in TFP. The output variable consisted of crops and animals. Input comprised of land, labor, livestock, tractors and fertilizer.

The results indicated that the average rate of technical change was 1.0%, slightly less than the 1.1% reported by Coelli and Rao (2005). The highest TFP was observed in Nepal during 1970s, Nepal and Zimbabwe during the 1980s, and Nepal and Thailand during the 1990s. Changes in TFP of Australia and U.S. were attributed mainly to output oriented mix efficiency and residual output oriented scale efficiency. The main cause for change in the TFP in New Zealand was identified as output oriented technical efficiency. It was observed that agricultural productivity in Australia, New Zealand and the United States responded to changes in the agricultural terms of trade (TT). The study highlighted that improvements in TT encouraged technically efficient optimizing firms to expand their operations, even to the extent that returns to scale and scope decreased. Thus increases in profitability may be associated with decline in productivity.

Balcombe and Rapsomanikis (2010) empirically examined the impact of Research and Development on productivity, with special emphasis on lag selection. Further, the study aimed to understand potential structural changes in agriculture. Using data on the U. S. agricultural sector covering the period 1889 to 1990, the study adopted a Bayesian model averaging (BMA) with reverse jump (RJ) algorithm, standard autoregressive distributed lag specification with structural breaks, and gamma lag weightings to approximate lag structure when specifying constrained distributed lags. The dependent variable was the percentage rate of change in productivity, while the predictor variable was the Research and Development expenditure.

The results indicated that Research and Develoment expenditures have little or no influence on productivity growth rates beyond twenty years. Sometimes the impact of research on productivity may not have a long gestation period but may have an immediate impact, may fade away after two or three years, and then have a positive impact some ten or more years later. Evidence of the existence structural breaks was inconclusive.

Salim and Islam (2010) examined the importance of Research and Development and climate change in the agricultural sector using data on Western Australia over the period 1977/78 to 2005/06. The study used indexing (Törnqvist indexes) and econometric methods applied to standard material-augmented Cobb-Douglas production function and standard Solow's growth accounting technique.

TFP indices were calculated using Solow’s standard growth accounting techniques (output growth not accounted for by input growth) and by applying Tornqvist indexing methods following Islam (2004). R&D expenditures was obtained by extending the data series obtained from Mullen et al. (1996) with figures

collected from the Department of Agriculture and Food, Western Australia (DAFWA). Cumulative rainfall data, in millimeters, was used as a proxy for the climate variable.

The results indicated that both Research and Development (long-run elasticity 0.497) and rainfall (long run elasticity 0.506) were strongly correlated with output and TFP growth. Secondly, unidirectional causality existed running from Research and Development to TFP growth in both long run and short run. With R&D having less impact in the short run, implying a lagged impact on output.

Fuglie (2010) presented a comprehensive global and regional picture of agricultural TFP growth between 1961 and 2007 using data on 171 countries. The study adopted indexing (Törnqvist-Theil index) and econometric methods. The output growth was measured using the FAO output index, which was a Laspeyres index, valuing about 195 crop and livestock commodities at a fixed set of average global prices. For inputs, several country-level case studies that had acquired representative input cost data were brought together. Törnqvist-Theil growth accounting indexes of agricultural TFP growth was constructed for these countries.

The results indicated that, firstly, there was no evidence of general slowdown in sectorwide agricultural productivity. Secondly, accelerating TFP growth and decelerating input growth have largely offset each other to keep the real output of global agriculture growing at slightly more than 2% per year since the 1970s. Thirdly, there was a slowdown in the growth in agricultural investment.

Hussian (2006) applying a Cobb-Douglas function estimated an agricultural sector production function for Jordan were he concluded that the agricultural sector was actually characterized by increasing returns to scale, since it was estimated that the sum of elasticities of variables included in the study was about 1,087 and indicated that the agricultural sector was indeed capital intensive where elasticity of labor was estimated to be 0.455 compare to capital which was estimated to be 0,130.

Autumn (1998) applied a simple basic approach of a cobb-dougals function approach with the traditional factors of production (land capital and labour) on the Canadian economy where he concluded that the total productivity growth rate for Canadian agriculture was 0.35%.

According to Change and Zepeda (2010) labour productivity in china increase by 4.13% whilst that of the United States was 7.16% during 1987-1994. In general land productivity is higher in less developed countries as compared to developed countries due to land reform. It must be noted that growth in agricultural productivity depends on primarily on technological change, improved input use efficiency

and conservation of natural resources. These in turn, depend crucially upon investment in agricultural research, extension and human capital.

Zepeda (2001) examined agricultural investment and productivity in the context of developing countries. The study used number of models of production growth (index numbers or growth accounting techniques, econometric estimation of production relationships and nonparametric approaches) to measure the change in output, to identity the relative contribution of different inputs to output growth and to identify the Solow residual or output growth not due to increases in inputs. Results show a relatively weak relationship between physical capital and growth, as compared to investment in technology and human capital. Other factors found to be stimulants to growth included; the policy environment, political stability and natural resources degradation.

Many authors support the findings of Zepeda (2001). Fulginiti and Perrin (2006) examined changes in agricultural productivity in eighteen developing countries over the period 1961–1985. The study used a nonparametric, output based malmquist index and a parametric variable coefficient Cobb-Douglas production function to examine, whether declining agricultural productivity in less developed countries was due to use of inputs. Econometric analysis indicated that most output growth was attributed to commercial inputs like machinery and fertilizers.

Velazco (2001) examined trends in agricultural production growth for the period 1950-1995, identified factors that affect agricultural growth and investigated any underlying constraints. The study used a Cobb-Douglas production function and supply function to analyze data. The study looked at how changes in land, labor and fertilizer, the role of public and private investment, technological change, policy and political violence influenced Peru's agricultural sector. A specific outcome of the agricultural growth estimation of the aggregate production function for 1970-1995 indicated that increasing agricultural employment would have the greatest impact on the output, followed by land, fertilizer and tractors. The general conclusion was that public and private investment was required to increase agricultural production. There is a relationship between public and private investment with the latter responding to increases in the former. However, it must be noted that land is still concentrated in larger holdings. Only few people have large farms, while a large group of the population has small holdings and little or no education. The implication is that investment in human capital appears to be an obstacle to the effectiveness of extension programmes and technological change.

Elias, (1992) in (Gujarati and Sangeetha, 2007) estimated a Cobb-Douglas using Restricted Least Squares to observe Mexican Economy from 1955 – 1974. Using data on the country's GDP, Employment (labour), and Fixed capital, they found that Mexican economy was probably characterized by constant returns to scale over the sampled period and concluded that using Restricted Least Squares that increasing capital/employment ratio by 1 percent, on the average will increase the labor productivity by about 1 percent.

Effiong and Umoh, (2010) estimated the profit efficiency and the relevant determining levels for egg-laying industry in Akwa state, Nigeria utilizing Cobb-Douglas production function based on stochastic profit frontier. With the aid of a structured questionnaire, they collected primary data from sixty poultry farms across the six agricultural zones of the state. Empirical results revealed the mean economic efficiency of 65.00% implying the need for increased resource use efficiency Their results further showed that variable inputs such as price of feeds, price of drugs and medication were statistically significant thus indicating that profit decreased with increase in input prices while fixed inputs such as capital inputs and farm size were statistically significant and had the right sign a-priori indicating that profit increased with increase in the level of its utilization.

In recent years (2001–2005), rice production in Ghana has been expanding at the rate of 6% per annum, with 70% of the production increase due mainly to land expansion and only 30% being attributed to an increase in productivity (Sank-hayan, 1983). It is widely recognized that the improvement of agricultural productivity is critical for poverty reduction and economic growth in sub-Saharan Africa, where agriculture is the main source of income for about 65 percent of population (Sakurai et al., 2006).

Martin and Mitra (1993) tested the hypothesis of constant return to scale by estimating a three factor constant returns to scale function for agriculture, use a regression approach instead of the budget shares approach to overcome the problems posed by the operating surplus. According to their estimates, in the OECD countries agriculture is less capital intensive than industry, and labor intensity is similar in both sectors. They obtain elasticities of land, capital, and labour in agriculture of 0.16, 0.25, and 0.59 respectively, and elasticities of capital and labour in industry of 0.40 and 0.60.3 Once these elasticities are estimated, they use a Cobb-Douglas production function to estimate total factor productivity growth in agriculture They conclude that in Canada during the period 1970-89 the rate of technical change in agriculture, 1%, is larger than the rate of technical change in manufactures, 0.5%.

Echevarria (1998) found that in Canada agriculture is less labour intensive than both services and industry, but capital intensity is similar in the three sectors. The shares of land, capital, and labour in value added are 16%, 43% and 41% respectively, while the shares of capital and labour are 41% and 59% in industry and 49% and 51% in services, according to previous estimations (Echevarria 1997).Second, the rate of technological change in Canadian agriculture for the period 1971- 91 has been 0.3%, very similar to the rate of technical change in Canadian industry according to the above estimations.

Muhammad et al, (2011) investigated the relationship between financial development and agriculture growth employing Cobb-Douglas function which incorporates financial development as an important factor of production for the period 1971-2011. Used the autoregressive distributed lag (ARDL) bounds testing approach to test for co-integration and examined the long run relationship between the variables. The direction of causality was detected by vector error correction method (VECM) Granger causality test and robustness of causality results was tested through innovative accounting approach (IAA). The findings confirmed that the variables are co-integrated for equilibrium long run relationship between agriculture growth, financial development, capital and labour. The results indicated that financial development has a positive effect on agricultural growth. This implies that financial development plays its significant role in stemming agricultural production and hence agricultural growth. The capital use in the agriculture sector also contributes to the agricultural growth. The Granger causality analysis reveals bidirectional causality between agricultural growth and financial development. The robustness of these results was confirmed by innovative accounting approach (IAA).

3.14 Conclusion

Agricultural productivity is important with regards to economic efficiency, living standards, international competitiveness, economic sustainability, and has important policy implications. Agricultural productivity is also a key driver for the well-being of the farmers, the agro-based industry and mankind at large. Over the years numerous studies have contributed to the field of agricultural productivity. This chapter has taken a comprehensive look at the literature on agriculture productivity from 1950 to 2012 while focusing on the various methodologies used and important results for policy formulation purpose.

The following chapter will outline the theoretical model and the statistical/econometric methodologies that will be employed to estimate the aggregate and sub-sectoral agricultural production functions for the purposes of assessing the relative share (productivities) of land, labour and capital for the South African economy. Additionally the chapter will describe the variables used and their sources and methodologies (techniques) used to transform the data.

CHAPTER FOUR

METHODOLOGY

4.0 INTRODUCTION

This chapter aims to outline the theoretical model and the statistical/econometric methodologies that will be employed to estimate the aggregate and subsectoral agricultural production functions for the purposes of assessing the relative share (productivities) of land, labour and capital for the South African economy. Additionally the chapter will describe the variables used and their sources. The rest of the chapter is structured as follows: section 4.1 describes the Cobb-Douglas production function, while sections 4.2 to 4.4 outline the stationarity and co-integration methodologies used in this study. Thereafter sections 4.5 to 4.9 will describe the vector autoregression (VAR) and the Johansen vector error correction methodologies, as well as the single equation methods (FMOLS, DOLS and CCR). Finally sector 4.10 to 4.14 provides a detailed description of the variables used, their sources and the data transformations.

4.1Cobb–Douglas production function

The dynamic version of the Cobb-Douglas function will be used to estimate the South African agricultural production function. In the field economics, the Cobb–Douglas production function is a popular functional form used to represent the technical relationship between the amounts of two or more inputs - physical capital and labor are the inputs mainly used in empirical work - and the amount of output that can be produced by those inputs. The Cobb-Douglas form was developed and tested against statistical evidence by Charles Cobb and Paul Douglas during 1927–1947 and ever since it has become the workhorse of both macro-and-microeconomic models.

In its most standard form for production of a single good with two factors, the function is

Y= $AL^{\beta}K^{\alpha}$..... (1)

Where:

Y = total production (the real value of all goods produced in a year)

L = labour input (the total number of person-hours worked in a year)

K = capital input (the real value of all machinery, equipment, and buildings)

A = total factor productivity (which is measured by A =$\frac{Y}{L^{\beta}\ K^{\alpha}}$)

A- Measures the real output per unit of input. Moreover, it is sometimes referred to as the level of technology in the economy that reflects the rate at which unit inputs are converted into output.

α and β are the output elasticities of capital and labor, respectively. These values are constants determined by available technology.

Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production, ceteris paribus. For example if α = 0.45, a 1% increase in capital usage would lead to approximately a 0.45% increase in output.

Further, if

α + β = 1,

The production function has constant returns to scale, meaning that doubling the usage of capital K and labor L will also double output Y. If

α + β < 1,

Returns to scale are decreasing, and if

α + β > 1,

Returns to scale are increasing. Assuming perfect competition and α + β = 1, α and β can be shown to be capital's and labour's shares of output. Cobb and Douglas were influenced by statistical evidence that appeared to show that labour and capital shares of total output were constant over time in developed countries; they explained this by statistical fitting least-squares regression of their production function. There is now doubt over whether constancy over time exists.

The theoretical model that will be applied in this study is as follows:

$\mathrm{Y_t} = \mathrm{AX_{1t}^{\beta 1}X_{2t}^{\beta 2}X_{3t}^{\beta 3}X_{4t}^{\beta 4}}e^{ui}$..... (2)

t=time

$\mathrm{Y_t}$= agricultural output in million rands

$\mathrm{X_{1t}}$= land (area planted)

$\mathrm{X_{2t}}$ = fixed capital formation in million rands

X_{3t} = labour (number of employees)

X_{4t} = average rainfall in mil-litras (controlling variable)

e^{ui} = exponential error term

The following is the log transformation of above equation to linearize the Cobb Douglas Function so that OLS estimation technique may be applied to it:

$\ln Y_t = \beta_0 + \beta_1 \ln X_{1t} + \beta_2 \ln X_{2t} + \beta_3 \ln X_{3t} + \beta_4 \ln X_{4t} + u_i$..... (3)

Were β_1 is the elasticity of output with respect to land, β_2 is the elasticity of output with respect to capital, β_3 is the elasticity of output with respect to labour and β_4 (controlling variable)is the elasticity of output with respect to rainfall.

A priori expectations are as follows:

$\beta_1 < 0$ We expect the number of farms to be falling since there are fewer but bigger farms producing more

$\beta_2 > 0$ This to be large and highly significant coefficient, since we hypothesize that farmers have been shifting toward capital intensive processes.

We expect $\beta_3 > 0$ ie labour productivity to be increasing since fewer workers are supposedly producing a higher volume of output

We expect $\beta_4 < 0$ ie due to climate change rainfall will be declining causing production output to be decreasing.

u_i~NID (0,s^2).

Now one can see that the model is linear in parameters β_1, β_2,β_3 and β_4 and is therefore a linear regression model. Though, it is nonlinear in variables Y and X but linear in the log of these variables.

The model has the following properties.

β_1 is the elasticity of the Agricultural sector production output with respect to land(area planted) , that is, it measures the percentage change in Agricultural sector production output for 1% change in land (area planted) input, holding the other variables constant.

β_2 is the elasticity of Agricultural sector production output with respect to fixed capital formation input, that is, it measures the percentage change in Agricultural sector production output for 1% change in fixed capital formation input, holding the other variables constant.

β_3 is the elasticity of Agricultural sector production output with respect to labour (number of employees) input, that is, it measures the percentage change in Agricultural sector production output for 1% change in labour (number of employees)input, holding the other variables constant.

β_4 is the elasticity of Agricultural sector production output with respect to average rainfall (controlling variable) in mil-litras input, that is, it measures the percentage change in Agricultural sector production output for 1% change in average rainfall in mil-litras input, holding the other variables constant.

The sum of four betas (β_1+ β_2+ β_3+β_4) will yield the information about the returns of the scale. The sum (β_1+ β_2+ β_3+β_4) gives information about the returns to scale, that is, if sum (β_1+ β_2+ β_3+β_4) =1 then there are constant returns to scale, that is, doubling the inputs will double the output, tripling the inputs will triple the output, and so on. If sum
(β_1+ β_2+ β_3+β_4) >1 then there are increasing return to scale, that is, doubling the inputs will more than double the output and finally, if sum (β_1+ β_2+ β_3+β_4) <1 then there are decreasing return to scale, that is, doubling the inputs will less than double the output.

4.2 Time Series Data Analysis Technique

Time series design is one in which data is collected on the same variable at regular intervals and the data is usually in the form of aggregate measures of a population (Neuman 2011; Barbie 2010; Cooper and Schindler 2001).The current research used contemporary time series methodology to study the relationship between critical variables under the agricultural sector in South Africa. In particular the study explored the short-run and the long-run relationships between the two variables and examined how the system readjusts when there is a deviation from this long run relationship. All-time series were subjected to stationary tests to determine their stationarity status. First, all sets of times series data went through logarithmic transformations so as to eliminate what Lo (2010) refers to as “the problems of heteroskedacsticity and skewed distributions”. Lo further explains that the right transformation of data must be done to avoid producing wrong data and therefore, wrong interpretation of the results. All

the sets of time series were then subjected to three common time series tests in order to establish the relationship between all the variables.

First, the order of integration was carried out using unit root tests, to establish their stationarity status of all the variables were done using unit root tests. This in turn determined whether to use OLS or vector co-integration techniques to explore the long-run relationship between variables. Finally, this study used the Granger-Causality test to investigate whether the direction of causality runs from agricultural output to Independent variables or independent variables to agricultural output to independent variables.

4.3 stationarity tests

The time series in this research were of yearly frequency and extends from 1970 to 2012. To analyse the series, the study specifically used the Augmented Dickey Fuller (ADF, 1979) test to check for unit root. The aim here was to establish whether the data was stationary or in simple terms if it was mean reverting. Stationary data is known to possess the property of not deviating too far from its mean value over time. Moreover, in the long term, positive and negative deviations from the average value tend to cancel each other out. Non-stationary data on the other hand tends to drift away from its mean. Generally non-stationary data may be usefully described as a random walk, where the best guess of the next period's value is the current value plus an unpredictable random error term.

Majority of macroeconomic time series data tend to be non-stationary but upon differencing (meaning, the current value of the series minus its one period lag) just once, the data is rendered stationary. Such data are termed as integrated of the order one I(1) which means differencing them just once renders the data stationary or I(0) (that is, integrated of the order of zero).The ADF tests revealed that the all variables were stationary of order I(1). That means it was rendered stationary upon first differencing. Simple linear regression Ordinary Least Squares (OLS) models produce valid results when applied to stationary data, that is, data that is stationary of the order I(0) Karlsson and Rohl (2002) This study used the Johansen (1988, 1991) and Johansen and Juselius (1990), cointegration method and VECM techniques to study the long-run equilibrium relationships between agricultural output and the independent variables as well as the short-run adjustment. Note that we cannot use OLS since all variables were established to be non-stationary or stationary of the order I(1). The use of simple linear regression models in the context of non-stationary data would result in spurious regressions (Engle and Granger, 1987; Enders, 2005). Although, one can also use OLS estimates for the data, a richer picture is obtained if the Johansen Co-integration VECM is used since it includes the error correction mechanism which is absent in the OLS model.

4.4 Stationarity

Stationarity data possess the property of not deviating too far from its mean value over time, especially in the long-run. But non-stationary data tends to drift far away from its mean, hence it is referred to as the random walk. In non-stationary data the guess for the next period's value is the current value plus an unpredictable random error term. Kwiatkowski, Phillips, Schmidt and Shin (1992) explain that it is useful to carry out the test of null hypothesis of stationarity and the test of null hypothesis of a root unit on economic data to establish if they are stationary or integrated. They note that in this test the "…statistic should be close to zero under the stationary but not the alternative of a unit…"

There are some questions that arise before such tests are done include; "Does the data possess the property of deviating too far from its mean value over time or in the long-run? Are the deviations stationary or non-stationary?" This study used Augmented Dickey Fuller (ADF, 1979) to test for unit root, that is, to check whether the data is stationary or in simple terms, if it is mean reverting. The ADF test equation used to test the stationarity of variables is described below;

$\Delta y_t = \alpha_0 + {}^{\gamma} y_{t-1} + \alpha_1 \mathrm{t} + \sum_{i=1}^{m} \delta\, y_{t-1} + e_t$……. (4)

Where, y_t is the variable being tested for unit root (independent variable, Agricultural output), Δ is the first difference operator, t is a time trend and e_t is the residual.

The null hypothesis of the test is ${}^{\gamma}$=0(non-stationary).OLS is used to estimate (4) and the statistic associated with the ${}^{\gamma}$ parameter is compared to the critical value in the dickey-fuller tables to determine if the null hypothesis can be reject. The lag length m is chosen by adding additional lags until no more autocorrection is found in the residuals. The procedure outline by Enders (2004) for determining whether to include a constant and a time trend and sequentially imposing restrictions that tests whether a regressor can be excluded from the equation.

In order to apply correct econometric techniques on time series, it is important to identify whether the data is stationary or not. Lo (2010) explains that if the times series are found to be stationary, the Ordinary Least Square (OLS) method and VAR methodology may be applied to the data. But if the data is found to be non-stationary, co-integration techniques of Engle and Granger (1980) of the Johansen methodology must be applied. Granger-causality is applied to time series, but if it is non-stationary, the co-integration test is carried out first. Below is a discussion on how co-integration is established.

4.5 Co-integration

Once the data has been tested and proved to be integrated of the same order, it is then tested for co-integration. The co-integration analysis is carried out if the variables are discovered to be non-stationary. The presence of co-integration between the variables was tested using Johansen (1988, 1991) and Johansen and Juselius (1990 techniques. Johansen co-integration test is VAR-based and is used to determine if the long-run relationship is existent in the time series or not. Co-integration is meant to establish long-run relationship between time series variables, that is to check if a co-integrating relationship is present or not between two I(1) time series (Granger 1981, 1983; Engle and Granger, 1987), for example, Yt and kt in the case of the current study. To do this, Engle and Granger (1987) suggest a regression of Yt on Kt to establish if the regression residual µt is stationary as shown in the co-integrating regression equation below which is a linear equation;

$$Y_t = c + \beta k_t + u_t \ldots\ldots\ldots\ldots (5)$$

Where,

c = the explained or deterministic variable

Y_t = Agricultural sector production output,

βk_t =s the coefficient of the fixed capital formation and

u_i = the unexplained random component

This equation can be rewritten as;

$Y_t - \beta k_t - c = u_t$

The equation implies that if manufacturing and electricity outputs are co-integrated will be stationary and then ADF can be used to test for stationarity of the u_t residuals. In the next sub-section the study discusses the vector auto-regressive and the vector error correction models. The above Engle-Granger specification of the co-integrating relationship was not estimated in the study. Johansen (1991, 1995) approach was be used instead (see equation 5.7) for model proposed by Johansen, 1991, 1995).

4.6 Vector Auto-Regressive (VAR) Model

Vector auto-regression is a multiple equation system used to establish the short and longrun relationships between stationary variables in time series. Karlsson and Rohl (2002) note that estimating a VAR model allows the treatment of the variables assumed to be stationary. VAR model can be estimated to test data that is presumably stationary and asymmetrical. It is believed past values of all

the variables involved in the model have the ability to influence each other. . Suppose economic theory suggests a relationship between two variables y_{t1} and y_{t2}, modelling each variable separately may involve auto-regressions of y_{t1} on lagged values of y_{t1} and y_{t2} on lagged of y_{t2}. However such separation approach would not capture the interaction between the variables that might be present. For example suppose $y_{t1}$is the agricultural growth in an agricultural production output andy_{t2} is the fixed capital formation in a proxy of nominal capital, then it is likely that these two variables are related and modelling these variables should take place in a multivariate frame work. In a VAR $y_{t2}$is related not just to it own lagged values and those of y_{t1} .A VAR has two dimensions: the length or order *P* of the longest lag in the auto-regression and the number, l, of the variables being jointly modelled.

When the variables in y_t are I(1) then a linear combination may be i(0) and are said to be co-integrated, and hence they may be modelled in levels via the use of a VAR model. However more than one co-integrating combinations may arise from the k I(1) variables which are stationary, each of which may be a candidate regressors. Under these circumstances implication four of Granger representation theorem is invoked to formulate models that capture the short run responses while the long run relationships are represented in a co-integrating combinations. This involves applying implication four of Granger Representation theorem which state**s** that if the k x 1 vector of variables y_t is Ci(1.1) then there exists an error correction. The below equation represent error correction or shows how the Granger implication four utilised.

$\Delta y_t = \alpha z_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} \ldots\ldots \Gamma_{\rho-1} \Delta y_{t(p-1)} + \varepsilon t$ …… (7)

Where z_{t-1} = β y_{t-1} are the Γ linear cointegrating combination amongst the k variables, with β the k x r matrix of the r cointegrating vectors and εt a matrix of disturbances. The above error correction representation may be interpreted as the long run or equilibrium relationships in the levels of the variables, which are captured by the co-integrations z_{t-1} = β y_{t-1} ; z_{t-1} represent lagged disequilibrium that are removed through the adjustment coefficients in α. α is a $K\ x\ \Gamma$ matrix of coefficients, with each column associated with one of the r cointegrating combinations. The short run dynamic combinations are captured by the elements in Γi. Note that the vector error correction representations modelled entirely with I(0) variables since β y_{t-1} is I(0) through cointegration and Δy_t is stationary though differencing.

4.7 Co-integration in the VAR

General the numbers of co-integration relationships among the K variables is not know the limits are 0 and K while the economic theory might provide a guide to the number of equilibrium relationships. In practice the Johansen (1991) full maximum likelihood procedure is wildly used to estimate co-integration relationships.

The first step of Johansen procedure, which distinguishes between equilibrium and dynamic adjustment to equilibrium, involves the estimation of a congruent, unrestricted, closed *p*th order VAR in a k variables. In this framework linearity is assumed, perhaps in logs of the variables. The VAR is *p*th order in the sense that longest lag length *p*, which becomes *p-1* on the ΔYt in the VECM is chosen to eradicate serial correlation among error terms. There are k equations in the VAR/VECM thus no variables are left unexplained implying that the system is closed. Moreover no current dated stochastic variables appear as explanatory variables thus the model is a reduced form model. The lag length and the information set (ie., the Y*t* and D*t* vectors) are determined in a practical application. The model design criteria requires that the estimated model must exhibit congruency in the sense that the estimated residuals must not demonstrate serial correlation (autocorrelation) and should not be heteroscedastic conditional on the information set, in addition the residuals must be normally distributed. In the effort to attain autocorrelation free residuals the key decision variable in practice is the choice of the lag length p via the use of AIC, SBC or Lagrange multiplier terestrsts. Further under certain circumstances intervention dummy and I(0) exogenous variables may be required to remove outliers that contribute to the evidence of non-normality and heteroscedasticity, as you can see to the above equation that the dummy variable were introduced to cater for this.

The procedure adopted in this study is a representation of the approach of analyzing multivariate co-integrated systems developed and expanded by Johansen and Juselius (1990, 1992, and 1994) Unlike the Engle Granger static procedure, the Johansen Vector Autoregressive (VAR) procedure allows the simultaneous evaluation of multiple relationships and imposes no prior restrictions on the co-integration space. The Johansen co-integration approach tests for the co-integration rank for a VAR process, estimates the TRACE and LMAX stats, the eigen values, and the eigenvectors. It computes the long-run equilibrium coefficients, the adjustment coefficients, the covariance matrix of the errors, and the R-squares for each of the equations in the VECM. In addition, it also tests for linear restriction on the long-run equilibrium coefficients. Thus, the approach consists of full information maximum likelihood

estimation FIML Of a system characterized by *r* co-integrating vectors. If for instance, we assume y_t Such that *t=1…T*, whereby *(px1)* denotes a vector of random variables and follows a p-dimensional Vector Autoregressive (VAR) model with Gaussian errors (whereby p is the number of jointly endogenous variables).

The following model is estimated:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + \mu + \varepsilon_t \quad \text{…… (8)}$$

Where, y_t is a (*n x 1*) vector of the *n* variables of interest, i.e. state education expenditure, economic growth, education enrolment (both tertiary and higher) and innovation (proxy by patent registration), μ is a (*n x* 1) vector of constants, Γ represents a (*n x (k*-1*)*) matrix of short-run coefficients, εt denotes a (*n x 1*) vector of white noise residuals, and $\prod$ is a (*n x n*) coefficient matrix. If the matrix $\prod$ has reduced rank (*0 < r < n*), it can be split into a (*n x r*) matrix of loading coefficients α , and a (*n x r*) matrix of co-integrating vectors β. The former indicates the importance of the co-integration relationships in the individual equations of the system and of the speed of adjustment to disequilibrium, while the latter represents the long-run equilibrium relationship, so that $\prod = \alpha, \beta$. *k* is number of lags, *t* denotes time and Δ is a difference operator.

The model in equation seven (8) is the vector error correction model for the co-integrated series. In this case, the short-run dynamics of the variables in the system are represented by the series in differences and the long-run relationships by the variables in levels. A shock to the ith variable not only directly affects the ith variable but is also transmitted to all of the other endogenous variables through the dynamic (lag) structure of the VAR. An impulse response function traces the effect of a one-time shock to one of the variables on current and future values of the endogenous variables. The accumulated response is the accumulated sum of the impulse responses. It can be interpreted as the response to step impulse where the same shock occurs in every period from the first. If the estimated ARMA (autoregressive moving average) model is stationary, the impulse responses will asymptote to zero, while the accumulated responses will asymptote to its long-run value. If the variables are contemporaneously uncorrelated, interpretation of the impulse response is straightforward. Variables, however, are usually correlated, and may be viewed as having a common component that cannot be associated with a specific variable. While impulse response functions trace the effects of a shock to one endogenous variable on to the other variables in the VAR, variance decomposition separates the variation in an endogenous variable into the component shocks to the VAR. Thus, the variance

decomposition provides information about the relative importance of each random innovation in affecting the variables in the VAR.

4.8 Vector Error Correction Model (VECM)

Vector Error Correction Model (VECM) exploit the non-stationary nature of I(1) variables that are co-integrated by separating out the long run co-integrated relationships from that of short disequilibria. Such a separation can be interpreted as long and short run Granger causal relationships. (Zou and Chau, 2006). Once it is proved that co-integration exists between the variables involved, via the trace and maximum eigenvalue statistics, thereafter a VEC model that has the variables in their differences is used to bring out the long-run relationship and the short run adjustment to the long run equilibrium in the form of error correction term is estimated.

4.9 Deterministic Components in a VAR Model

The presence of the intercepts and trends in the short run (VECM) and/or the long run model is crucial in determining which table of critical values should be used in determining the number of cointegration relationships in the model. If the levels of data contain linear trends then the specified model must cater for the non-stationary relationships in the model to drift, (*i.e* the trend component between the cointegrated variables cancel out each other). Moreover in specifying this model it is assumed that the constant in the cointegrating space is cancelled out by the constant in the short run model (VECM), thus leaving only one intercept in the VECM. If the a constant term is included in a VECM and not in the cointegrating space leads to linear trends in the data, while confining the intercept to the cointegrating space alone is only relevant for data which exhibits no linear trends component. Thus it is necessary to include the intercept into both VECM and cointegrating space, in order to prevent the above mentioned problem.

Furthermore when the individual data series contain a linear trend which do not cancel in a cointegrating space it is necessary to include a linear trend in a cointegrating space. Note that the role played by the linear trend differs by one level if it is in the VECM and no in the cointegrating space; a linear trend in a VECM but not in a cointegrating space leads to a quadratic trends in the data; a quadratic in VECM and not in the cointegrating space leads to cubic in the data. Thus models with unrestricted intercepts and trends allows for quadratic trends in the data, which seldom occurs, Patterson (2000) suggest that the cause of these quadratic trends must be found and explained via

other variables instead of using the quadratic trend term. Thus unrestricted intercepts and trends models as well as non intercept and trends models mentioned earlier are considered as extremes which are not useful in practice, hence the study will not consider them.

The most common models used in practice are the restricted intercepts (the intercept is restricted to the cointegrating space) no trends model (model A) and unrestricted intercept (the intercept is partitioned in the VECM and the cointegrating space implying that a linear trend in the cointegrating space arises) no trends model (model B). The choice between model A or B depends upon whether there is a need to allow for the possibility of the trends in the data. A preliminary graphing of the data is often useful in this respect. If model B is preferred to model A then only does the one involving unrestricted intercepts and restricted trends (model C need to be considered, since the data has to have a linear trend, if one is to consider allowing a trend in a cointegrating space Patterson (2000).

Patterson (2000), suggested that a plot of residuals of model B against time should prove useful in deciding whether to choose Model C. If the residuals are clustered around the origin model C is not preferable, however if the residuals demonstrate a significant trend over time the model C must be considered. However Harris (1995) suggests that this approach provides little information because the choice of model C arises when the available data cannot account for the unmeasured factors that induce autonomous growth in some or all variables. As an alternative approach, he prefers invoking the Pantula Principle which Johansen (1992) had suggested. The Pantula Principle requires that all three models must be first estimated, thereafter their trace/maximum eigenvalue statistics must be compared and the model whose trace/maximum eigenvalue statistics selects the smallest r value (*ie.*the most restricted model) is regarded as the most appropriate model for estimation. The study applied the Pantula Princeple in deciding upon which deterministic components ought to be included

4.10 Single equations

4.10.1 The Fully Modified Ordinary Least Squares (FMOLS) Test

This cointegration method by Philips and Hansen (1990) assumes the existence of a single cointegrating vectorand involves adjusting OLS estimates of both long run parameters and their associated t-values to accommodate for any bias owing to autocorrelation and endogeneity problems present in OLS residuals Harris, (1995); Harris and Sollis, (2003). Consequently, the resulting estimator is asymptotically unbiased and has fully efficient normal asymptotical properties allowing for the use of standard Wald tests using asymptotic chi-square (χ^2) statistical inference (Belke and Czudaj, 2010). Following Belke and Czudaj (2010), consider the following (y_t, X_t') vector process:

$$y_t = X_t'\beta + D_t'\gamma_1 + u_{1t} \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

where y_t is the $I(1)$ dependent variable and X_t' denotes the stochastic regressors governed by $X_t = \Gamma_{21}'D_{1t} + \Gamma_{22}'D_{2t} + \varepsilon_{2t}$ with $\Delta\varepsilon_{2t} = u_{2t}$. Moreover, $D = (D_{1t}', D_{2t}')$ are the deterministic trend regressors and u_{1t} is error term with zero mean and covariance(Ω). The FMOLS estimator is therefore given by:

$$\hat{\theta}_{FMOLS} = \begin{bmatrix} \hat{\beta} \\ \hat{\gamma}_1 \end{bmatrix} = \left[\sum_{t=1}^{T} Z_t Z_t'\right]^{-1} \left[\sum_{t=1}^{T} Z_t y_t^+ - T\begin{bmatrix} \hat{\lambda}_{12} \\ 0 \end{bmatrix}\right] \ldots\ldots\ldots\ldots\ldots(10)$$

where $Z_t = (X_t', D_t')'$, $y_t^+ = y_t - \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\hat{u}_2$ signifies the transformed data and $\hat{\lambda}_{12}^+ = \widehat{\omega}_{12}\widehat{\Omega}_{22}^{-1}\widehat{\Lambda}_{22}$ represents the estimated bias correction term with the long-run covariance matrices $\widehat{\Omega}$ and $\widehat{\Lambda}$ and their respective elements, which are computed using $u_t = (\hat{u}_{1t}', \hat{u}_{2t}')'$.

4.10.2 Canonical Cointegrating Regressions (CCR)

The CCR estimation method, developed by Park (1992), is a non-parametric approach for statistical inference in a cointegrated model involving adjustments of the integrated processes using only stationary components to account for long-run correlation between regressors and the error term. According to Han (1996), this method yields asymptotically efficient estimators and χ^2 inference. Drawing from equation (a), the CCR estimator is defined as:

$$\hat{\theta}_{CCR} = \begin{bmatrix} \hat{\beta} \\ \hat{\gamma}_1 \end{bmatrix} = [\textstyle\sum_{t=1}^{T} Z_t^* Z_t^{*\prime}]^{-1} \textstyle\sum_{t=1}^{T} Z_t^* y_t^* \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

where $Z_t^* = (X_t^{*\prime}, D_t')'$, $X_t^t = X_t - (\hat{\Sigma}^{-1}\hat{\Lambda}_2)'\hat{u}_t$ and $y_t^* = y_t - \left[\hat{\Sigma}^{-1}\hat{\Lambda}_2\tilde{\beta} + \begin{bmatrix} 0 \\ \hat{\Omega}_{22}^{-1}\hat{\omega}_{21} \end{bmatrix}\right]' u_t$ represents the transformed data. The $\tilde{\beta}$ coefficients are estimates of cointegrating equation applying static OLS, $\hat{\Lambda}_2$ is the second column of $\hat{\Lambda}$ and lastly, $\hat{\Sigma}$ denotes the estimated contemporaneous covariance matrix of the error terms.

4.10.3 The Dynamic Ordinary Least Squares (DOLS) Test

The DOLS test is another alternative to the EG approach. Suggested by Stock and Watson (1993), the test is a parametric method in which the lagged first difference terms are explicitly estimated Saayman, (2010). It extends the cointegrating regression by augmenting the errors with leads, lags and contemporaneous values of the regressors (ΔX_t) Saayman, (2010), such that the new cointegrating equation error term is orthogonal to the entire history of the stochastic regressor innovations Belke and Czudaj, (2010). The DOLS results in a more powerful test for cointegration and gives unbiased estimates of the long-run relationship Harris, (1995); Harris and Sollis, (2003). According to Belke and Czudaj (2010), this method assumes that the added q lags and r leads of ΔX_t (exemplified in equation (14)), completely eliminate the long run correlation between error terms, u_{1t} and u_{2t}.

$$y_t = X_t'\beta + D_t'\gamma_1 + \sum_{j=-q}^{r} \Delta X_{t+j}'\delta + v_{1t} \quad \text{.....} \quad (12)$$

The DOLS estimator of equation is hence given by $\hat{\theta}_{DOLS} = (\hat{\beta}', \hat{\gamma}_1')'$.

In all the above-discussed single equation approaches, when variables in a regression model are found to be cointegrated through the use of hypothesis testing, then the long run relationship between them can be estimated by the cointegrating regression. In these circumstances, OLS estimation would yield super consistent estimators of the long run parameters Enders, (2010). Conversely, a drawback of these approaches arises due to their lack of systematic procedures to separately estimate multiple cointegrating regressions when there are more than two variable in a model. According to Harris and Sollis (2003), assuming that there is only one cointegration vector when there actually is more than one, leads to inefficiency as only a linear combination of these vectors can be obtained.

4.11 A theoretical and practical basis for the choice of variables

$y_t$vector of jointly determined (or endogenous) variables were chosen on the basis of the theoretical considerations of chapter two, the South African agricultural sector economic growth experiences and on the economic growth modelling experiences of the south African agricultural sector and other countries covered in chapter three.

The main variable agricultural production output was used as an indicator of the impact the independent variables play in economic growth rate of the agricultural sector. Moreover the lagged production output is used ~~to~~ in this study to represent the Cobb-Douglas theory of production formation behaviour, including labour and fixed capital formation.

The choice of the fixed capital formation is used to represent the capital side of the Cobb-Douglas production function as explained on chapter two and three. The choice of labour represented by number of employees was also based on the fundamentals of the Cobb-Douglas theory of production. Variables such as Land and rainfall were included due to the central role their play in the agricultural sector production processes.

4.12 Data source

In conducting this study we will use data from South African Reserve Bank (www.resbank.co.za), Department of agriculture, forestry and fisheries (www.daff.gov.za) South Africa Weather service (www.SAweather .co.za) and South African statistics (www.statsaa.co.za).

4.13 Nature of the data

Aggregated data

The yearly data was used for empirical analysis. The labour input $(\mathrm{X}_{3\mathrm{t}})$ represents the number of employed people in the agricultural sector which was downloaded from the statsSA (www.statsaa.co.za). The variable describing the capital in the agricultural sector (X_{2t}) represents the gross value of fixed capital in the agricultural sector and was obtained from the South African Reserve Bank. The nominal agricultural sector production output $(\mathrm{Y}_{1\mathrm{t}})$ and Land $(\mathrm{X}_{1\mathrm{t}})$ variables were taken from publications(south African agricultural sector abstract data, 2013) of the department of agriculture and fisheries .the data on the average rainfall was downloaded from the SA weather service website((www.SAweather .co.za) in milliliters $(\mathrm{X}_{4\mathrm{t}})$.

4.14 Estimate of labour and capital for the sub-sector data

As discussed in the methodology section, this study will estimate aggregate agricultural production function for the entire economy, as well as three sub-sectors production functions (maize, wheat, sugar cane). Due to the unavailability of sectoral data on capital and labour this study will estimate their values using aggregated data. In order to find proxy estimates for sectoral level capital and labour this study will make use of the assumption that capital or labor share is proportional to the sector contribution to the overall output. This can be easily expressed using the formula below:

Proportion of labour employed in the sub-sector $=\frac{sectoral\ output}{\text{total agricultural output}}$ X (total labour) ……13.1

Proportion of capital employed in the sub-sector $=\frac{sectoral\ output}{\text{total agricultural output}}$ X (total capital) …….13.2

4.15 Conclusion

This chapter has outlined the theoretical model and the statistical/econometric methodologies that were employed to estimate the aggregate and sub-sectoral agricultural production functions for the purposes of assessing the relative marginal productive of land, labour and capital for the South African agricultural sector both aggregated and maize and wheat subsectors. Additionally the chapter has described the variables used and their sources.

This chapter has explained the theoretical model (Cobb-Douglas) that is apply in the study and the went on to break down the problem of the spurious regressions and showed that by applying integration test and by formulating regression specifications involving co-integrated variables long run relationship between time series variables may be achieved, which not only avoid the problems of the spurious regressions, but also obtain super consistent parameter estimates. Moreover the relevant integration and co-integration test, which included the much-preferred Johansen's VAR multivariate approach to co-integration have been outlined and will be applied in the succeeding chapter to derive stable long run relationship between the mentioned variables. The Johansen approach is preferred to the Engle Granger single equation approach because it identifies more than one co-integrating relationship that may exist amongst the variables and co-integration tests are more powerful than the letter approach because it leads to smaller variances even in cases of a single co-integrating vector.

It was also demonstrated that if variables are co-integrated, then short run dynamics may be captured via error correction models, the estimation of which is one of the main aims of the study however it was noted that alpha parameter estimation generated by Microsoft are not uniquely determined due to the non-inclusion restriction being placed on the equations of a particular VECM.

Additionally this chapter specified the econometric models to be estimated in the succeeding chapter and motivated that the relevant variables to be modelled were chosen in accordance with the theoretical and practical considerations chapters two and three. Moreover the study used the, FMOLS, DOLS and CCR models for the confirmation purpose.

CHAPTER FIVE

EMPIRICAL ANALYSIS AND RESULTS INTERPRETATIONS

5.0 Introduction

The previous chapters have emphasised, the main focus of this study is to analysis the influence of varies input variables (land, labour, fixed capital and rainfall) on production output under the South African agricultural sector. This chapter applies all the empirical approaches that was discussed in chapter four of this study in order to quantify the input-output relationship between labour, land, fixed capital and production output for the aggregate South African agricultural sector, as well as, for the wheat and maize subsectors in order to understand the dynamics of the South African agricultural sector production frontier especially in regard to estimating the elasticity's for land, labour and capital which are critical for policy purposes. Moreover this chapter presents and interprets the findings of the empirical investigations.

Preliminary examinations of the data utilised in the study in order to depict its basic features. Thus, the chapter presents basic descriptive statistical and graphical evidence to summarise the properties of the natural log-transformed variables used in this study which include: agricultural production output, land, labour, capital and rainfall. Determining the order of integration, is done through the use of the augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. The vector autoregression (VAR) and vector error correction model (VECM) analysis processes and results are presented.

To verify the results obtained from the VAR and VECM multi-equation approach, single equation estimation methods, namely; the fully modified ordinary least squares (FMOLS), canonical cointegrating regressions (CCR), dynamic ordinary least squares (DOLS) and autoregressive distributed lag (ARDL) modelling techniques are employed.

5.1 Description of Data

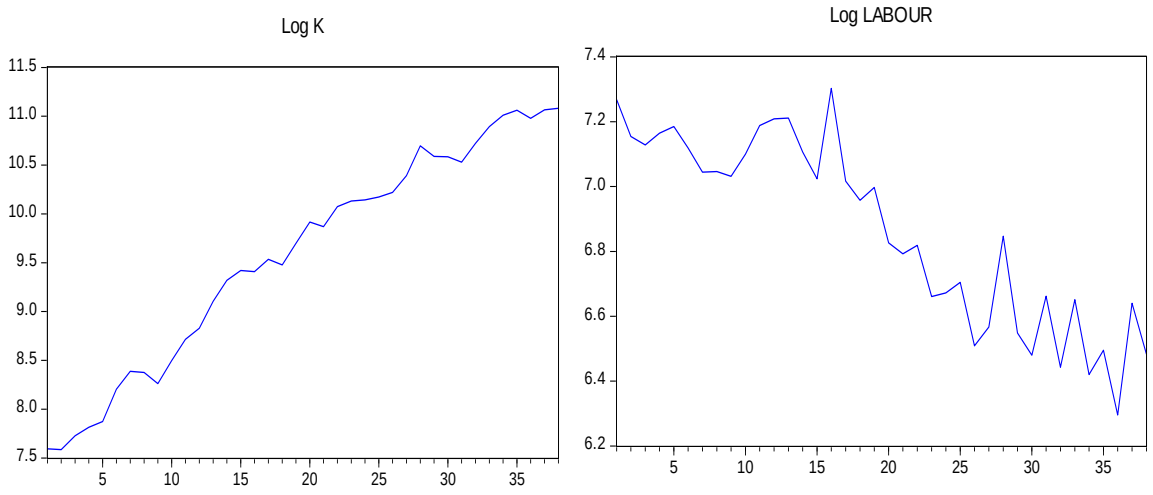
It is critical to do an initial inspection of the data series being employed in order to understand the basic features of the data in question before performing any empirical econometric analysis.

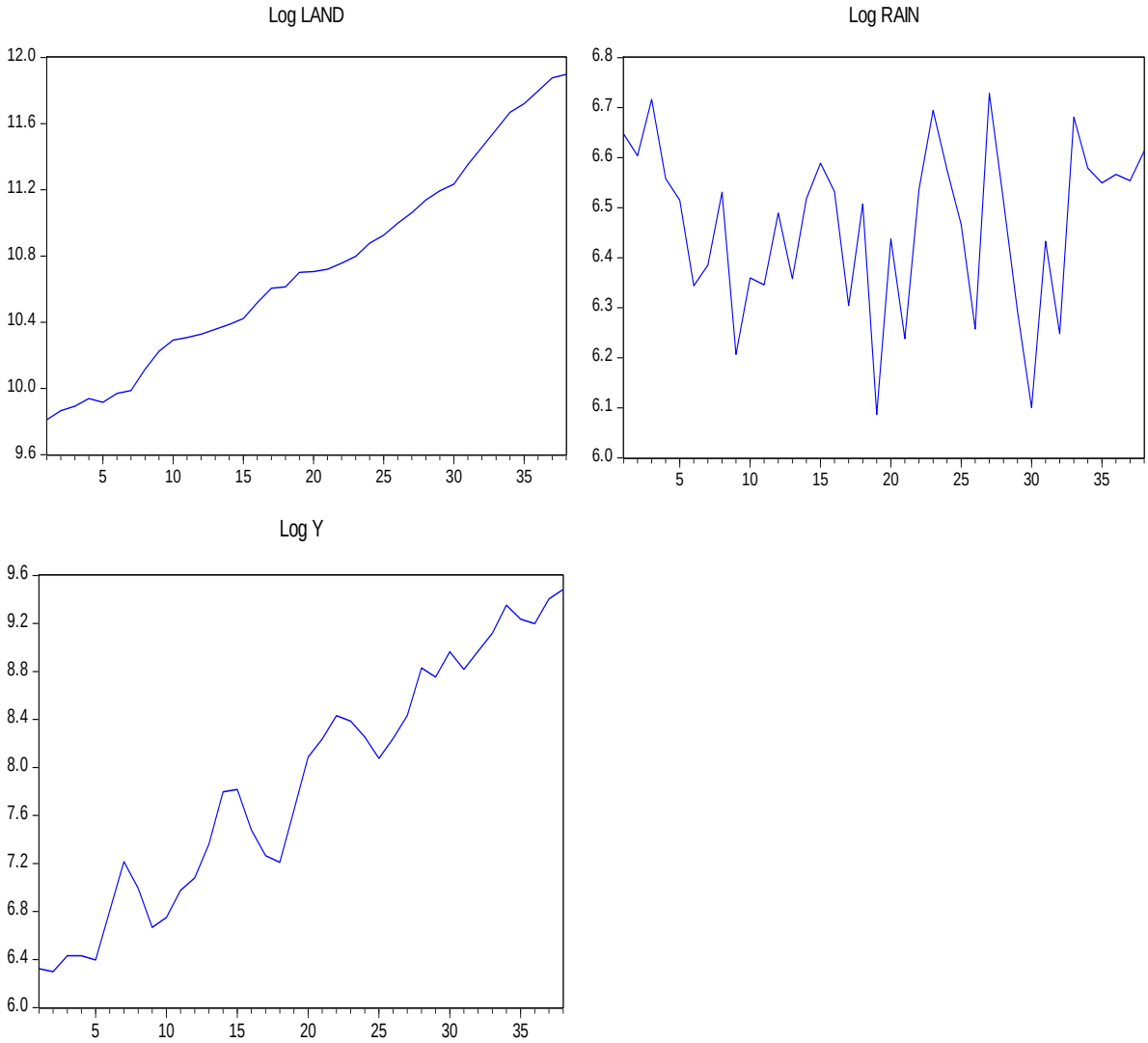
5.1.1 Graphical Analysis of Data

The first phase involved the visual inspection of time series data used in this study for the purposes of getting a rough account of the time series properties of the series. Accordingly, Figure 2.1 shows plots for each of the variables against time in level form on aggregated data. The figure shows that most of the series are likely to be nonstationary, except for rainfall (LRAIN) which appears to be stationary with no trend (1975-2013), capital, land and output are characterised by an upward trend but labour is the only variable the shows a downward trend. Similar trends are noted for the subsectoral data, see figures 2.2 and 2.3 shows plots for maize and wheat subsector variables, respectively.

In contrast to Figure 2.1, when all the variables are plotted in first differences, stationarity is observed (see Appendix A1), and thus the variables display time-independent and mean-reverting tendencies inherently observed in stationary time series.

Figure 2.1: Graphic Plots of aggregated Variables in Levels I(0)



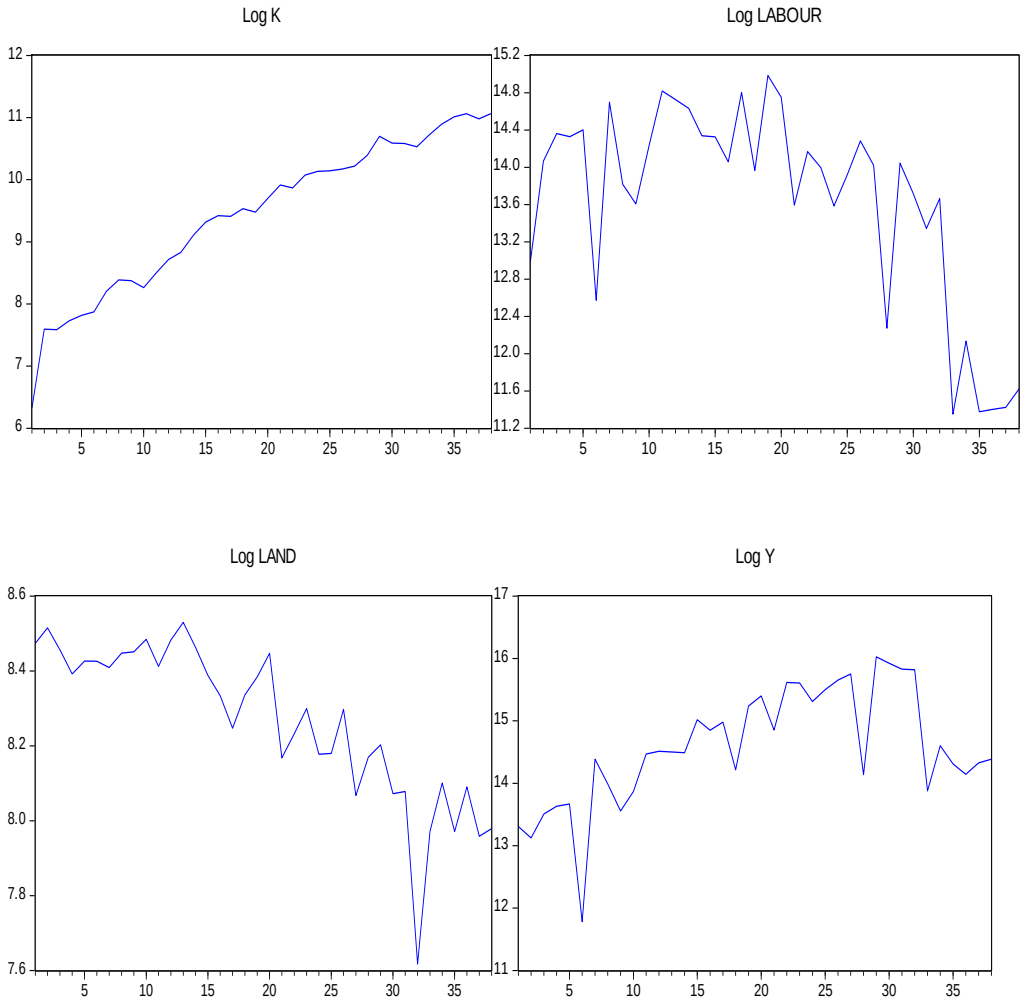


Source: Generated by researcher.

A review of the subsector maize variables (Figure 2.2) shows that all of the series are nonstationary, with capital and output characterised by an upward trend but labour and land characterised by downward trend.

In contrast to Figure 2.2, when all the variables are plotted in first differences, stationarity is observed (see Appendix B2), and thus the variables display time-independent and mean-reverting tendencies inherently observed in stationary time series.

Figure 2.2: Graphic Plots of maize Variables in Levels I(0)

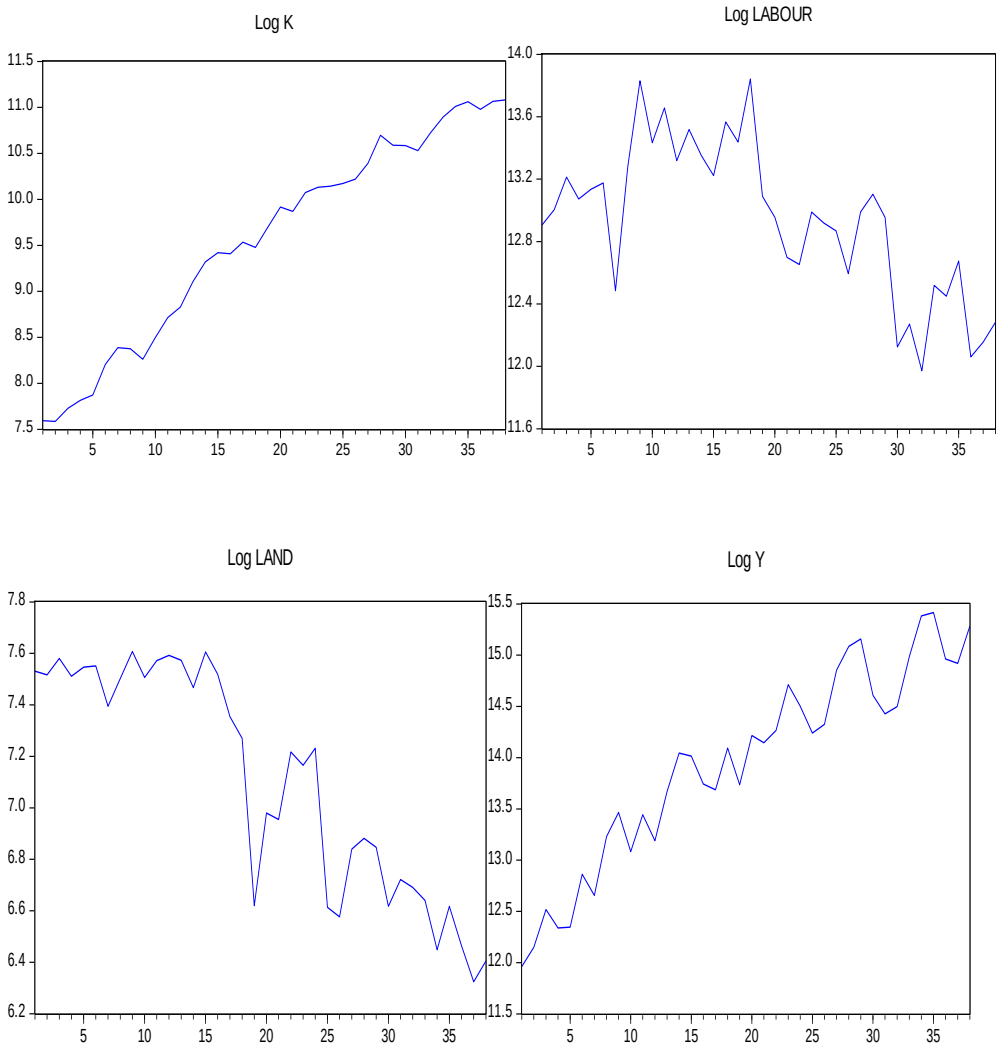


Source: Generated by researcher.

A review of the subsector wheat variables (Figure 2.3) shows that all of the series are nonstationary, with capital and output characterised by an upward trend but labour and land characterised by downward trend.

In contrast to Figure 2.3, when all the variables are plotted in first differences, stationarity is observed (see Appendix C3), and thus the variables display time-independent and mean-reverting tendencies inherently observed in stationary time series.

Figure 2.3: Graphic Plots of wheat Variables in Levels I(0)



Source: Generated by researcher.

5.1.2 Descriptive Statistics

The data series' descriptive statistics, as presented in Tables 1.1, 1.2 and 1.3 point to a symmetrical distribution of agricultural output (LY), capital (LK), land (Lland), labour(Llabour) and average rainfall (Lrain). The distribution of the series can be determined by evaluating different statistical measures. Firstly, since the mean and median values are relatively identical, and the values of skewness are very close to zero, the variables are normally distributed. The positive skewness in the distribution of LK, LLAND, LLABOUR and LRAIN indicate that their distributions are skewed to the left and therefore have longer left tails relative to their right tails. Consequently, the skewness value for LY is negative and this

implies that the distribution has a longer right tail compared to the left. The minimum and maximum estimates show that there are very little variations in the variables, implying stability in the series over the study period.

Table 1.1 Descriptive Statistics Results: aggregated data

	LK	LLABOUR	LLAND	LY	LRAIN
Mean	9.577816	6.862344	10.73683	7.874183	6.464840
Median	9.783340	6.902209	10.70338	7.946314	6.513971
Maximum	11.08190	7.302968	11.89730	9.483287	6.728629
Minimum	7.584773	6.295266	9.811093	6.299684	6.086775
Std. Dev.	1.128331	0.288834	0.625452	1.008513	0.164770
Skewness	-0.342264	-0.230013	0.310495	-0.020620	-0.538845
Kurtosis	1.835702	1.707656	2.029775	1.713922	2.568348
Jarque-Bera	2.888268	2.979480	2.101029	2.621522	2.133917
Probability	0.235950	0.225431	0.349758	0.269615	0.344053
Sum	363.9570	260.7691	407.9994	299.2190	245.6639
Sum Sq. Dev.	47.10586	3.086738	14.47403	37.63264	1.004514

Note: the number of observations $(n) = 38$.

Source: Estimation results.

Table 1.2 Descriptive Statistics Results: Maize subsector

	LY	LLAND	LLABOUR	LK
Mean	13.95324	7.106759	12.94140	15.65688
Median	14.11933	7.224365	12.98900	15.93197
Maximum	15.41643	7.607381	13.84214	17.24179
Minimum	11.96165	6.324359	11.97165	13.23102
Std. Dev.	0.969197	0.437177	0.491083	1.131609
Skewness	-0.412117	-0.305318	-0.205958	-0.675164
Kurtosis	2.194739	1.513561	2.325825	2.342373
Jarque-Bera	2.102360	4.088765	0.988297	3.571773
Probability	0.349525	0.129460	0.610090	0.167648
Sum	530.2232	270.0568	491.7734	594.9613
Sum Sq. Dev.	34.75565	7.071592	8.923002	47.37993

Note: the number of observations $(\mathrm{n}) = 38$.

Source: Estimation results.

Table 1.3 Descriptive Statistics Result: wheat subsector

	LY	LLAND	LLABOUR	LK
Mean	13.95324	13.64158	12.94140	16.21119
Median	14.11933	14.00716	12.98900	16.25118
Maximum	15.41643	15.41643	13.84214	17.89559
Minimum	11.96165	14.98350	11.97165	12.03695
Std. Dev.	0.969197	11.35149	0.491083	1.273942
Skewness	-0.412117	1.088269	-0.205958	-1.140363
Kurtosis	2.194739	-1.028127	2.325825	4.675659
Jarque-Bera	2.102360	6.730976	0.988297	12.68177
Probability	0.349525	0.034545	0.610090	0.001763
Sum	530.2232	518.3799	491.7734	616.0251
Sum Sq. Dev.	34.75565	43.82015	8.923002	60.04835

Note: the number of observations $(\mathrm{n}) = 38$.

Source: Estimation results.

The Kurtosis coefficient, which measures the thickness of the distribution tails, is meant to be three for a normal distribution; if it is less than three then the distribution is fat relative to being normally distributed. It is evident from Table 1.1, 1.2 and 1.3 that the Kurtosis coefficients are well below the required level in both the aggregated data and the subsectors (wheat and maize), therefore the results indicate fat or platykurtic distributions of the series. A more formal method of testing for normality is by means of the Jarque–Bera (JB) test statistic. The JB test is a test of the joint hypothesis that the skewness and Kurtosis coefficients are 0 and 3, respectively. Under the null hypothesis of normally distributed observations, the JB test statistic follows a chi-square χ^2 distribution with 2 degrees of freedom. Should the JB test statistic, in absolute value, be greater than the critical value of χ^2 at a chosen significance level, the null hypothesis may be rejected in favour of the alternative. Thus, if the computed probability (p) value of the JB test statistic is sufficiently low, which occurs when the value of the statistic is very different from 0, the hypothesis that the observations are normally distributed can be rejected. In the context of this study, the results of the JB test indicate that all series follow a normal distribution.

5.2 Stationary Tests

As discussed in the previous chapter, it is of great importance to test for stationarity (or examine integration properties) of all the time series data before estimation in order to avoid spurious results. Hence, to ascertain the order of integration of each variable that enters the multivariate model of this study, the ADF and the PP tests of stationarity are conducted KPPS for confirmation purposes.

Table 2.1, 2.2, 2.3 reports the unit root test results of the ADF and PP test results, with the KPSS test being a confirmatory test measure in the case of inconclusiveness. As discussed in the previous chapter, both the ADF and PP tests are conducted on the null hypothesis that the data generating process has a unit root, while the KPSS test is used to assess the null hypothesis that a time series has no unit root. In performing the main tests (ADF and PP), if the computed test statistic value is greater than the critical value then the null hypothesis is rejected, hence, there is no unit root or nonstationarity. For the KPSS test, the computed test statistic value needs to be smaller than the critical value in order for its null hypothesis not to be rejected. Table 2.1, 2.2 and 2.3 show that that all variables across all sectors are rendered stationary in the first order across all data set. The below results were generated on the basis of no trend and intercept since their respective coefficients were found to be insignificant. In addition, all the standard order of integration tests confirm first difference stationarity "I(1)" at the 5 per cent level. But when referring to tables A1,B1,C1 to appendix A,B,C all data sets are presented at levels form I(0).

Table 2.1: Summary of Unit Root Test Results aggregated data

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-5.756558 (-2.93)	-6.955822	0.500000	I(1)
LK	-6.063975 (-1.95)	-13.00272	0.500000	I(1)
Lland	-4.807719 (-2.93)	-4.848172	0.053916	I(1)
Lrain	-10.28466 (-2.93)	-32.84570	0.209469	I(1)

Source: Estimation results.

Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represent the natural logs of agricultural output and fixed capital formation, respectively.

Table 2.2: Summary of Unit Root Test Results Maize subsector

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-9.968742 (-2.93)	-22.48000	0.147919	I(1)
LK	-7.392875 (-2.93)	-39.64904	0.105764	I(1)
Lland	-6.676791 (-2.93)	-19.14217	0.096781	I(1)
Llabour	-10.49422 (-2.93)	-25.13270	0.046144	I(1)

Source: Estimation results.

Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represent the natural logs of agricultural output and fixed capital formation, respectively.

Table 2.3: Summary of Unit Root Test Results Wheat subsector

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-7.744615 (-2.93)	-12.67730	0.346258	I(1)
LK	-6.140697 (-2.93)	-17.41590	0.453791	I(1)
Lland	-7.483612 (-2.93)	-18.47392	0.365263	I(1)
Llabour	-4.950823 (-2.93)	-20.37581	0.336461	I(1)

Source: Estimation results.

Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represent the natural logs of agricultural output and fixed capital formation, respectively.

5.3 VAR and VECM Estimation Processes

5.3.1 Lag Length Selection

Before estimating a VAR or VECM it is standard practice to first perform the selection of unrestricted VAR order (p). The highest number of lags to be used in the cointegration test and following VAR or VECM model is pinpointed by the Akaike, Schwarz and Hannan-Quinn information criteria, the sequential modified likelihood ratio, and the final prediction error tests as the VAR and VECM methodologies are sensitive to lag lengths. To determine the lag length, the unrestricted VAR is estimated with all variables in levels with a maximum number of lags, then decreasing by re-estimating the model for one lag less until zero. In each of these models, the values of the Akaike information criterion (AIC) and Schwarz information criterion (SIC) criterion and their respective autocorrelation, heteroskedasticity and normality diagnostics are analysed and the model that minimises AIC and, SBC and passes all diagnostic checks is selected as the one with the optimal lag length. With limited observations such as the ones used in this study, the maximum number of lags of this study was originally set at three, and sequentially reduced to two, which was found to meet the Gaussian conditions.

From the unrestricted VAR output, the lag order selection criterion is then generated, of which the results are presented in Table A2, B2 ,C2, Appendix A, B, C. Although a majority of the tests suggest the optimal lag in the model to be one in all Tables, this study utilised two lags as recommended by the AIC and FPE since both these criteria have superiority when dealing with small observations. This finding suggests under the aggregated data and maize subsector a second order $(p = 2)$ VAR model is most appropriate, , and therefore a first order $(p - 1)$ VECM can be estimated since EViews estimates the VAR model in level form and takes the first difference of the VAR variables to estimate the VECM, hence under the VECM framework, one degree of freedom is lost and therefore reducing the lag order by one. Therefore, a second order $(p = 2)$ VAR in the VECM framework is estimated as a first order $(p = 1)$.but contrary to the wheat subsector data which reveals that a third order $(p = 3)$ VAR model is most appropriate, , and therefore a first order $(p - 2)$ VECM is estimated.

5.3.2 Stability of the VAR

The study used the Autoregressive (AR) roots test to examine the stability of the VAR(2) process and found that there is a roots laying outside the unit circle under the aggregated data, thus the stability condition does not holds, as shown in figure A2 but figure B2 and C2 confirm that under the two subsectors (wheat and maize) there is no roots laying outside the unit circle. According to Johnston (1999), if each root has a modulus less than one, all the endogenous variables in a VAR system will be $I(0)$ and therefore the variables to be estimated in the VAR model require no differencing. Since both maize and wheat subsector data moduli on the AR table are strictly under one, a VAR approach may be appropriate to estimate short run interactions in the dynamic model of this study under the two subsectors but not the aggregated data as its modulus is above 1. However, the highest modulus under the two subsectors is 0.95 which is also very close to one, suggesting that the Johansen VECM approach may also be successfully estimated to test for cointegrating effects. Given the results of the AR roots test, both the VAR and VECM are plausible models to consider under the maize and wheat subsectors, but not under the aggregated data. Additionally, since all the variables are I(1) it serves as further justification to utilise the Johansen VAR/VECM methodology.

5.3.2.1 The VECM Estimation

As shown reported previously, the AR roots test reveals that one of the roots has a value very close to one. This finding, together with the fact that all the series in the study's multivariate model are$\mathrm{I}(1)$, it is feasible to use the VECM method and test whether a long run relationship exists between the series for the two subsectors maize and wheat. For this purpose, the Johansen test of cointegration is applied. However, prior to generating the test, the appropriate model regarding the deterministic component in the multivariate system needs to be ascertained.

5.3.2.2 Deterministic Components

This step is concerned with determining whether an intercept and trend should be included in the model. According to Asteriou and Hall (2007) and Harris (1995), five different deterministic models (i.e., cases) can be considered:

- Case 1: No intercept or trend in the cointegrating equation or VAR. This rarely occurs in practice since the intercept is needed in order to account for adjustments in the unit of measurements of the variables in the model.

- Case 2: Intercept but no trend in the VAR model. In this instance, the intercept is restricted to the long run model.

- Case 3: Intercept in the cointegrating vector with no trend in the cointegrating vector and VAR model. It is assumed that the intercept in cointegrating equation is cancelled out by the intercept in the VAR, therefore leaving only one intercept in the short-run.

- Case 4: Intercept in both the cointegrating equation and the VAR model, a linear trend in the cointegrating equation but not in the VAR model. In this model, no time trend exists in the short run.

- Case 5: Intercept and quadratic trend in the cointegrating equation, and an intercept and linear trend in the VAR model. This case is also not an implausible option as it is problematic to interpret in an economics standpoint.

Accordingly, Table 3.1, 3.2 and 3.3 below, shows the five assumptions that can be made regarding the possible cointegrating relations that might exist among all the variables in the study's model.

Table 3.1: Summary of Test Assumptions: Aggregate Data

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	1
Max-Eig	2	1	1	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Table 3.1, since cases 1 and 5 are deemed implausible for macroeconomic time series data in practice, we focus on the remaining options. For the remaining three cases, the results show strong evidence of the existence of a long run equilibrium relationship among one variable in the model. Specifically, when there are no restrictive conditions, such as in case 2 and case 3 the trace and maximum eigenvalue tests confirm the existence of only one cointegrating vectors, respectively.

Table 3.2: Summary of Test Assumptions: Maize Data

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	0	0

*Critical values based on MacKinnon-Haug-Michelis (1999)

Table 3.2, since cases 1 and 5 are deemed implausible for macroeconomic time series data in practice, we focus on the remaining options. For the remaining three cases, the results show evidence of the existence of a long run equilibrium relationship among all variables in the model. Specifically, when there are no restrictive conditions, such as in case 2, the trace and maximum eigenvalue tests confirm the existence of one cointegrating vectors, respectively. In case 3, the trace test suggests two cointegrating vectors while the maximum eigenvalue test finds only one. The one cointegrating vector found by the maximum eigenvalue test in case 2 is supported by both tests in case 4, which suggests strong evidence of only one cointegrating vector.

Table 3.3: Summary of Test Assumptions: Wheat Data

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	4	3	3	2	1
Max-Eig	2	3	1	2	2

*Critical values based on MacKinnon-Haug-Michelis (1999)

Table 3.3, since cases 1 and 5 are deemed implausible for macroeconomic time series data in practice, we focus on the remaining options. For the remaining three cases, the results show strong evidence of the existence of a long run equilibrium relationship among all variables in the model. Specifically, when there are no restrictive conditions, such as in case 2, the trace and maximum eigenvalue tests confirm the existence of three cointegrating vectors, respectively. In case 3, the trace test suggests three cointegrating vectors while the maximum eigenvalue test finds only one. The trace and maximum eigenvalue tests confirm the existence of two cointegrating vectors. Due to the fact that there are only 3 cointergrating variables in the model. The purpose of the analysis is to estimate a Cobb Douglas production function that includes all the variables hence the researcher follows the suggested eign value test which supporting the existence of one cointergrating test.

5.4 Cointegration Test Results

Table 4.1, 4.2 and 4.3 below shows the cointegration test results at 5 percent significance level for the aggregated data, the hypothesis of no cointegrating vector is rejected by both the trace and the maximum eigenvalue tests since their test statistics of 61.08 are greater than their respective critical values of 47.86, while it is accepted at r =1 (ie., The rank of the matrix is one, implying only one cointegrating vector exists in the long run relationship) since trace statistic is less than the critical value of 29.08.

Table 4.1 Cointegration Test Results – Aggregate Data

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.652556	61.08009	47.85613	0.0018
At most 1	0.424438	24.07978	29.79707	0.1971
At most 2	0.118415	4.745490	15.49471	0.8352
At most 3	0.009507	0.334320	3.841466	0.5631

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.652556	37.00031	27.58434	0.0023
At most 1	0.424438	19.33429	21.13162	0.0876
At most 2	0.118415	4.411170	14.26460	0.8136
At most 3	0.009507	0.334320	3.841466	0.5631

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.2 below it shows the cointegration test results at 5 percent significance level for maize sector sector, the hypothesis of no cointegrating vector is rejected by both the trace and the maximum eigenvalue tests since their test statistics of 62.91 and 30.34 (respectively) are greater than their respective critical values of 47.86 and 29.79.

4.2 Conintegration Test Result- Maize Data

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.606662	62.99719	47.85613	0.0010
At most 1 *	0.357871	30.33919	29.79707	0.0433
At most 2	0.259274	14.83536	15.49471	0.0627
At most 3 *	0.116393	4.330989	3.841466	0.0374

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.606662	32.65800	27.58434	0.0102
At most 1	0.357871	15.50383	21.13162	0.2552
At most 2	0.259274	10.50437	14.26460	0.1809
At most 3 *	0.116393	4.330989	3.841466	0.0374

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4.3 below shows the cointegration test results at 5 percent significance level for the wheat subsector, the hypothesis of no cointegrating vector is rejected by both the trace and the maximum eigenvalue tests since their test statistics of 96.93, 37.81 and 17.49 (respectively) are greater than their respective critical values of 47.86, 29.79 and 15.49.

4.3 Cointegration Test Result – Wheat Data

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.815296	96.92985	47.85613	0.0000
At most 1 *	0.440365	37.81484	29.79707	0.0048
At most 2 *	0.344534	17.49840	15.49471	0.0246
At most 3	0.074616	2.714113	3.841466	0.0995

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.815296	59.11501	27.58434	0.0000
At most 1	0.440365	20.31644	21.13162	0.0647
At most 2 *	0.344534	14.78429	14.26460	0.0413
At most 3	0.074616	2.714113	3.841466	0.0995

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

5.5 VECM Analysis and Results

This subsection will report both the long and short run adjustment equation for agricultural output, for aggregate agricultural output as well as the maize and wheat subsectoral outputs, respectively. In chapter four the VAR/VECM was discussed under the following generic equation which is repeated here for convenience:

$$\Delta \boldsymbol{Y_t} = \boldsymbol{u_0} + \boldsymbol{\Pi Y_{t-1}} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma_{iY} \Delta Y_{t-i}} + \boldsymbol{\Psi D_t} + \boldsymbol{\varepsilon_t} \qquad (14)$$

It was established earlier in this chapter that the rank of matrix $\boldsymbol{\Pi}$ is one (ie., r=1, implying there exists just one long runcointegrating vector), hence the matrix can be written as $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$, with $\boldsymbol{\beta}$ containing the r cointegrating vectors and $\boldsymbol{\alpha}$ describing the speed of adjustment to the long run equilibrium. Additionally $\boldsymbol{\Gamma_i}$ are k x k coefficient matrices capturing the short run dynamic effects. However since the study used a second (third order for wheat data) order VAR model (p=2 for aggregate and maize data and p=3 for wheat) and in VECM form it is differenced to result in a first (second order for wheat) order VECM model (ie., p-1) $\boldsymbol{\Gamma_{iY}}$ becomes a single (two for wheat)k x k coefficient matrix (matrices) capturing just the first (second) order lags. $\boldsymbol{D_t}$ is a vector deterministic terms like dummy variables or exogenous variables like rainfall, while $\boldsymbol{\Psi}$ capture their impact on the dependent variable. Further, $\boldsymbol{\mu_0}$ captures the vector of constants; however these have been suppressed by Eviews. Moreover $\boldsymbol{\Pi y_{t-1}}$ can be expanded as follows:

$$\boldsymbol{\Pi y_{t-1}} = \begin{bmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ \alpha_{41} \end{bmatrix} \begin{bmatrix} \mathbf{1} & \boldsymbol{\beta_{12}} & \boldsymbol{\beta_{13}} & \boldsymbol{\beta_{14}} \end{bmatrix} \begin{pmatrix} \boldsymbol{LOutput} \\ \boldsymbol{LLand} \\ \boldsymbol{LCapital} \\ \boldsymbol{LLabour} \end{pmatrix}_{\boldsymbol{t-1}} \qquad (15)$$

In (14) the cointegrating vector is captured in the error correction format as follows:

$$\boldsymbol{ECM = \varepsilon_t = LOutput - \beta_{12}LLand - \beta_{13}LCapital - \beta_{14}Labour} \quad (16)$$

Equation (16) captures deviations of output from its long run relationship with the other variables, the $\boldsymbol{\alpha_{ij}}$ coefficients are the short run adjustment coefficients, for example, if output overshoots its long run relationship with the other variables in the previous period then $\boldsymbol{\alpha_{11} < 0}$ captures the readjustment of output downwards in order to restore equilibrium in the next period, while all the other variables in the next period have to adjust upwards in order to restore equilibrium, ie., $\boldsymbol{\alpha_{12}, \alpha_{13}, \alpha_{14} > 0}$.

As mentioned above (16) captures the long run cointegrating vector in error correction format, however if it is rewritten is its normal regression format the relationship takes the following form:

$$\boldsymbol{LOutput = \beta_{12}LLand + \beta_{13}LCapital + \beta_{14}Labour + \varepsilon_t} \quad (17)$$

Notice the long run coefficients now take on a positive sign, this is the format in which the rest of this study interpret these coefficients. Further note that the constant in the cointegrating vector has been excluded but it can be easily included by adding a scalar = 1 as the fifth variable and variable vector and then include the constant term in the long coefficient vector of equation 16.

The full results of equations 14 -17 are presented in in tables 5.1 to 5.3 and will be discussed below.

5.5.1 Production Function Analysis

The four (rainfall is not included in the cointegration vector due to its exogenous nature its included as part of the deterministic terms for all the VECM analyses conducted below) variable VECM results are presented in Tables 5.1, 5.2 and 5.3 below.

The four variable VECM results generated from the aggregated data are presented in Table 5.1 below:

Table 5.1 VECM Estimates- Aggregate Data production function

Cointegrating Eq:	CointEq1
LY(-1)	1.000000
LLAND(-1)	-1.151117 (0.28695) [-4.01151]
LLABOUR(-1)	0.989629 (0.36583) [2.70519]
LK(-1)	-0.141158 (0.13305) [-1.06092]
C	-4.993499

	(4.63933)			
	[-1.07634]			
Error Correction:	D(LY)	D(LLAND)	D(LLABOUR)	D(LK)
CointEq1	-0.502004	0.020730	-0.064553	-0.112930
	(0.11153)	(0.02290)	(0.08703)	(0.07765)
	[-4.50106]	[0.90527]	[-0.74172]	[-1.45430]
D(LY(-1))	0.336434	0.019031	0.112445	0.014184
	(0.21986)	(0.04514)	(0.17157)	(0.15308)
	[1.53021]	[0.42157]	[0.65540]	[0.09266]
D(LLAND(-1))	-2.122663	0.255414	-0.256110	-0.857444
	(0.92078)	(0.18906)	(0.71852)	(0.64109)
	[-2.30528]	[1.35099]	[-0.35644]	[-1.33747]
D(LLABOUR(-1))	0.171096	0.011967	-0.494802	0.126030
	(0.20317)	(0.04171)	(0.15854)	(0.14145)
	[0.84214]	[0.28687]	[-3.12100]	[0.89095]
D(LK(-1))	0.282990	-0.145329	-0.222074	0.052120
	(0.39955)	(0.08204)	(0.31178)	(0.27818)
	[0.70828]	[-1.77152]	[-0.71227]	[0.18736]
LRAIN	-0.289524	0.021373	-0.040352	-0.048517
	(0.06974)	(0.01432)	(0.05442)	(0.04855)
	[-4.15164]	[1.49267]	[-0.74151]	[-0.99922]
R-squared	0.452792	0.178095	0.327549	0.102753
Adj. R-squared	0.361591	0.041111	0.215474	-0.046789
Sum sq. resids	0.920628	0.038811	0.560599	0.446286
S.E. equation	0.175179	0.035968	0.136699	0.121968
F-statistic	4.964754	1.300116	2.922580	0.687119
Log likelihood	14.91014	71.90430	23.83905	27.94388
Akaike AIC	-0.495008	-3.661350	-0.991059	-1.219105
Schwarz SC	-0.231088	-3.397430	-0.727139	-0.955185
Mean dependent	0.088433	0.056439	-0.018653	0.097142
S.D. dependent	0.219246	0.036731	0.154334	0.119211
Determinant resid covariance (dof adj.)		2.16E-09		
Determinant resid covariance		1.04E-09		
Log likelihood		167.9186		
Akaike information criterion		-7.717698		
Schwarz criterion		-6.442086		

The following long run cointegrated Cobb-Douglas production for the aggregate agricultural sector was extracted from the table, based on the reasoning captured in equation 15 1bove:

$$\text{LOutput} = 4.3 + 1.15\ \text{LLand} + 0.14\text{LCapital} - 0.99\ \text{LLabour} \ldots\ldots (18)$$

t statisitc (4.6) (4.01) (1.06) (-2.7)

The magnitudes of the estimated long run equilibrium relationship coefficients for the variables, as defined by the β vector, prove to be plausible and have the expected signs correct signs except for labour.

According to the results, the long run coefficient for land of 1.15 is statistically significant at the 1% significance level and is consistent with our hypothesis outlined in the previous chapter and implies that if the land usage ~~its~~ increases by 1 percent, agricultural production will also increase by a magnitude of 1.15 percent in the long run, ceteris paribus. This implies that land productivity exhibits increasing returns to scale (doubling land input more than doubles output)

Moreover, a percentage rise in capital causes a 0.14 percent rise in agricultural production output but the variable is not significant for aggregate data. Conversely, labour input appears to affect economic growth inversely, thus, a 1 percent rise in labour will lead to a 0.99 percent decline in production output. This negative coefficient is statistically significant at 5 percent level, thus implying that the South African aggregate agricultural sector is beset by severe diminishing marginal returns to labour, which explains the observed persistent decline in employment in the agricultural sector over the past three decades.

In regard to the short run adjustment coefficients as described in equation 15, above, which explains how the variables readjusts to its long run equilibrium when output overshoots its long run relationship with the other variables in the cointegrating vector, in the previous period. Notice only the $\alpha_{11} = -0.5$ coefficient is statistically significant at the 1% significance level. This coefficient suggests that 50% of the disequilibrium arising from output overshooting its long run equilibrium is corrected in the first year and by the second year the full adjustment is achieved. Since α_{12}, α_{13} and α_{14} are statistically insignificant, it implies that land, capital and labour does not respond to output's overshooting of its long run equilibrium with these variables. This implies that these inputs cannot easily enter or exit the production process. The puzzling result is the negative but statistically significant coefficient on the exogenous natural log of rainfall variable. The result suggests that a 1% rise in rainfall causes agricultural output to decline by 0.29%.

In regard to the short run dynamic adjustment of the variables as captured by the Γ_{iY} vector only two are significant (highlighted in blue). The coefficient in column one suggests that a 1% decrease in the

change in land usage for agricultural production in the previous year causes output change to rise by 2% in the succeeding year. This is the likely manner that agribusinesses may have been using in maintaining profitable enterprises and keeping land productivity at high long run levels.

The highlighted tau coefficient in column three suggests a 1% increase in the change of labour in the agricultural sector in the previous period causes labour change to adjust downwards in the next period by 0.5%. This is the reflection of the phenomenon of diminishing returns to labour in the aggregate agricultural sector hence in order to maintain profitability agribusinesses are forced to cut back on labour input.

5.5.2 VECM Estimates - Maize Subsector Production Function Analysis

The four variable VECM results generated from the maize subsector data are presented in Table 5.2 below:

Table 5.2 VECM Estimates: Maize Subsector Production Function

Cointegrating Eq:	CointEq1			
LY(-1)	1.000000			
LLAND(-1)	1.485028			
	(0.38197)			
	[3.88778]			
LLABOUR(-1)	-0.234867			
	(0.06552)			
	[-3.58489]			
LK(-1)	-0.655255			
	(0.04858)			
	[-13.4886]			
C	-9.263433			
	(3.54669)			
	[-2.61185]			
Error Correction:	**D(LY)**	**D(LLAND)**	**D(LLABOUR)**	**D(LK)**
CointEq1	-0.100508	-0.326940	0.584128	0.273671
	(0.63792)	(0.09714)	(0.63260)	(0.61134)
	[-0.15756]	[-3.36578]	[0.92338]	[0.44766]
D(LY(-1))	-0.297069	0.044904	-0.590878	-0.562863
	(0.43007)	(0.06549)	(0.42648)	(0.41215)
	[-0.69075]	[0.68570]	[-1.38547]	[-1.36567]

D(LLAND(-1))	1.964446	-0.228250	1.452841	1.662799
	(1.01360)	(0.15434)	(1.00514)	(0.97137)
	[1.93809]	[-1.47887]	[1.44541]	[1.71182]
D(LLABOUR(-1))	-0.493727	-0.069492	-0.322575	-0.142785
	(0.65660)	(0.09998)	(0.65112)	(0.62924)
	[-0.75195]	[-0.69506]	[-0.49542]	[-0.22692]
D(LK(-1))	0.371799	0.022256	0.355129	0.220122
	(0.50037)	(0.07619)	(0.49620)	(0.47952)
	[0.74305]	[0.29210]	[0.71570]	[0.45904]
LRAIN	0.058824	0.184366	-0.349842	-0.149456
	(0.36542)	(0.05564)	(0.36237)	(0.35019)
	[0.16098]	[3.31342]	[-0.96543]	[-0.42678]
R-squared	0.347062	0.421869	0.411969	0.380269
Adj. R-squared	0.238239	0.325514	0.313964	0.276981
Sum sq. resids	16.25610	0.376921	15.98591	14.92966
S.E. equation	0.736118	0.112089	0.729975	0.705447
F-statistic	3.189236	4.378271	4.203550	3.681623
Log likelihood	-36.77088	30.98452	-36.46919	-35.23874
Akaike AIC	2.376160	-1.388029	2.359399	2.291041
Schwarz SC	2.640080	-1.124109	2.623319	2.554961
Mean dependent	0.035048	-0.014889	-0.067955	0.045962
S.D. dependent	0.843409	0.136483	0.881322	0.829639
Determinant resid covariance (dof adj.)		1.94E-06		
Determinant resid covariance		9.37E-07		
Log likelihood		45.53099		
Akaike information criterion		-0.918388		
Schwarz criterion		0.357224		

The following long run cointegrated Cobb-Douglas production function for the maize subsector was extracted from the above table, using the justification captured in equation 16, above:

$$\text{LOutput} = 9.2 - 1.5\ \text{LLand} + 0.66\text{LCapital} + 0.23\ \text{LLabour} \ldots . (19)$$

t statisitc (2.6) (-3.9) (13.5) (3.6)

Interestingly the production function for the maize subsector is quite different for that of the aggregate sector discussed above. This sector exhibits severe diminishing margining returns to land in the sense that land has been over allocated to maize to the extent that a decrease in land usage will raise the marginal productivity of land. Microeconomic theory suggests that in regard to land usage the production is at the stage three level where an additional percentage of land farmed results in a reduction in total output by 1.5%. This estimate is significant at the 99% confidence interval, hence it

will make sense under these circumstances to cut back on land usage drastically, especially since land usage is demonstrating increasing returns to scale in the negative direction.

Capital and labour on the other hand are consistent with our *a priori* expectation that their respective marginal productivities are positive and statistically significant. A 1% rise is capital usage results in a 0.66% rise in maize output, while a 1% rise is labour input results in a 0.23% rise in output. This implies that in regard to maize production, the industry ought to employ more capital relative to labour over the long term.

In regard to the short run adjustment coefficients as described in equation 15, above, which explains how the variables readjusts to its long run equilibrium when output overshoots its long run relationship with the other variables in the cointegrating vector, in the previous period. Notice that $\alpha_{11} = -0.1$ coefficient has the correct sign but is statistically insignificant at the conventional significance levels, thus implying that no adjustment to the long run equilibrium arises in the short run, should maize production overstep (or under-step) the equilibrium. Addtionally, $\alpha_{12}, = -0.33$, since the is a long run negative association between land and maize output it makes sense that if output overshoots its long run equilibrium in the previous year than in the current year land devoted to maize production decreases. Notice α_{12} and α_{14} are statistically insignificant, it implies that capital and labour does not respond to output's overshooting of its long run equilibrium with these variables.

In regard to the short run dynamic adjustment of the variables as captured by the Γ_{iY} vector only two are significant (highlighted in blue). The coefficient in column one suggests that a 1% increase in the change in land usage for maize production in the previous year causes output change to rise by 2% in the succeeding year. This finding is paradoxical since in the short run positive changes in land usage for maize cultivation raises output but over the long term increased land usage leads to overall reduction in output.

The highlighted tau coefficient in column three suggests a 1% increase in the change of land usage in the maize sector in the previous period causes technology changes to adjust upwards in the next period by 1.7%. This is perhaps indicative of the relative greater importance of capital intensive production processes in the maize sector

Lastly in the short run rainfall which is treated as an exogenous variable in the analysis (ie., it is not part of the cointegrating vector but has a short run influence on the variables entering the vector) appears to play a significant role in making land available for short run production of maize. A 1% rise in the rainfall causes 0.18% arable land to be made available. This finding makes economic sense since rainfall a natural resource is taken advantage of whenever it is bountiful. To some extent it implies that the release of arable land for maize production does exhibit a degree of flexibility.

5.5.3 VECM Estimates - Wheat Subsector Production Function Analysis

The four variable wheat subsector VECM results are presented in Table 5.3, below.

5.3 VECM Estimates: Wheat Subsector Production Function

Cointegrating Eq:	CointEq1			
LY(-1)	1.000000			
LLAND(-1)	-1.894042			
	(0.16491)			
	[-11.4852]			
LLABOUR(-1)	1.289742			
	(0.09502)			
	[13.5729]			
LK(-1)	-1.128600			
	(0.03695)			
	[-30.5417]			
C	0.495998			
Error Correction:	**D(LY)**	**D(LLAND)**	**D(LLABOUR)**	**D(LK)**
CointEq1	-0.447991	0.382092	-0.608111	-0.800535
	(0.35563)	(0.17032)	(0.37037)	(0.35592)
	[-1.25970]	[2.24340]	[-1.64190]	[-2.24917]
D(LY(-1))	0.774083	-0.208585	0.025335	0.704024
	(0.75493)	(0.36155)	(0.78622)	(0.75556)
	[1.02537]	[-0.57692]	[0.03222]	[0.93180]
D(LY(-2))	0.306698	0.529974	0.847737	0.903607
	(0.54613)	(0.26155)	(0.56876)	(0.54658)
	[0.56159]	[2.02628]	[1.49049]	[1.65321]
D(LLAND(-1))	-0.815879	-0.051246	-0.690548	-1.110920
	(0.51613)	(0.24718)	(0.53752)	(0.51656)
	[-1.58076]	[-0.20732]	[-1.28468]	[-2.15062]
D(LLAND(-2))	-0.325654	0.175910	-0.495088	-0.626638

	(0.42630)	(0.20416)	(0.44397)	(0.42665)
	[-0.76391]	[0.86161]	[-1.11514]	[-1.46873]
D(LLABOUR(-1))	0.555959	-0.389808	0.226726	1.059879
	(0.64450)	(0.30866)	(0.67121)	(0.64503)
	[0.86262]	[-1.26289]	[0.33778]	[1.64314]
D(LLABOUR(-2))	0.732264	0.120277	0.470769	0.930920
	(0.56428)	(0.27025)	(0.58767)	(0.56475)
	[1.29769]	[0.44506]	[0.80108]	[1.64838]
D(LK(-1))	-1.062307	0.386229	-0.166381	-1.307656
	(1.05630)	(0.50588)	(1.10008)	(1.05717)
	[-1.00569]	[0.76348]	[-0.15124]	[-1.23694]
D(LK(-2))	-1.089967	-0.796214	-1.125417	-1.559410
	(0.78500)	(0.37595)	(0.81754)	(0.78565)
	[-1.38849]	[-2.11786]	[-1.37659]	[-1.98487]
C	-3.348494	-3.198464	-5.848631	-4.659029
	(2.40207)	(1.15039)	(2.50162)	(2.40405)
	[-1.39400]	[-2.78032]	[-2.33793]	[-1.93799]
LRAIN	0.548713	0.492865	0.907745	0.756601
	(0.37074)	(0.17755)	(0.38611)	(0.37105)
	[1.48004]	[2.77585]	[2.35102]	[2.03910]
R-squared	0.343013	0.605252	0.458962	0.425392
Adj. R-squared	0.069268	0.440773	0.233530	0.185972
Sum sq. resids	2.352016	0.539463	2.551019	2.355893
S.E. equation	0.313051	0.149925	0.326025	0.313308
F-statistic	1.253040	3.679821	2.035921	1.776760
Log likelihood	-2.411534	23.35640	-3.832883	-2.440353
Akaike AIC	0.766373	-0.706080	0.847593	0.768020
Schwarz SC	1.255197	-0.217256	1.336417	1.256844
Mean dependent	0.079040	-0.033570	-0.026562	0.087729
S.D. dependent	0.324491	0.200485	0.372395	0.347258

Determinant resid covariance (dof adj.)	1.94E-07
Determinant resid covariance	4.30E-08
Log likelihood	98.20469
Akaike information criterion	-2.868839
Schwarz criterion	-0.735791

The following long run cointegrated Cobb-Douglas production for the aggregate agricultural sector was extracted from the table, based on the reasoning captured in equation 16 above:

$$\text{LOutput} = 0.5 + 1.89\ \text{LLand} + 1.13\text{LCapital} - 1.29\ \text{LLabour} \ldots\ldots (20)$$

t statisitc (0,0) (11.5) (30.5) (-13.6)

The long run cointegrated Cobb-Douglas function for the wheat sub sector is strikingly similar to that of the aggregate agricultural sector. The results show that the long run coefficient for land of 1.89 is statistically significant at the 1% significance level and is consistent with our hypothesis outlined in the previous chapter which implies that if the land usage increases by 1%, wheat production will also increase by a magnitude of 1.89% in the long run, ceteris paribus. This implies that land productivity exhibits increasing returns to scale and is the dominant input in influencing profitability.

Capital also appears to be a critical factor in raising productivity in the wheat sector, a 1% rise in capital causes a 1.13% rise in wheat production output and the variable is significant at the 1% significance level. Labour by contrast appears to affect wheat production inversely, thus, a 1% rise in labour will lead to a 1.3% decline in wheat production output. This negative coefficient is statistically significant at 1% level thus indicating that the South African wheat production subsector sector like the aggregate sector is overwhelmed by diminishing marginal returns to labour.

In regard to the short run adjustment coefficients as described in equation 15, above, which explains how the variables readjusts to its long run equilibrium when output overshoots its long run relationship with the other variables in the cointegrating vector, in the previous period. Notice $\alpha_{11} = -0.45$ coefficient although it has the correct sign it is statistically insignificant at the conventional significance levels, thus suggesting that wheat production does not readjusts should it overshoot (undershoot) its cointegrating equilibrium. The α_{12} has the correct sign and is statistically significant at 5% significance level. The coefficient suggests that should wheat production last period overshoot its cointegrating equilibrium by 1% then in the next period more land is made available by a magnitude of 0.38%. The α_{14} coefficient is statistically significant but has the incorrect sign, it implies that capital responds to output's overshooting of its long run equilibrium by decreasing significantly (about 0.8% for a 1% overshooting)) thus indicating capital can be a flexible input in the short run.

In regard to the short run dynamic adjustment of the variables as captured by the Γ_{iY} vector only one significant (highlighted in blue) coefficient was found. The coefficient in column three suggests that a 1% increase in the change in land usage for wheat production in the previous year causes capital change to fall by 1% in the succeeding year. This might suggest that land and capital might be substitutes in the wheat production business.

The interesting statistically significant (at the 5% significant level) finding is in regard to the influence rainfall has on the harnessing of the land labour and capital inputs for wheat production in the short run (see green highlighted results). The results suggest a 1% increase in rainfall will cause the change in land, labour and capital devoted to wheat production to rise by 0.5%, 0.91% and 0.76% respectively. It is quite interesting that these inputs are quite flexible and can be easily harnessed in the short run.

5.6 Single Equation Estimation Methods

This section is concerned with the estimation of the FMOLS, CCR, and DOLS methods to confirm findings from the VAR and VECM regarding the nature of the long and short run relationship between agricultural production output, land, labour, rainfall and capital in both aggraegated data and subsector sectors (maize, wheat) in South Africa.

5.6.1.a Fully-Modified Ordinary Least Squares (FMOLS) : Aggreagted data production function

Table A4, Appendix A shows the results estimated on non-prewhitened Barlett kernel, Newey-West fixed bandwidth $= 40.000$ FMOLS model and its cointegrating equation is expressed as:

$$LY = 0.62 + 0.52\,Lland - 0.53\,Llabour + 0.48\,LCapital + 0.10\,LRain \;\ldots \qquad (21)$$

(0.9) (1.95) (-1.69) (3.47) (0.7)

The FMOLS results indicate that land and capital are significant at 10% significance level while capital is significant at the 1% level. Rainfall is insignificant. The land coefficient suggests, a 1 percent increase in land causes agricultural production use to rise by approximately 0.52 percent. The detected negative coefficient of labour implies that a 1% increase in labour would result in a 0.53 percent decline in agricultural production output, ceteris paribus. As expected, capital and rainfall also impacts on agricultural production output positively, with elasticity coefficients of 0.48 and 0.10, respectively but rainfall not being significant. Overall, the FMOLS results confirms a long run cointegrating relationship exist between agricultural production output and its regressors. The signs are identical to the VECM counterpart captured in equation 20 above, however the magnitudes vary. In the single equation capital's contribution to production output is much higher while land's is lower and labour has a smaller negative impact compared to the VECM based cointegrating long run equation.

5.6.2. a Canonical Cointegration Regression (CCR) : Aggregated data production function

the below equation shows the long-run equilibrium equation is obtained from the CCR estimation of the study's model (see Table A5, Appendix A) and shows that all the specified explanatory variables impact on agricultural production output in driving agricultural production output in South Africa in the long run, hence there is cointegration among the variables.

$$LY = 1.62 + 0.54LLand - 0.61\,LLabour + 0.46LCapital + 0.04\,LRain \qquad (22)$$

t statistic (0.34) (1.89) (-1.57) (3.2) (0.14)

The regression results shows that increasing investment in capital by 1 percent will lead to a 0.46 percent increase in production output at 1 percent level of significance, everything else held constant. In contrast, a 1 percent rise in labour investment causes production out to fall by 0.61 percent which is the right sign but statstcially insignficant. The coefficient for Lrainfall and Lland indicate that if land use and rainfall individually increased by 1 percent, then the agricultural production output would grow by 0.54 (significant at 10% level) and 0.04% (not significant), respectively. The CCR estimates are similar to the FMOLS estimates discussed above. Moreover, notice that the signs are identical to the VECM counterpart captured in equation 22 above, however the magnitudes vary. In the single equation capital's contribution to GDP is much higher while land's is lower and labour has a smaller negative impact compared to the VECM based cointegrating long run equation.

5.6.3. a Dynamic Ordinary Least Squares (DOLS) : Aggregated data production function

It is shown on Table A6 (Appendix A) shows the impact of varies resources on agricultural production output in the long run. The long-run equilibrium equation is given by:

$$LY = 2.89 + 0.66\,Lland - 0.73\,Llabour - 0.38LCapital - 0.11\,LRain \qquad (23)$$

t statistic (0.7) (2.3) (-2.13) (2.87) (-0.51)

The above results show that the coefficients on land labour and capital are significant at the 5% significance level. Equation 23 shows that a percentage increase in capital investment would result in a 0.38 percent rise in production output, ceteris paribus. Contrary to labour were a percentage increase will results in a 0.73 fall in production output. The coefficient for Lrainfall and Lland indicate that if land use and rainfall individually increased by 1 percent, then the agricultural production output would grow by 0.66 and 0.11 percent, respectively. These results therefore confirm those attained from both the

FMOLS and CCR approaches with regards to aggregated production function under the agricultural sector.

5.6.1. b Fully-Modified Ordinary Least Squares (FMOLS) : Maize production function

Table B4, reports the FMOLS cointegrating equation as follows:

$$LY = 5.37 - 1.10\,LLand + 0.21\,LLabour + 0.65\,LCapital + 0.75\,LRain \qquad (24)$$

t statistic (1.31) (-2.47) (2.6) (9.8) (2.37)

The FMOLS results indicate that all variables at 5% level, except for capital which is significant at the 1% level. Thus, a 1 percent increase in labour causes agricultural production use to rise by approximately 0.21 percent which indicates that labour is a critical variable under the maize subsector. The negative coefficient for land implies that a 1% increase in land would result in a 1.10 percent decline in agricultural production output, ceteris paribus. As expected, capital and rainfall also impacts on agricultural production output positively, with elasticity coefficients of 0.65 and 0.75, respectively, with rainfall being highly significant which means that the weather plays a important role in maize production. Overall, the FMOLS results confirms a long run cointegrating relationship exist between agricultural production output and its regressors. The input coefficients have the same signs as that of the VAR/VECM long run cointegrating vector with the magnitudes being slightly different in the two equations. The VECM suggested that rainfall releases more land for production, while FMOLS suggests that rainfall has a direct impact on maize output in the current period.

5.6.2. b Canonical Cointegration Regression (CCR) : Maize production function

Equation 27, below, shows the long-run equilibrium equation is obtained from the CCR estimation of the study's model (see Table B5, Appendix B) and shows that all the specified explanatory variables impact on agricultural production output in driving agricultural production output in South Africa in the long run, hence there is cointegration among the variables.

$$LY = 5.23 - 1.14LLand + 0.23\,LLabour + 0.64LCapital + 0.83\,LRain \qquad (25)$$

t statistic (0.92) (-1.87) (2.13) (9.03) (0.02)

The regression results shows that increasing investment in land by 1 percent will lead to a 1.14 percent decrease in production output at 10 percent level of significance, everything else held constant. In contrast, a 1 percent rise in labour investment causes production output to increase by 0.23 percent which is statstcially signficant at the 5% significance level. The coefficient for capital and rainfall indicate

that if land use and rainfall individually increased by 1 percent, then the agricultural production output would grow by 0.64 and 0.83 percent, respectively. Here again the on the inputs are quite similar to that of the VAR/VECM cointegrating vector.

5.6.3.b Dynamic Ordinary Least Squares (DOLS) : Maize production function

Table B6 (Appendix B) shows the impact of varies resources on agricultural production output in the long run. The long-run equilibrium equation is given by:

$$LY = 3.72 - 0.37\,LLand + 0.06\,LLabour + 0.75LCapital + 0.13\,LRain \quad (26)$$

t statistic (0.61) (-0.5) (0.5) (9.5) (0.4)

The above equation shows that a percentage increase in capital investment would result in a 0.75 percent rise in production output, at the 1% significance level, ceteris paribus. All the other coefficients are statistically insignificantly different from zero. Hence the DOLS model contrasts with the FMOLS and CCR which have produced similar results

5.6.1.c Fully-Modified Ordinary Least Squares (FMOLS) : Wheat production function

Table C4, Appendix C reports the FMOLS cointegrating equation as follows:

$$LY = 4.00 + 0.25\,LLand - 0.41LLabour + 0.85\,LCapital - 0.03\,LRain \quad (27)$$

t statistic (3.2) (1.81) (-4.9) (22.3) (0.8)

The FMOLS results indicate that the coefficient on land is significant at the 10% significance level, while the coefficients of labour and capital are significant at the 1% level. The land coefficient many be interpreted as a 1% increase in land cultivation in land causes agricultural production use to rise by approximately 0.25 percent. The detected negative coefficient of labour implies that a 1% increase in labour would result in a 0.41 percent decline in agricultural production output, ceteris paribus. As expected, capital also impacts on agricultural production output positively, with elasticity coefficients of 0.85, rainfall impact wheat production negatively 1 percent rise resulting in 0.03 decrease in production but statistically insignificant. Overall, the FMOLS results confirms a long run cointegrating relationship exist between agricultural production output and its regressors. Note that these results are in agreement with the results obtained by the VAR/VECM model. However, the magnitudes of the coefficients in Johansen cointegrating vector are much larger (see equation 20)

5.6.2 .c Canonical Cointegration Regression (CCR) : Wheat production function

Equation 28 below, Shows the long-run equilibrium equation is obtained from the CCR estimation of the

study's model (see Table C5, Appendix C) and shows that all the specified explanatory variables impact on agricultural production output in driving agricultural production output in South Africa in the long run, hence there is cointegration among the variables.

$$LY = 5.85 + 0.28\,LLand - 0.48\,LLabour + 0.85LCapital + 0.76\,LRain \ldots.(28)$$

t statistic (1.58) (1.87) (-4.8) (22.15) (-0.49)

The regression results shows that increasing investment in capital by 1 percent will lead to a 0.85 percent increase in production output at 10 percent level of significance, everything else held constant. In contrast, a 1 percent rise in labour investment causes production out to fall by 0.48 percent which is the right sign and statstcially signficant at the 1% level. The coefficient for and Lland indicates that if land use increased by 1 percent, then the agricultural production output would grow by 0.28 percent. The rainfall coefficient was found to be insignificant. The signs on the coefficients are consisent with that of the VAR/VECM cointegrating vector, ie., equation 20.

5.6.3.c Dynamic Ordinary Least Squares (DOLS) : Wheat production function

It is shown on Table C6 (Appendix C) shows the impact of varies resources on agricultural production output in the long run. The long-run equilibrium equation is given by:

$$LY = 4.03 + 0.58Land - 0.65\,LLabour + 0.89Lcapital + 0.04\,LRain \ldots..(29)$$

t statistic (2.74) (3.02) (-5.65) (20.65) (0.28)

The above equation shows that a percentage increase in capital investment would result in a 0.58 percent rise in production output, ceteris paribus. Contrary to labour were a percentage increase will results in a 0.65 fall in production output. The coefficient for Lrainfall and Lland indicate that if land use and rainfall individually increased by 1 percent, then the agricultural production out put would grow by 0.89 and 0.04 percent, respectively. These results therefore echo the results obtained from both the FMOLS and CCR approaches with regards to the wheat production function.

5.7 Summary of Long Run Cointegrating Coefficients

Table 6.1, 6.2 and 6.3 give us a brief summary of long run contergrating coefficients in both the aggregated data and subsectoral data(rainfall is not included in the cointegration vector due to its exogenous nature its included as part of the deterministic terms for all the VECM analyses conducted below).

Table 6.1 Summary of Long Run Cointegrating Coefficients: Aggregated Data

variables	VECM	FMOLS	CCR	DOLS
LLAND	1.151117 (-4.01151)	0.522170 (1.892816)	0.537198 (1.892816)	0.660094 (2.313181)
LLABOUR	-0.989626 (2.70519)	-0.528005 (-1.565831)	-0.605619 (-1.565831)	-0.733656 (-2.134403)
LK	0.141158 (-1.06092)	0.479565 (3.324260)	0.459805 (3.324260)	0.380526 (2.868690)

All the numbers in bracket are equal to the critical value
LK represents the natural logs of agricultural fixed capital formation.

From the earlier presentation of results under the aggregated data, the researcher has found that the VECM, FMOLS, CCR and DOLS methods suggest that a long run cointegrating relationship between land, labour, capital and production output do exist. From Table 6.1, we find that the long run elasticity (as given by the FMOLS, CCR and DLOS) estimates for land are similar ranging from 0.52, 0.53 and 0.66. While the VECM estimate of 1.15 is significant at 10 percent level meaning that land has an increasing return to effect (doubling land input will more than double output). These findings are plausible and make economic sense as this study hypothesized that land is a critical input variable in the agricultural production process.

In the long run, economic labour role towards production output is negative and carries elasticities that range from -0.53 to -0.99 (significant at 10 percent level). Hence, capital has a positive impact and statistically significant impact ranging from 0.14 to 0.48 on production output in the long run, this finding is consistent with most empirical literature on the subject matter (significant at 1 percent level). The elasticity coefficients also found to be of similar magnitudes with those of Fedderke et al., (2006), Kumo (2012) and Pooloo (2009). Confirming that the South African aggregate agricultural sector is beset by severe diminishing marginal returns to labour, which explains the observed persistent decline in employment in the agricultural sector over the past three decades.

Table 6.2 Summary of Long Run Cointegrating Coefficients: Maize Subsector

variables	VECM	FMOLS	CCR	DOLS
LLAND	-1.485028 (-3.88778)	-1.095267 (-2.469164)	-1.139427 (-1.869634)	-0.374547 (-0.493552)
LLABOUR	0.234867 (-3.58489)	0.207482 (2.600818)	0.228406 (2.130696)	0.061786 (0.468668)
LK	0.655255 (-13.4886)	0.654732 (9.834544)	0.636971 (9.039705)	0.753664 (9.506438)

All the numbers in bracket are equal to the critical value
LK represents the natural logs of agricultural fixed capital formation.

From the earlier presentation of results under the maize subsector, the researcher has found that the VECM, FMOLS, CCR and DOLS methods suggest that a long run cointegrating relationship between land, labour, capital and production output do exist. From Table 6.2, we find that the long run elasticity (as given by the VECM, FMOLS, CCR and DLOS) estimates for land are ranging from -1.49, -1.10 ,-1.14and -0.37 (significant at 5 percent level) .contrary to the aggregated data under the maize subsector land has an negative(diminishing return to scale) effect with all of the methods producing negative coefficients. Meaning that land has been over allocated to maize production to the extent that an increase in land usage will decrease marginal productive. According to microeconomic theory land usage has reached stage three where an additional input of land will result in a reduction in total output.

In the long run, labour contribution towards production output is positive and carries elasticities that range from 0.23 to 0.06 (significant at 5 percent level). Capital also confirms our prior expectation with a positive impact and statistically significant impact ranging from 0.64 to 0.75 (significant at 1 percent level) on production output in the long run, this finding is consistent with theory that any increase in production input is complemented by an increase in production output.

Table 6.3 Summary of Long Run Cointegrating Coefficients: Wheat Subsector

variables	VECM	FMOLS	CCR	DOLS
LLAND	1.894042 (-11.4852)	0.2439567 (1.814778)	0.284519 (1.865986)	0.576503 (3.021163)
LLABOUR	- 1.289742 (13.5729)	-0.412427 (-4900983)	-0.480480 (-4.806429)	-0.647412 (-5.648098)
LK	1.128600 (-30.5417)	0.851375 (22.32843)	0.847240 (22.15173)	0.891785 (20.64552)

All the numbers in bracket are equal to the critical value
LK represents the natural logs of agricultural fixed capital formation.

From the earlier presentation of results under the wheat subsector, the researcher has found that the VECM, FMOLS, CCR and DOLS methods suggest that a long run cointegrating relationship between land, labour, capital and production output do exist. From Table 6.3, we find that the long run elasticity (as given by the FMOLS, CCR and DLOS) estimates for land are similar ranging from 0.25, 0.28 and 0.58 respectively (significant at 1 percent level). While the VECM estimate of 1.89 is significant at 5 percent level meaning that land has an increasing return to effect (doubling land input will more than double output). These findings are plausible and make economic sense as this study hypothesized that land is a critical input variable in the agricultural production process.

In the long run, economic labour role towards production output negatively and carries elasticities that range from -0.41 to -129 (significant at 10 percent level). Hence, capital has a positive impact and statistically significant impact ranging from 0.84 to 1.13 (significant at 10 percent level) on production output in the long run, this wheat subsector findings are remarkably similar to that of the aggregated agricultural sector.

5.8 Conclusion

This chapter provided an empirical analysis of this study using using EViews 8 and Microfit 5.0 statistical software packages. Elemental examinations of the data were conducted and all the variables were tested on their stationarity using ADF and PPS but KPSS was to confirm the findings in levels and then difference to I (1) if necessary. The Johansen cointegration test was then carried out and long run equilibrium between the variables was established. The study carried on to estimate a VECM. Due to implausible results exhibited by land, labour and capital coefficients, single equation estimation methods were estimated. Overall, we found that a long run relationship exists between land, labour, capital and agricultural production output. Findings from both multiple and single equation methods reveal that under the aggregated agricultural sector land and capital are critical determinant of production output, but labour is not vital to production output as the other two variables. Contrary to the maize subsector labour and capital are important input variables in the maize production process but not land. Amazingly the wheat subsector produced similar results as the aggregated agricultural production function land and capital proving to be vital input variables and labour showing diminishing return to scale.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

This chapter provides a succinct summary of the overall study and provides synthesis the findings and thereafter gives policy recommendations based on the findings. The chapter consists of three sections. Section 6.1 presents the brief summary of the study and empirical findings are discussed. Policy implications and recommendations are given in section 6.2. While section 6.3 provides the study's strengths and weaknesses (limitations of study), section 6.4 outlines recommendations for future research.

6.1 Summary of the Study

As noted in the introduction although agriculture contributes only about 2% to GDP, a decline from past years, it still is a significant source of especially rural employment and plays a critical indirect role in the economy through its backward and forward linkages to other sectors, for example 70% of national agricultural output serves as intermediate inputs in the manufacturing sector. It is for this reason that the NGP (2011) and the NDP (2012) see the agricultural sector as an engine of economic growth and employment creation in order to improve the quality of life of the rural underpriviliged. It is from this perspective that this study strove to estimate Cobb Douglas functions for the South African aggregate agricultural sector and the wheat and maize subsectors.

Surprisingly, to date no South African studies exist where the marginal productivities of capital and labour are estimated, while controlling for rainfall. The study was guided by the seminal Cobb-Douglas production function model developed in 1928 where the marginal productiiviites of capital and labour have a neat interpretation in the natural log linearized version of the specification and can easily be estimated via the least squares methodology. The choice of the variables that were inputted into the production function was further justified on the grounds of the variaous theoretical insights discussed in chapter two of this study. The study was also supported by the extensive international literature discussed in chapter three that have employed a natural log linearized version of the Cobb-Douglas function in their analyses.

6.2 Methodology and Data issues

The study set out to empirically quantify the impact of the factors of production (land, labour, capital) for both aggregated and subsectoral (maize, wheat) production outputs in the South African agricultural sector. The objective of the study was centred around three hypotheses which were constructed to examine how key factors of production variables such as land, labour and capital impact on the agricultural production output while including rainfall as an exogenous variable between 1975 and 2012. Furthermore, through this study, the key determinants (input variables) of growth under both the aggregated data and subsectors in the South African agricultural in both the short and long run were identified.

Due to the unavailability of sectoral data on capital and labour this study estimated their values using aggregate data based on the strong assumption that the proportion of capital and labour used as inputs in the subsectoral production is directly proportional to that subsector's share of total agricultural output. Hence the conclusions that were drawn from the analyses although very interesting must be viewed with caution for it might not necessary be the case that the two subsectors use similar proportions of capital and labour since it is possible one sector might use proportionately more capital relative to labour compared to the other Unfortunately we had no priori reason to make such an assumption. Future studies ought to correct for this deficiency.

To achieve the study's objective and address the respective hypotheses, preliminary examinations of the data were conducted through the use of visual and unit root tests and the variables that were found to be non-stationary (or I(1)) in levels were differenced in the first order for them to be stationary (i.e., $\mathrm{I}(0)$). Both the unrestricted VAR and VECM techniques were estimated since the AR table used for establishing the stability of the unrestricted VAR at a lag length of 2 for both the aggregated and maize subsector but wheat lag length 3 contained a root with a modulus of 0.95 for both subsectors and a value of 1.01 for the aggregated data. The study proceeded to estimate a first order VECM, for the aggregate agricultural sector and the maize subsector and a second order VECM for the wheat subsector. Finally the long run estimates of the cointegrating vectors were compared to estimates from single equation models which FMOLS, DOLS and CCR approaches.

6.3 Synthesis of the Results

The long run cointegrating results suggested that the marginal productivities of capital and land were positive while that of labour was negative; all the coefficients were statistically significant except for capital. Moreover the marginal productrivity of land exceeded unity (ie. 1.15), thus implying that land productivity exhibits increasing returns to scale which confirms the trends that the number of farms have been decreasing but their land acreage have been increasing. While the negative marginal productivity of labour suggests that the South African aggregate agricultural sector is overwhelmed by severe diminishing marginal returns to labour, which explains the observed persistent decline in employment in the agricultural sector over the past three decades or more.

The results also found that aggregate output is sensitive to its long run equilibrium relationship with the input vector, thus when output overshoots its long run equilibrium then in the short run 50% of the disequilibrium is corrected in the first year and by the second year the full adjustment is achieved. This implies that output is quite responsive, however the short run adjustment coefficients for land and capital were found to be statistically insignificant, thus creating the impression that factors of production are weakly mobile in the short run. This outcome is quite puzzling, for output to adjust up or down with relative ease it ought to follow that the factors of production can easily enter or exit the production process. Further research is required to solve this conundrum.

The tau (Γ_{iY}) or dynamic short run adjustment coefficients of the aggregate VECM also suggests that short run positive changes in land usage for agricultural production in the previous year causes output change to rise by 2% in the succeeding year. This is the likely manner that agribusinesses may have been using in maintaining profitable enterprises and keeping land productivity at high long run levels. This adjustment when viewed in reverse may address the above conundrum to a large extent for it means when output overshoots its equilibrium then just small decreases in the change in land usage will succeed in causing output to adjust downwards in succeeding years. Moroever, this land changes may not be in accordance with the long run cointegrating phenomenon, thereby explaining why its α coefficient is not significant.

Furthermore, the tau coefficient representing the short run dynamic adjustment of labour in the aggregate aggregate sector suggests that an increase in the change of labour in the agricultural sector

in the previous period causes labour change to adjust downwards in the next period by 50% of the change. This is the reflection of the phenomenon of diminishing returns to labour in the aggregate agricultural sector hence profitability in the aggregate agricultural sector is sensitive to labour input thus agribusiness entrepreneurs are forced to cut back on labour input the very next period when they temporarily demand more labour in the previous period.

Yet another puzzling short run result from the aggregate agriculture VECM suggests that increases in rainfall is the current year actually diminishes output in the same year. More research needs to be done to confirm this finding. Pure conjecture on the part of this study might suggest that perhaps South Africa which is largely arid has become used to farming under conditions of low rainfall, however this result is contradicted by the findings of the sectoral models discussed below.

The wheat subsector Cobb-Douglas production function is similar to that of the aggregate agricultural sector. The long run coefficient for land confirms the hypothesis that land productivity exhibits increasing returns to scale, likewise capital demonstrates increasing returning to scale while labour demonstrates diminishing marginal returns to labour. All the coefficients were significant at the 1% significance level.

The wheat subsector In regard to the short run adjustment coefficients (α) suggests that wheat production does not readjusts should it overshoot (undershoot) its cointegrating equilibrium. While land tends to rise and capital tends to fall when adjusting to previous period's overshooting ofoutput. The adjustments in opposite directions might suggest there is greater compensation upward in the land input and a deliberate decrease in the capital input, thereby implying that perhaps more land is being substituted for capital due to increased expected shortrun wheat production.

In regard to the short run dynamic adjustment of the by the variables as captured by the tau (Γ_{iY}) coefficients only one significant coefficient was found, which may be interpreted as a change in land usage for wheat production in the previous year causes capital change to fall by 1% in the succeeding year. This might suggest that land and capital might be substitutes in the wheat production business. This perspective is also echoed by the interpretation of the opposite adjustments of the α coeffients, in the previous paragraph.

The influence rainfall has in the harnessing of land, labour and capital inputs for wheat production in the short run is quite remarkable. As noted in the previous chapter a 1% rise in rainfall causes the sort term

change in land, labour and capital devoted to wheat production to rise by 0.5%, 0.91% and 0.76% respectively. It is quite interesting that these inputs are quite flexible and can be easily harnessed in the short run. This point is echoed by the alpha and tau short run adjustment coefficients above.

The VECM results from the maize subsector produced somewhat contrasting results compared to the aggregate sector and wheat subsector. The long run coefficient for land is statistically significant and negative thus the sector exhibits acute diminishing margining returns to land while capital and labour enjoy positive marginal productivities hence maize cultivation ought to employ more capital relative to labour over the long term.

In regard to the short run analysis the only significant alpha coefficient that there is a long run negative association between land and maize output thus implying that if output overshoots its long run equilibrium in the previous year, in the current year land devoted to maize production decreases. Here again the relative flexibility of land usage is the short run is demonstrated.

The first of the significant tau coefficients suggest that in the short run positive changes in land usage for maize cultivation raises output but over the long term increased land usage leads to overall reduction in output this result is counterintuitive and warrants further investigation. While the second tau coefficient suggests that there is relative greater importance of capital intensive production processes in the maize sector.

The maize subsector is weakly response to rainfall a 1% rise in rainfall causes a 0.18% release of arable land for production in the short run. When compared to wheat the maize subsector is quite inelastic in its response to rainfall for the short run coefficients for capital and labour are no different from zero while land is weakly responsive

The FMOLS, DOLS and CCR results on the whole appeared to support the findings of the the long run cointegrating eqautions, however their coefficient estimates were generally of a smaller magnitude than the the VECM long run coefficients. Moreover the VECM analysis suggested that rainifall is a critical factor in the wheat cultivation for all factors of production are increased during periods of high rainfall and that more land is made available in maize farming due to good seasonal rainfall. In the single equation model rainfall had no longrun impact in the general agricultural sector or the wheat subsector but a significant long run impact on the maize sector. Overall the results pertaining rainfall suggests that most of the South African agicultural sector is accustomed to using the existing water resources to

produce most of the agricultural output hence changes in rainfall patterns does not seem to affect the overall sector. However as far as the maize sector is concerned the future of the industry depends on adequate water resources. Windfall gains are exacted from the wheat industry during favourable rainy seasons due to the industry's flexibility in harnessing land, labour and capital inputs in the short run. These findings are supported by Clay *et al., (2003).*

6.4 Policy Implications and Recommendations

The findings summarised above suggest that land plays a critical role in the overall 'agricultural production, however in the maize subsector land has been overused and is producing at a negative marginal productivity level, hence cutting back on land usage and increasing capital and labour usage is a strong recommendation for the subsector. The negative marginal productivity for land might be explained by the possibility that the maize sector was slow to decrease the number of farms and increase amount of land as has been the trend in the general agricultural sector perhaps because maize is a staple diet among local people and is farmed extensively in both the traditional subsistence survivalist farming approaches and modern and modern high technological based approaches.

In regard to the general agricultural sector, land and capital produce at positive marginal productivities hence these inputs must be increased. While Labour appears to be producing at negative marginal productivities in these two sectors, hence this input must be decreased which perhaps explains the long run declining trend in the agricultural sector labour input. Townsend *et al.* (1997) explain this declining long run labour trend by arguing that large machinery-using biases in technology have been developed with minimal labour-using biases and these biases have not contributed to alleviating the unemployment problem currently facing the labour-surplus economy of South Africa. According to the authors, the biases have largely been caused by policies favouring the large-scale capital-intensive production model. Hence the National Development Plan (2012) called for the situation to change by prioritising investment in the labour-intensive agricultural sector including investment in infrastructural projects such as the creation of roads and irrigation systems using labour.

The policy recommendation that labour input must be decreased is certain to sound politically incorrect and an increase in the land size made available is likely to quickly lead to negative marginal returns. Hence the paper calls for a coordinated strategy for South Africa to become a net food exporters that can be found in many government reports and white papers, these include: educating current and future agricultural workers through rural based further and training colleges, rural community forums, agricultural cooperatives and agricultural non-governmental organisations. The main aim of such

endeavours would be to set up market driven large scale enterprises that fulfils the needs of both local and global consumers. Increasing land size available for agriculture cannot be done in isolation to building a strong agribusiness entrepreneurial culture among selected individuals from the local communities; hence to this end mentorship programmes should be instituted where government offers appropriate incentives for successful private agribusiness entrepreneurs to mentor the new generation.

Recall it was reported that the subsectoral estimates of capital and labour was derived from the aggregate data on capital and labour in the agricultural sector on the basis that it was proportional to the ratio of the subsector's output to total aggregate output. The government allocates resources to ensure that Statistics South Africa compiles both sectoral and subsectoral data for all the important agriculture subsectors.

6.3 Strengths, Weaknesses The inclusive long run results (especially from the single equation methods) confirm the policy prescription of the South African authorities that capital and land are key input variables of growth within the agricultural sector and so too is skilled labour so it can complement the capital intensive production model. The minimum wage policy in the agriculture sector however well-meaning for the indigent rural worker functions against the interest of the very people it was supposed to benefit, for the sole reason that the marginal productivity of labour is negative, hence by increasing the wage rate disincentivises the farmers from employing more workers.

The main weakness of this study is that it utilised a very small data set and might be the main reason why contradictions were noted in the VECM analysis which performs best with long time series data sets.

A secondary weakness of this study is that it neglected to accommodate for two variables. Firstly it did not attempt to assess the VECM or the single equation models by using fertiliser usage which is considered to be a critical input into modern agricultural processes. Furthermore this study neglected to consider running the VAR/VECM or single equation models where minimum wage was included as an dummy variable especially since earlier in chapters a strong case was made for the possibility that the decrease in employment, in the last decade, is a the results of unfriendly labour laws (ie., determined by political factors) to the variables included in the model.

The third weakness of this study is that it never conduct formal tests to identify possible structural breaks in the data for example the transition to democracy in 1994 might have been a structural break in the data which this study neglected to test for.

6.5 Recommendations for Future Research

Future studies ought to search the archives for much larger data sets in order to carry out VAR/VECM type models which work best with large sample sizes. Together with larger sample size, future research ought to include proxies for the fertiliser variable as well as a dummy variable for minimum wage. Additionally, such studies ought to accommodate for possible structural breaks in the data. Furthermore, there is not data available at the subsectoral level for capital and labour hence future studies ought to seek other secondary sources of the subsectoral data.

Finally, a more sophisticated estimation method such as dynamic computable general equilibrium (DCGE) ought to be employed for it is based on a microeconomic foundations of how the different variables of interest with one another in a macroeconomic setting.

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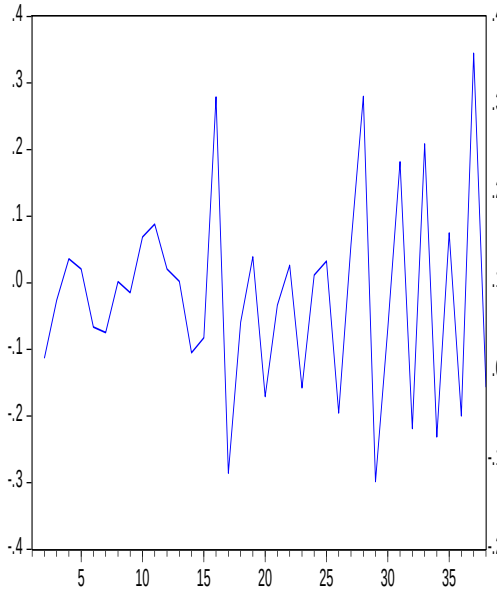
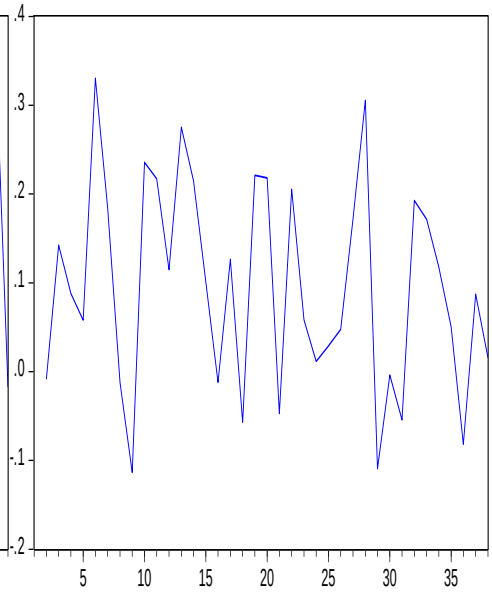
Appendix A

Figure A1: Graphic Plots of Aggregated Data in Fisrt difference (1)

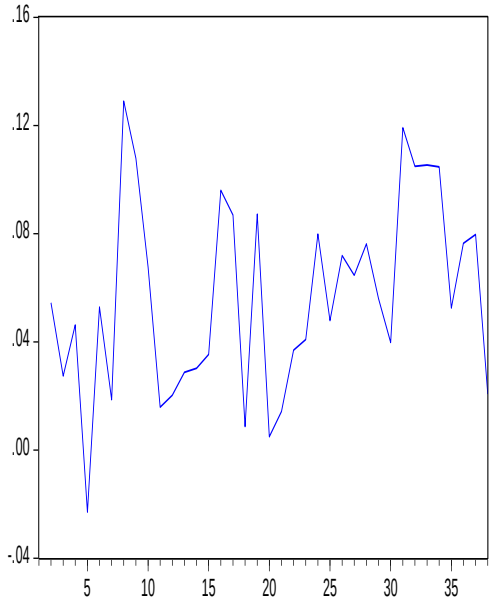
Differenced LLABOUR



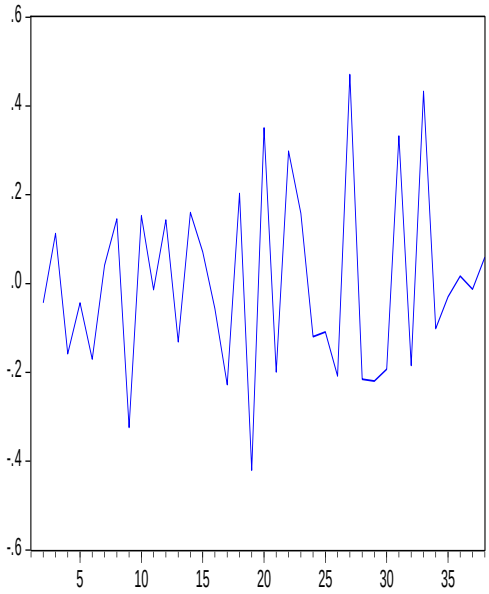
Differenced LK



Differenced LLAND



Differenced LRAIN



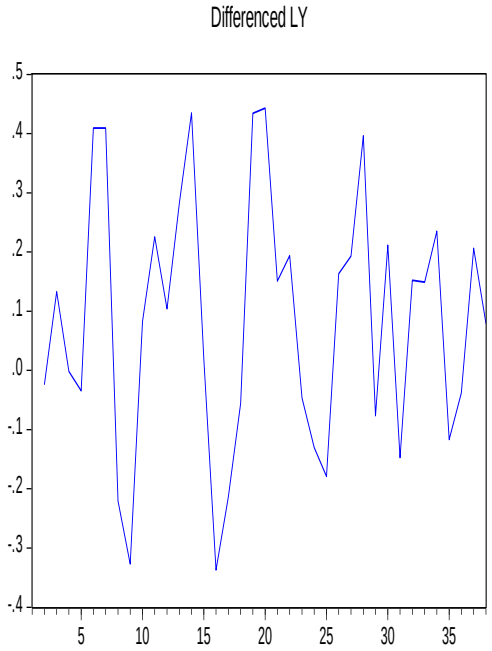


Table A1: Summary of Unit Root Test Results aggregated data

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-6.18519 (-2.93)	-3.488944	0.258424	I(0)
LK	-1.526161 (-2.93)	-1.168417	0.216569	I(0)
Lland	-1.050790 (-2.93)	-1.050790	0.184081	I(0)
Llabour	-4.448286 (-2.93)	-4.226815	0.114451	I(0)
Lrain	-4.912887 (-2.93)	-4.866643	0.135455	I(0)

Source: Estimation results.
Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represents the natural logs of agricultural output and fixed capital formation, respectively.

Table A2- Roots of Characteristic Polynomial: Aggregated Data

Root	Modulus
1.057544	1.057544
1.006486	1.006486
0.869714	0.869714
0.491840 - 0.678826i	0.838279
0.491840 + 0.678826i	0.838279
-0.368900 - 0.189418i	0.414688
-0.368900 + 0.189418i	0.414688
-0.068532	0.068532

Warning: At least one root outside the unit circle.
VAR does not satisfy the stability condition.

Figure A2: aggregated data

figure 2A- Aggreagted Data

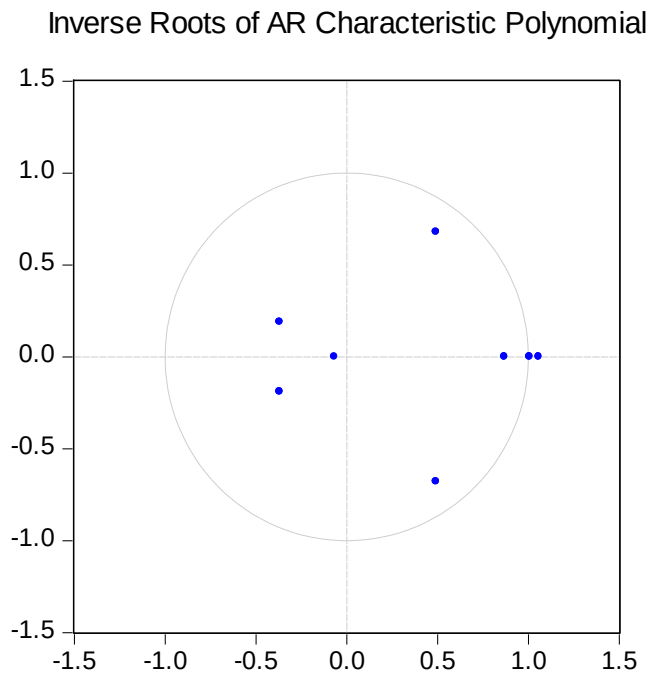


Table A3 - VAR Lag Order Selection Criteria: Aggreagated Data

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-34.83319	NA	0.000108	2.219040	2.396794	2.280400
1	147.5666	312.6853	8.09e-09	-7.289518	-6.400748*	-6.982715
2	175.1687	41.00888*	4.33e-09*	-7.952497*	-6.352711	-7.400251*
3	189.6610	18.21885	5.23e-09	-7.866341	-5.555538	-7.068652

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Single equations: aggregated data

Table A4- Fully Modified Least Squares (FMOLS): Aggregated Data

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.522170	0.267854	1.949463	0.0600
LLABOUR	-0.528005	0.313348	-1.685044	0.1017
LK	0.479565	0.138120	3.472089	0.0015
C	0.622872	3.875108	0.160737	0.8733
LRAIN	0.104780	0.256753	0.408097	0.6859
R-squared	0.959771	Mean dependent var		7.916080
Adjusted R-squared	0.954743	S.D. dependent var		0.988329
S.E. of regression	0.210255	Sum squared resid		1.414632
Long-run variance	0.062095			

Table A5 - Canonical Cointegrating Regression (CCR): Aggregated Data

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.537198	0.283809	1.892816	0.0675
LLABOUR	-0.605619	0.386772	-1.565831	0.1272
LK	0.459805	0.138318	3.324260	0.0022
C	1.618631	4.721133	0.342848	0.7340
LRAIN	0.038171	0.265594	0.143720	0.8866
R-squared	0.958046	Mean dependent var		7.916080
Adjusted R-squared	0.952802	S.D. dependent var		0.988329
S.E. of regression	0.214715	Sum squared resid		1.475282
Long-run variance	0.062095			

Table A6 - Dynamic Least Squares (DOLS): Aggregated Data

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.660094	0.285362	2.313181	0.0309
LLABOUR	-0.733656	0.343729	-2.134403	0.0448
LK	0.380526	0.132648	2.868690	0.0092
C	2.886948	4.421755	0.652896	0.5209
LRAIN	-0.106348	0.210368	-0.505532	0.6185
R-squared	0.981169	Mean dependent var		7.917485
Adjusted R-squared	0.969511	S.D. dependent var		0.940833
S.E. of regression	0.164279	Sum squared resid		0.566742
Long-run variance	0.030232			

Appendix B1

Figure B1: Graphic Plots of Maize Subsector in Fisrt difference (1)

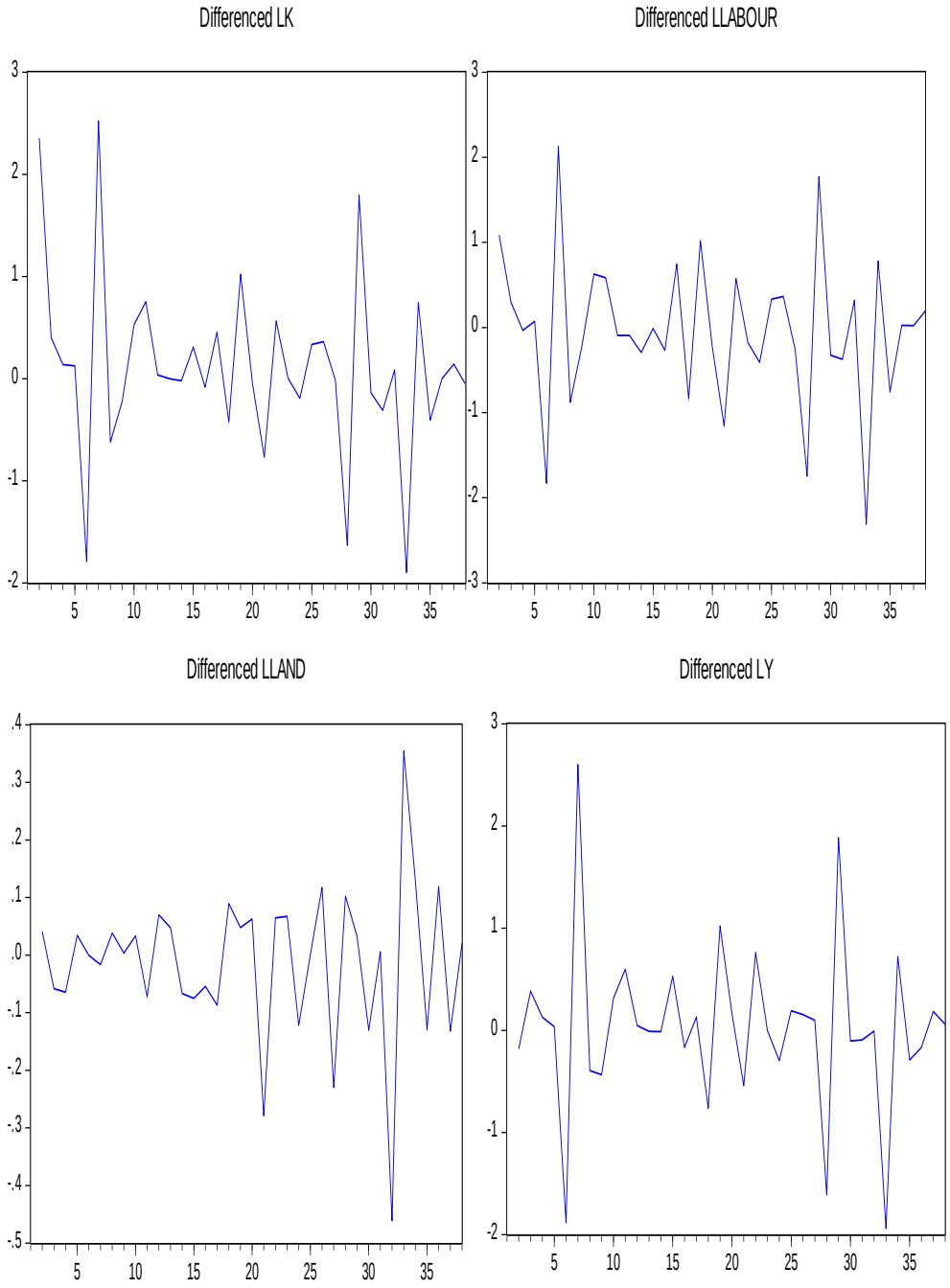


Table B1 Summary of Unit Root Test Results Maize Subsector

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-1.968742 (-2.93)	-1.48000	0.147919	I(0)
LK	-2.392875 (-2.93)	-2.64904	0.105764	I(0)
Lland	-1.676791 (-2.93)	-1.114217	0.096781	I(0)
Llabour	-10.49422 (-2.93)	-25.13270	0.046144	I(0)

Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represents the natural logs of agricultural output and fixed capital formation, respectively.

Table B2 - Roots of Characteristic Polynomial: Maize Subsector

Root	Modulus
0.960599 - 0.017424i	0.960757
0.960599 + 0.017424i	0.960757
0.594943	0.594943
0.261448 - 0.491691i	0.556880
0.261448 + 0.491691i	0.556880
-0.381605 - 0.092988i	0.392772
-0.381605 + 0.092988i	0.392772
-0.114598	0.114598

No root lies outside the unit circle.
VAR satisfies the stability condition.

Figure B2: Maize Subsector

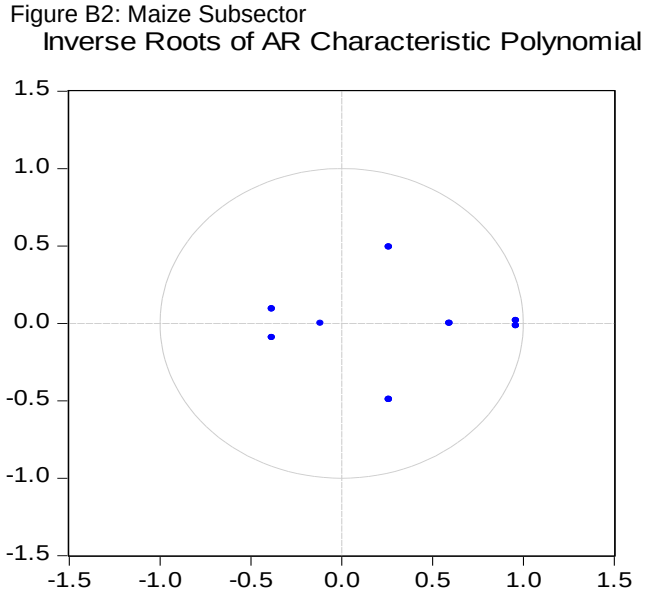


Table B3 - VAR Lag Order Selection Criteria: Maize Subsector

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-85.21555	NA	0.001924	5.098031	5.275786	5.159392
1	34.32498	204.9266	5.22e-06	-0.818570	0.070200*	-0.511767*
2	54.59350	30.11323*	4.26e-06*	-1.062486*	0.537301	-0.510240
3	63.52704	11.23073	7.06e-06	-0.658688	1.652115	0.139001

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Single equations: Maize subsector

Table B4- Fully Modified Least Squares (FMOLS): Maize Subsector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	-1.095267	0.443578	-2.469164	0.0191
LLABOUR	0.207482	0.079776	2.600818	0.0140
LK	0.654732	0.066575	9.834544	0.0000
C	5.366558	4.184195	1.282578	0.2089
LRAIN	0.745699	0.319141	2.336584	0.0259
R-squared	0.949414	Mean dependent var		14.61753
Adjusted R-squared	0.943090	S.D. dependent var		0.921299
S.E. of regression	0.219782	Sum squared resid		1.545739
Long-run variance	0.084183			

Table B5 - Canonical Cointegrating Regression (CCR): Maize Subsector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	-0.374547	0.758880	-0.493552	0.6267
LLABOUR	0.061786	0.131833	0.468668	0.6441
LK	0.753664	0.079279	9.506438	0.0000
C	3.716205	6.072382	0.611985	0.5471
LRAIN	0.125790	0.310063	0.405692	0.6891
R-squared	0.977525	Mean dependent var		14.66688
Adjusted R-squared	0.963612	S.D. dependent var		0.910459
S.E. of regression	0.173677	Sum squared resid		0.633435
Long-run variance	0.051532			

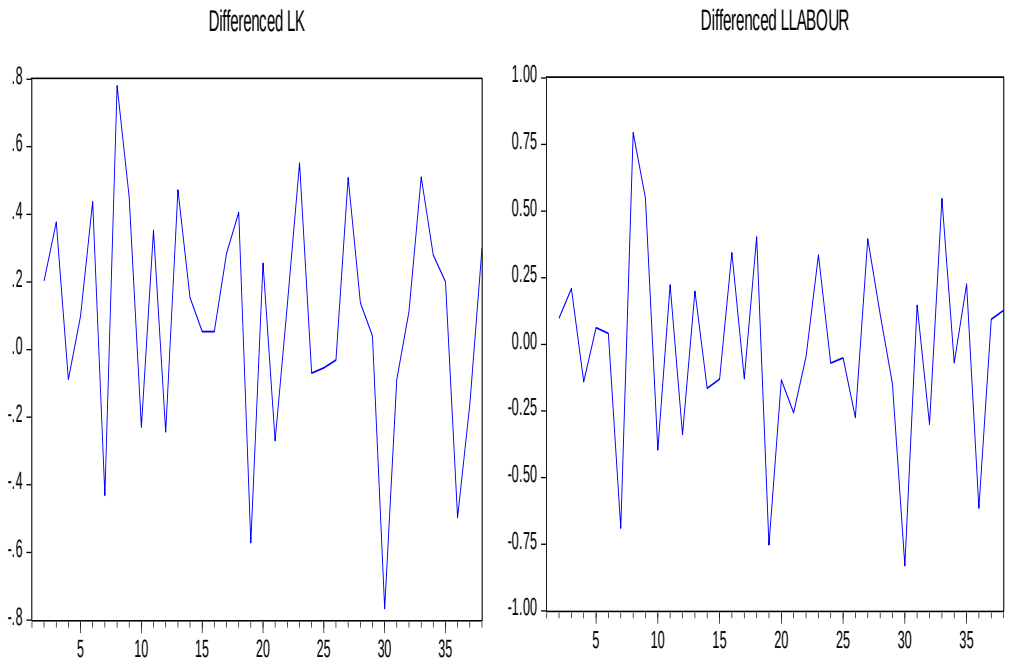
Table B6 - Dynamic Least Squares (DOLS): Maize Subsector

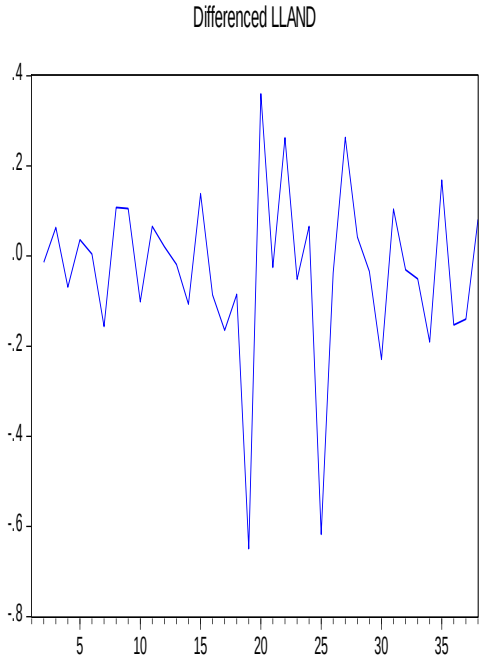
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	-1.139427	0.609438	-1.869634	0.0707
LLABOUR	0.228406	0.107198	2.130696	0.0409
LK	0.636971	0.070464	9.039705	0.0000
C	5.232938	5.663808	0.923926	0.3624
LRAIN	0.825238	0.344841	2.393098	0.0227

R-squared	0.943363	Mean dependent var	14.61753
Adjusted R-squared	0.936284	S.D. dependent var	0.921299
S.E. of regression	0.232555	Sum squared resid	1.730623
Long-run variance	0.084183		

Appendix C

Figure C1: Graphic Plots of Wheat Subsector in Fisrt difference (1)





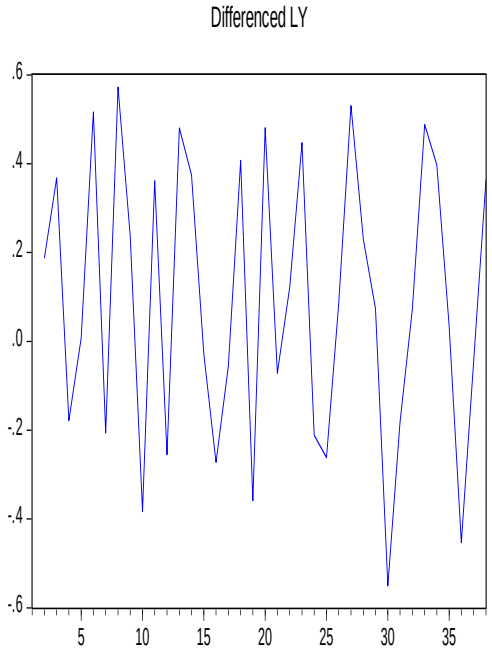


Table C1 Summary of Unit Root Test Results Wheat Subsector

Sample period 1975 to 2012				
Variables	ADF (SIC)	Pp	KPSS	Order of Integration
LY	-2.602469 (-2.93)	-1.909099	0.729367	I(0)
LK	-3.105837 (-2.93)	-1.977467	0.696409	I(0)
Lland	-1.055008 (-2.93)	-0.683276	0.605622	I(0)
Llabour	-2.143889 (-2.93)	-1.977467	0.696409	I(0)

Source: Estimation results.
Notes: ADF (SIC): number of lags determined by the Schwartz information criteria
DF-GLS: Elliott-Rothenberg-Stock (DF-GLS) test statistic
KSS: Kwiatkowski Phillips-Schmidt-Shin (KPSS) test statistic
All the numbers in bracket are equal to the critical value
LY and LK represent the natural logs of agricultural output and fixed capital formation, respectively.

Table 2C - Roots of Characteristic Polynomial: Wheat Subsector

Root	Modulus
0.965472	0.965472
0.744415	0.744415
0.488330 - 0.531383i	0.721688
0.488330 + 0.531383i	0.721688
-0.502955	0.502955
0.162085 - 0.343403i	0.379733
0.162085 + 0.343403i	0.379733
-0.194721	0.194721

No root lies outside the unit circle.
VAR satisfies the stability condition.

Figure C2: Wheat Subsector

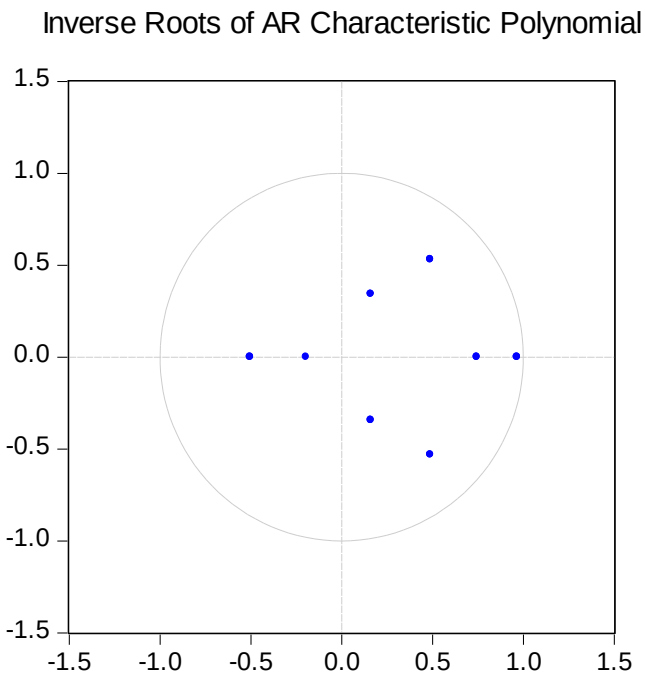


Table C3 - VAR Lag Order Selection Criteria: Wheat Subsector

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-48.13717	NA	0.000231	2.979267	3.157021	3.040628
1	61.62243	188.1593	1.10e-06	-2.378424	-1.489654*	-2.071621
2	78.61510	25.24625	1.08e-06	-2.435149	-0.835362	-1.882902
3	111.8532	41.78502*	4.46e-07*	-3.420182*	-1.109379	-2.622493*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Single equations: wheat subsector

Table C4 – Fully Modified Least Squares (FMOLS): Wheat Subsector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.249567	0.137519	1.814778	0.0789
LLABOUR	-0.412427	0.084162	-4.900383	0.0000
LK	0.851375	0.038130	22.32843	0.0000
C	4.000777	1.266750	3.158301	0.0035
LRAIN	0.030759	0.140764	0.218513	0.8284

R-squared	0.975497	Mean dependent var	14.00707
Adjusted R-squared	0.972434	S.D. dependent var	0.923189
S.E. of regression	0.153278	Sum squared resid	0.751815
Long-run variance	0.018171		

Table C5 - Canonical Cointegrating Regression (CCR): Wheat Susector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.576503	0.190821	3.021163	0.0065
LLABOUR	-0.647412	0.114625	-5.648098	0.0000
LK	0.891785	0.043195	20.64552	0.0000
C	4.038110	1.475955	2.735930	0.0124
LRAIN	0.037473	0.133479	0.280742	0.7817

R-squared	0.992391	Mean dependent var	14.02369
Adjusted R-squared	0.987681	S.D. dependent var	0.867566
S.E. of regression	0.096293	Sum squared resid	0.194718
Long-run variance	0.008840		

Table C6 - Dynamic Least Squares (DOLS): Wheat Subsector

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLAND	0.284519	0.152477	1.865986	0.0712
LLABOUR	-0.480480	0.099966	-4.806429	0.0000
LK	0.847240	0.038247	22.15173	0.0000
C	5.384058	1.587394	3.391759	0.0019
LRAIN	-0.075644	0.155839	-0.485397	0.6307

R-squared	0.972074	Mean dependent var	14.00707
Adjusted R-squared	0.968583	S.D. dependent var	0.923189
S.E. of regression	0.163634	Sum squared resid	0.856839
Long-run variance	0.018171		