FARM-LEVEL RESOURCE USE AND OUTPUT SUPPLY RESPONSE:
A FREE STATE CASE STUDY

BY

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ABSTRACT

The ability to use knowledge of factors that affect resource use and output supply response to achieve a highly efficient and economically viable market-directed farming sector is explored in the context of implementing market and land reform in a Free State case study.

This study developed an agricultural sector model with the Positive Mathematical Programming calibration approach and Expected-Variance Risk analysis to represent and simulate the potential effects of risks in selected crops and livestock, the targeted rate of land redistribution, and the proposed land tax on farm-level resource use and output supply response. The study aggregated established large-scale commercial (mainly white) farms into a large farm type and developing (mainly black) farms into a small farm type to evaluate how responses differ between farm types and different farm enterprises. Policies on land redistribution and the proposed agricultural land tax were conceptualised into some scenarios. The model was used to simulate the possible impacts of these scenarios.

In scenario I, after 30% of the farmland will have been transferred from the large farm type to settle more units of the small farm type by 2015, the decrease in the number of large farm units from about 8,531 units in the base year to about 7,112 farm units will lead to a decline in crop and animal product supplies. Such declines (about 15.3%) will overwhelm the increase of more than 1,600% in supplies as a result of increased small farm units. Scenario II confirms the negative impact of the decreasing number of large farms and transferring land to settle more units of small farms on regional supplies, especially capital-intensive products. Results of scenario III demonstrate that since farm size is indicative of efficiency, market and land reform that establishes farm units that are large and viable in a liberalised market can enhance the efficient and increasing use of resources for profitable supply response.

In scenario IV, levying a land tax of 2% on land value will induce the large farm type to decrease marginally the level of production activities. The highest effects are observed on irrigated areas of sunflowers (0.23%) and wheat (0.17%). The results of the declines in supply are 0.07% for sunflower seeds; 0.06% for wheat; 0.04% for soya beans; 0.03 for each of white maize and sorghum; and 0.02% for yellow maize production. The response is insignificant for the small farm type. It can be concluded that levying a land tax may discourage intensive production such as irrigated farming.

Given the challenges in a free market, there is a need for measures to balance equity with efficiency. Implementing land transfer needs not be radical and should, in a very balanced way, encourage the establishment of more viable and efficient farm units as well as prevent the decline in large-scale commercial farms. In order to have a very effective and highly competitive farm industry, there is a need for training and comprehensive support services for settled farmers. There is a need to avoid settling groups of people and small farmers as this might become a poverty trap for the intended beneficiaries. There is a need to settle successful black large-scale farmers who can compete on the same basis with their white counterparts. Small farmers can be settled but only for very intensive projects with high value crops. Such small farms may be small in size but big in turnover. The settlement of small scale farmers will have a much smaller impact on output if the land of already inefficient farmers is bought for redistribution. It should also be noted that agricultural land can act as a safety net for the poor in which case the above efficiency argument does not hold. It

is not enough to liberalise the market; it will be more helpful to train farmers in the use of risk-hedging mechanisms. In addition, there is a need for continuous, very frequent studies on land valuations because the effective tax rate will depend on proper and efficient valuation of land. More research into these issues is necessary.

It should be noted that as a partial equilibrium model, the results show only the impact on the producer's profit. Changes in agricultural policies were deemed to represent a number of variables that interact in an economy where farmers operate. However, the effect of omitting variables that affect farmers' behaviour is controversial. Therefore, recent efforts in the field of policy analysis (linking partial equilibrium models to general equilibrium models) should be pursued as a further study.

Key terms: Farm-level, Resource use, Output supply response, land reform, market reform, Large and small farm, Free State Case study, Policy analysis, Agricultural sector model, Positive Mathematical Model, E-V Risk analysis.

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deur

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UITTREKSEL

Die vermoë om kennis aangaande faktore wat hulpbrongebruik en die aanbodrespons van uitsette beïnvloed, te gebruik om ’n hoogs doeltreffende en ekonomies uitvoerbare markgerigte boerderysektor daar te stel, word in die konteks van die implementering van mark- en grondhervorming in ’n gevallestudie in die Vrystaat ondersoek.

Met behulp van die Positiewe Wiskundige Programmering kalibreringsbenadering en die Verwagte-Variansie Risiko ontleding, is ’n boerderysektormodel ontwikkel om die potensiële uitwerking van risiko’s op geselekteerde gewasse en lewende hawe te verteenwoordig en na te boots, asook die beoogde tempo van die herverdeling van grond en die gebruik van hulpbronne op boerderyvlak en die aanbodrespons op voorgestelde grondbelasting te toets. Om die verskillende reaksies tussen die boerdery-tipes en verskillende boerderyondernemings te bepaal, het die studie bestaande grootskaalse kommersiële plase (hoofsaaklik wit) in ’n groot boerdery-tipe en ontwikkelende (hoofsaaklik swart) plase in ’n klein boerdery-tipe saamgevoeg. Beleidsrigtings betreffende die herverdeling van grond en die voorgestelde belasting op plaasgrond, is in bepaalde scenario’s saamgevat. Die model is gebruik om die moontlike uitwerking van sodanige scenario’s voor te stel.

In scenario I sal 30% van die plaasgrond teen 2015 vanaf die groot boerdery-tipe oorgedra word om meer eenhede van die klein boerdery-tipe te vestig. Die afname in die aantal groot boerdery-eenhede vanaf ongeveer 8,531 eenhede in die basisjaar tot ongeveer 7,112, sal lei tot 'n daling in oes, asook diereproduksie-aanbiedinge. Hierdie afname (ongeveer 15.3%) sal die toename in die styging van meer kleinboer produkte van 1,600% heeltemal oorskadu. Scenario II bevestig die negatiewe impak op streeksaanbod, wat die dalende aantal groot plase en die oordra van grond om meer klein boerdery-eenhede te vestig, veral op kapitaal-intensiewe produkte, sal hê. Aangesien die grootte van 'n boerdery-eenheid dui op die doeltreffendheid daarvan, toon die resultate van scenario III dat mark- en grondhervorming wat voorsiening maak vir boerdery-eenhede wat groot en volhoubaar is in 'n geliberaliseerde mark, doeltreffendheid en die gebruik van hulpbronne vir 'n winsgewende aanbodrespons, kan verhoog.

In scenario IV word getoon dat indien grondbelasting teen 2% van grondwaarde gehef word, dit die groot boerdery-tipe sal dwing om die vlak van produksie-aktiwiteite marginaal te verlaag. Die grootste uitwerking word bespeur op gewasse onder besproeiing, te wete sonneblom (0.23%) en koring (0.17%). Die persentasie afname in die aanbod van droëlandproduksie is 0.07% vir sonneblomsaad; 0.06% vir koring; 0.04% vir sojabone; 0.03% vir elk van witmielies en sorghum; en 0.02% vir geelmielie- produksie. Die respons ten opsigte van die klein boerdery-tipe is onbeduidend. Ter afsluiting kan genoem word dat die instel van grondbelasting intensiewe produksiemetodes soos beproeiingsboerdery kan ontmoedig.

Indien die uitdagings in 'n vrye mark in ag geneem word, is daar 'n behoefte aan maatstawwe om 'n balans te vind tussen gelykheid en doeltreffendheid. Die implementering van die oordra van grond hoef nie noodwendig op 'n radikale wyse te geskied nie en dit behoort die daarstelling van meer uitvoerbare en doeltreffende boerdery-eenhede op 'n gebalanseerde wyse aan te moedig en terselfdertyd die afname in grootskaal kommersiële plase te voorkom. Daar bestaan 'n behoefte aan opleidings- en omvattende ondersteuningsdienste vir gevestigde boere om 'n hoogs doeltreffende en uiters mededingende boerderybedryf daar te stel. Die vestiging van groepe mense en kleinboere moet vermy word, aangesien dit in 'n armoede-slagyster vir die voorgenome begunstigdes kan ontaard. Suksesvolle, swart grootskaalboere,

wat op dieselfde vlak met hulle wit eweknieë kan meeding, moet gevestig word. Daar kan kleinboere wees, maar slegs ten opsigte van intensiewe projekte met hoë waarde-gewasse. Sodanige klein plase mag klein in omvang wees, maar moet groot omsette kan behaal. Die vestiging van kleinboere sal 'n baie kleiner impak hê op uitsette as die grond van reeds oneffektiewe boere gekoop word vir herverdeling. Daar moet ook kennis geneem word dat grond kan optree as 'n veiligheidsnet vir armes in welke geval die bogenoemde doeltreffendheids argumente verval. Markliberalisering is nie genoeg nie; dit sal beter wees om boere te leer hoe om risiko's te hanteer. Aangesien die effektiewe grondbelastingkoers sal afhang van deeglike en doeltreffende waardering van grond, is daar ook 'n behoefte aan deurlopende, studies oor grondwaardasies. Meer navorsing in hierdie verband is nodig.

Omdat dit 'n gedeeltelike ewewigsmodel is, moet daar kennis geneem word van die feit dat die resultate slegs die impak op die produsent se wins aandui. Veranderings in landboubeleid word geag as verteenwoordigend van 'n aantal veranderlikes wat in 'n landbou-ekonomiese omgewing voorkom. Die weglating van veranderlikes wat boere se gedrag beïnvloed, is egter kontroversieel. Onlangse studie in die veld van beleidsanalise (die koppeling van gedeeltelike ewewigsmodelle met algemene – modelle) moet met verdere studie opgevolg word.

Sleutelterme: Boerderyvlak, Hulpbrongebruik, Uitset-aanbod, Grondhervorming, Markhervorming, Groot en klein plaas, Vrystaat gevallestudie, Beleidsanalise, Boerderysektormodel, Positiewe Wiskundige Model, V-V Risiko-analise.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

In an economy, factors that determine agricultural production potential include resource availability which itself among others, is a function of the climate. Government can enhance agricultural production potentials with the use of policy and development strategies that encourage effective allocation of existing resources, increasing the rate of use of the existing resources, improved technology, and competitive industry structure, among other things. For example, if there are only a certain amount of resources to use, government can invest on new methods for using such resources, redistribute the resources to where they are more productive and useful; that is, improve the "allocation of resources," and increase the use of resources that are not fully used.

South Africa is semi-arid with about 450mm average annual rainfall, which is less than the world average of 860mm. Only 3% of its land surface receives rain throughout the year. Most places have hot summers and a long growing season while other areas are frosty during winter. It is sub-tropical along the east coast and characterised by prolonged droughts. The climate determines the spatial distribution of farm resource use and output supply potentials. Subsequently, agricultural production potentials, across the country, vary from region to region and within each region. For example, Free State province is one of the few provinces with viable arable land. Most of the southern and western interior is semi-arid (Department of Water Affairs and Forestry [DWAF], 2002; Water Situation Assessment Model [WSAM], 2003).

During the greater parts of the twentieth century, the South African government through a number of policy and development strategies supported commercial large-scale agricultural production. The government created market and trade mechanisms that strongly linked the industry to the world market. The mechanisms protected the industry from the variation and or uncertainty in world prices. Because of the Apartheid policy black agriculture did not have access to information, support services, and improved technology. Therefore, the difference between black (mainly small-scale) and white (mainly large-scale) farmers is huge in relation to farm resource use and output supply potentials. Commercial large-scale agriculture has been remarkably successful in continuously improving its production systems while agricultural productivity in the smallholder sector has been very low (Baldwin, 1975; Freund, 1976; Townsend, 1996; Kirsten, 1998; National Directorate of Agriculture [NDA], 2004a).

Since 1994, after the democratic election when the African National Congress (ANC) took over government, the government's policy and development objectives include, among others, establishing and supporting new economic activities. This also involves establishing small-scale commercial farmers. Government also aims at a highly efficient and economically viable market-directed farming sector. To achieve these objectives, the governments at regional and national levels have been implementing a number of policy and development strategies.

To exploit the regional and national farm resource potentials, the government has embraced the principle of agriculture-led Growth, Empowerment and Redistribution (GEAR) strategies. One main developing strategy is the Agricultural Black Economic Empowerment (AgriBEE) policy. One aim of the AgriBEE policy is to assist, the portion (black, women and youth) of the population who are not well represented in the agricultural industry, in land acquisition, thereby creating new economic activities at small- and medium-scale (Department of Land Affairs [DLA], 2006). So also, to enhance competitiveness both domestically and internationally, the government liberalised agricultural trade, deregulated the markets and removed subsidies and price supports to large-scale commercial agriculture.

These policies may affect agricultural output potentials and consequently regional and national food self-sufficiency in the short-run and in the near future. This is because the changes in the policy variables and the market environment may directly or indirectly pose challenges to both the established and new entrant farmers who may respond by changing their level of resource use and output supply. This insight is based on the argument by Just (1993) that farmers do respond to changes in exogenous variables such as price or policy variables by changing land allocation and or cropping patterns.

1.2 PROBLEM STATEMENT

The literature shows that some of the changes in the policies and the implementation of the development strategies may be the causes of a number of the recent concerns and challenges in the South African agricultural sector. Primarily, to most stakeholders in the industry, the design and implementation of the AgriBEE policies remain controversial. For example, land reform and its implementation are raising, among other problems, uncertainty of property rights, insecure land tenure, free rider problems, land invasion, and crime in the farming communities (Bezuidenhout, 2000; Ortmann & Machethe, 2003).

Government's land redistribution target is to transfer (transact) 30% of commercial farmland to the previously disadvantaged portion of the population before 2015 (NDA, 1995). Failure to achieve the anticipated or planned progress in the land transfer programme is attributed to the willing-buyer, willing-seller government-assisted land market approach (Wethu, 2005). Another concern is that the principle of a willing-buyer, willing-seller government-assisted land market is probably fostering land speculation. In addition, there has been inconsistency in government policy on land redistribution strategies. The Government started with Settlement/Land Acquisition Grants (SLAG), which has later been changed to Land Redistribution for Agricultural Development (LRAD) because of the failure of the former.

Trade liberalisation and its implementation also pose certain challenges to established commercial farmers with respect to domestic supply vis-à-vis imported goods because world price and exchange rate volatility constitute market risks to farmers (Van Schalkwyk, Van Zyl and Joosté 1995; Skeen 1999). For instance, while exports have grown rapidly since 1990, imports have grown even faster in some sub-sectors of agriculture because of tariff reductions (Kistern, 1998). At a point the rate of farm sequestration increased due to a rising debt/asset ratio resulting not only from the effect of bad weather but also market deregulation, elimination of government support to commercial farmers and relatively high nominal interest rates (De Waal, 1994; Van Zyl, 2001; Ortmann & Machethe, 2003). The producer support level is negative for some crops though positive in the aggregate. However, it is relatively much smaller than it is in most countries of the world (Kirsten, Gouse, Tregurtha, Vink & Tswai, 2000). Jooste (1996) convincingly argues that if tariffs were reduced to zero in the beef industry, new entrant farmers would be negatively affected.

Report from Statistics South Africa (2005) on the 2002 Census of Commercial Agriculture shows that (i) the number of active farm units declined by about 27% from 57,980 in 1993 census to 45,818 in 2002 and (ii) the contribution of field crops to total farm income increased from 25.5% in 1993 to 30.9% in 2002. Likewise, the contribution of horticultural products to total farm income increased from 24% in 1993 to 26.7% in 2002. However, the contribution from animals and animal products decreased from 49.8% in 1993 to 39.8% in 2002.

In addition, the farming debt value of about R31 billion was reported at a debt ratio of about 31.4% (i.e. farming debt as percentage of the market value of assets). The NDA (2006) reports a consistent increase in total farming debt from 1970 to 2005. This may imply that there are a number of challenges, such as inflation, in the farm industry, which predates the changes in the agricultural policies and development strategies. It is theoretically plausible to expect farmers to respond to the changes in the agricultural policy and development strategies by changing their level of resource use and output supply in an effort to maximise farming profits.

The argument is based on the possibility that changes in policy and development strategies directly or indirectly translate to uncertain output prices and or the rate at which the cost is rising is faster than the rate at which the output price is rising (van Zyl, Vink and Kirsten, 2000). For example, van Zyl (1991) and Vink (2000) reported that as capital prices such as land fluctuated in the Northern Cape and Eastern Cape provinces but dropped markedly in the Free State Province, between 1995 and 1999, profit for maize production declined over the same period. In addition, while it is expected that farmers would take advantage of input substitution when inputs costs are increasing, Van Zyl *et. al.* (2000) reported that there had been a time in South

Africa when the government's intervention severely constrained farmers' ability to do so.

Agrarian and market reforms in the South African agriculture are to establish small-scale farms in a more liberal market. The new entrants will be affected by the macro-economic changes in the industry so also the established large-scale farmers. Production and price risks in the farm industry might however affect these farms to different degrees. The effects may also differ on different farming enterprises. Unless proper understanding of the factors that affect farm-level resource use and output supply response is achieved, implementing the agrarian and market reforms may lead to reduced regional and national competitive advantages in some crop and animal products if farmland is transferred from more efficient large farmers to establish less efficient small farmers. Proper implementation of these reforms depends on a thorough understanding of how the reforms will affect the different farmers and farm enterprises.

1.3 Justification for the Free State case study

Case study is a research method of understanding a complex instance based on a comprehensive understanding of that instance. Such comprehensive understanding might be obtained by extensive analysis of the instance, taken as a whole and in its context (Tellis, 1997; Horton, 1997). In this study, a case study of Free State province was undertaken because an analysis of the effects of changes in policy and development strategies, on resource use and output supply response, might be complex at national level. Agriculture happens to be very important in a number of contexts to the Free State province. So also is Free State agriculture important to the South African agriculture as a whole.

Firstly, Free State is the third largest province in South Africa. According to Statistics South Africa (2006), it has a total land area which is about 10.6% of the land area of South Africa. The province constitutes about 6.4% of the total South African population. The province also contributes about 4.9% of the country's GDP. Secondly, the climate, like in any other province and the nation as a whole, significantly determines resource use and spatial distribution of production potentials in the province. Free State is a summer-rainfall region of South Africa. About 3.2 million ha is cultivated while natural veld and grazing cover 8.7 million ha (DWAF, 2002; WSAM, 2003; Prasad, Van Kopper and Strzepek, 2006).

Thirdly, farmers in the Free State make significant contributions to both regional and national production levels. At provincial level, large-scale commercial farmers produce nearly all the marketed outputs and utilize about 98.2% of the land in the province. Agriculture in the province contributes a stable 9.2% of the Province's GDP between 1990 and 2002. Free State agriculture contributed 20.1% of commercial employment in the province (Free State Provincial government, 2005).

Fourthly, Free State is one of the leading provinces in terms of contribution to national agricultural production potential. Report of the 2002 commercial agricultural census shows that at national level, Free State contributes about 31% of gross farming income from field crop production and about 16% from animal and animal products (Statistics South Africa, 2005). Farmers in the Free State province have the largest ratio of farming debt to market value of assets at about 40.6%. Free State is the second largest employer of paid farm workers in formal agriculture. It employs about 12% or 115,478 paid farm workers. Out of about R45 trillion total expenditure in the formal agriculture in South Africa, Free State province contributed about 17.14%. However, of the national farming debt of about R31 billion, Free State province was responsible for 16.4%. Farming debt is increasing from previous years.

Fifthly, commercial, large-scale (mainly white) farmers dominate South Africa's agricultural industry. They utilise about 87% of the agricultural land in the country and contribute about 95% of value added. In the same vein, large-scale commercial (mainly white) farmers utilize about 98.2% of the land in Free State to produce nearly all the marketed outputs (Free State Provincial government, 2005; NDA, 2005). Therefore, the results of the Free State case study are to be valued in the Free State context. In addition, the results are expected to give indication of resource use and output supply response in other provinces and at a national level.

1.4 Motivation for the study

This study is motivated by the important place of agriculture in the South African economy. The challenges that changes in agricultural policies and market environments pose to the farm industry could affect the level of resource use and output supply at both farm and regional levels.

Agriculture is a major factor in rural economic growth and development (NDA, 1995). Therefore, broadening the economic activities of previously disadvantaged people will help to rebuild and strengthen the rural communities. Broadening the economic activities of the new entrants in the farm industry will justify the changes in agricultural policies and development strategies. In the same vein, sustaining the large-scale commercial production will improve the national economic efficiency and the competitiveness and comparative advantage of the region and nation as a whole in the world market. Therefore, sustainable competitiveness in the industry would result from an enabling market environment. Hence, providing information on the level of exposure to risk, risk attitudes and potential changes in resource use and output supply response in the farm industry is necessary for sustainable government intervention in the industry.

1.5 THE AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to make use of available farm-level and regional data to develop a risk-adjusted, regionalised, farm-level resource use and output supply response mathematical model for the Free State farm industry. The model was developed to represent resource use and output supply at the base year, 2004. The model could then be applied to simulate the potential resource use and output supply response with respect to changes in some policy and macro-economic variables. The aim of this study was achieved through the following specific objectives:

i. Estimating farm income risk
ii. Developing a 'representative farm' and typical analysis model
iii. Simulating farmers' risk attitudes and incorporating the risk attitudes into the model to improve the calibration and specification of the model.

iv. Applying the model to simulate potential changes in resource use and output supply as a result of implementation of
   a. land redistribution and
   b. agricultural land tax given the challenges (risks) in a free market.

1.6 METHODOLOGY

A mathematical model was developed and used to examine the potential effects, of changes in agricultural policies and development strategies, on the farm resource use and output supply response in the Free State. The choice of this methodology is based on the criteria, highlighted by McCarl (1992), for using mathematical models. The study explores the advantages of mathematical modelling and, as much as possible, minimises the problems of such methodology.

For example, to avoid over-specialisation, which is a common problem in mathematical modelling, the study used the Positive Mathematical Programming (PMP) calibration approach (Howitt, 1995a,b; Paris & Howitt, 1998; Heckelei & Britz, 1999). Efforts were also made to make the model's specification and calibration as rich and realistic as possible by incorporating risk and farmers' risk attitudes into the model. Previous trends in regional output producer prices and yields were used to estimate the risk in production revenues. The model was also calibrated to *a priori* supply response that was estimated with econometric models by other researchers. The model features constraints due to resource availability and land quality distribution.

1.7 Data used

Within the financial constraints to this study and the time frame for a PhD programme, it was not possible to conduct a region-wide farm survey in order to construct typical farms in the region. Most easily observed and obtainable data in a farm industry are regional data such as hectares allocated to crops, numbers of animal breeding stocks and output levels of some farming activities. These data are taken as farms' or farm types' decision variables; models are often calibrated to these variables (Howitt, 1995a; Paris and Arfini, 2000). In this study however, judicious use of available regional and farm-level data was made as allowed by the PMP modelling approach. The data used in this research are briefly described in the paragraphs that follow.

The enterprise budget data for each production activity include the unit costs of resources, resource requirement per activity level, yield, output prices and average activity level. These data were sourced from COMBUD Enterprise Budgets. The Combud enterprise budgets are compiled and updated from time to time by the Provicial Department of Agriculture (PDA) for the homogenous production sub-regions in each province. For the purpose of this study, the most recent ones for the years 2001 to 2004 were used to estimate averages.

Time series data between 1994 and 2004 on farm gate output prices, producer price index (output) and yields were used to formulate the probability distribution of the revenues.

Base year data on resource use and output supply at regional and farm-type levels were used as variables in the model according to the PMP modelling approach. The data include those necessary for accounting equations and resource constraints, activity levels, policy variables such as the proposed rural land tax, water quotas, regional farm land availability, farm-type land availability, farm land prices and rents, number of farm units, crop and animal products supply levels, etc. These data were sourced from the reports of censuses of commerical agriculture, reports of the survey for drought relief programme in the 5 zones of the province, agricultural information database at the Free State PDA, the database of LRAD projects from the Department of Land Affairs (DLA), the national register of water use from the national Department of Water and Forestry Affairs (DWAF), etc.

1.8 Data validation

The data were validated in consultation with resource persons (extention officers, agricultural economists and agronomists) from the PDA, DLA, DWAF, co-ops, etc. using their knowledge and experince to validate the data.

Also, data from other sources were used to cross-check the base source data. Other sources of data are publicatations of Grain South Africa (GrainSA), National African Farmers Union (NAFU), AgriSA, South African Grain Information System (SAGIS), Milk Producers Organisation (MPO) - Lactodata, South African Meat Industry Company (SAMIC), South African Feedlots Association (SAFA), etc. In addition, consultations with experts were undertaken to conceptualise and quantify each crop or industry specific policies and development strategies. Such information were used as policy parameters in the model. Detailed description of the data and validation approaches are presented in Chapter Five.

1.9 OUTLINE OF THE THESIS

This study is primarily concerned with analyzing the potential effects of implementing land redistribution, agricultural land tax in a free market characterized by market and production risk, on resource use and output supply by using the Free State as a case study. The study continues, in Chapter 2, with a general overview of the Free State agriculture. Issues discussed include the level of resource use and output supply in the Free State and its contribution to the national agricultural supply.

In Chapter 3 a review of literature, on factors that affect supply response and the criteria for choosing model approaches to analyse such responses is performed and presented. It is established that PMP modelling approach is appropriate when there is a dearth of data. Empirical applications of such a modelling approach in relevant studies are presented. In Chapter 4, justification for the modelling approach is presented. The model is developed with the PMP modelling approach with Expected Variance (E-V) Risk analysis to improve the model calibration. In addition, *a priori* supply response, estimated by other researchers who used econometric models, is used to specify the model's supply response behaviour. The model's features, characteristics and detailed mathematical specification are also presented in Chapter 4.

A detailed description of the data used, the sources and validation methods are presented in Chapter 5. The model developed in Chapter 4 is solved and validated based on its capability to reproduce the base year, observed data and *a priori* supply elasticities.

In Chapter 6, the model is applied to simulate the possible effects, of land reform and agricultural land tax given the revenue risk and the farmers' risk attitudes, on resource use and output supply response for the farmers. The responses are discussed. In Chapter 7, the summary and conclusions drawn from the results are presented. Policy recommendations based on the results are also made and presented. The chapter ends with presentation of areas of improvement on the model.

CHAPTER 2

GENERAL OVERVIEW OF AGRICULTURE IN THE FREE STATE

2.1 Introduction

In this chapter, efforts were made to paint the picture of agriculture in the Free State vis-à-vis the resource use and output supply potentials. The impacts of resource endowment, policy and development strategies on the Free State farm industry are presented. Some details on the Free State agriculture with emphasis on resource availability and previous policies that have influenced the resource use and supply potentials and farm industry structure across the districts and population groups of the province are explored and presented. The level of resource use and output supply potentials of the two farm types, the established commercial large-scale (mainly white) farmers and the developing small-scale (mainly black) farmers are presented. The chapter concludes with the challenges that the farm types may be facing because of changes in some agricultural polices and development strategies.

2.3 Geography of the Free State

Free State forms the central province of South Africa. It almost encloses the Kingdom of Lesotho. Figure 2.1 shows the map of the Free State with its five district municipalities namely, Northern Free State, Thabo Mofutsanyana, Lejweleputswa, Motheo and Xhariep. The province is the third largest in South Africa. It has a total land area of about 13 million ha which is about 10.6% of the total land area (122 million ha) of South Africa.

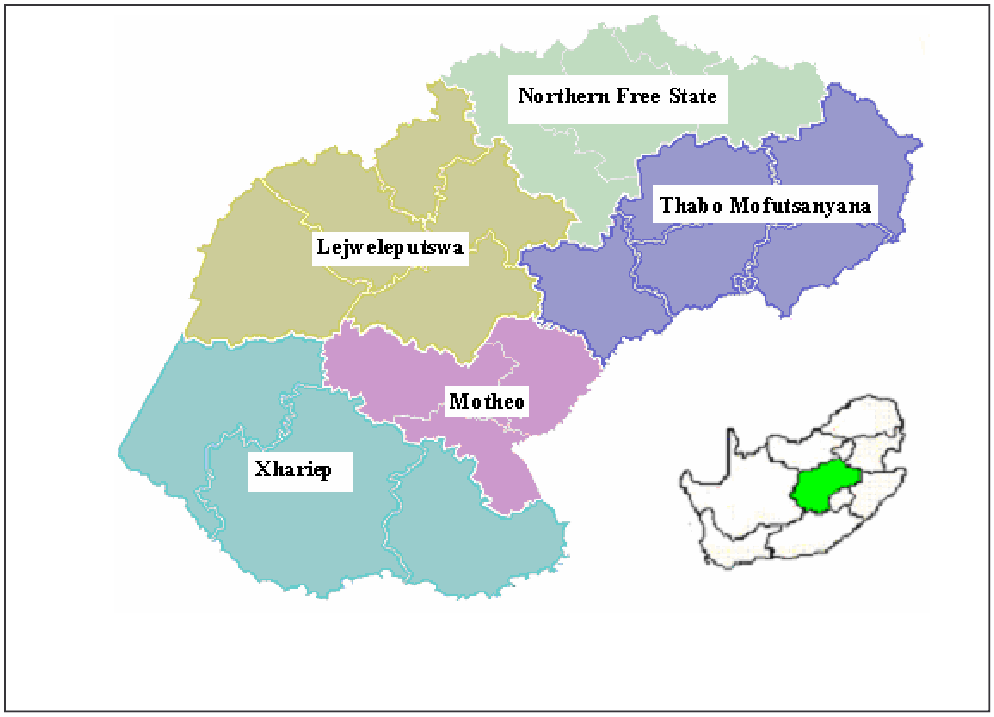

Figure 2.1: Map of the Free State province

2.3 Demography of Free State

Table 2.1 shows the mid-year (2005) estimates of the Free State population. The population is about 2.7 million which is about 6.4% of the total South African population (46.6 million). Motheo district has the highest population in the province followed by Thabo Mofutsanyana and Lejweleputswa. The black population has about 88% of the total population followed by whites with about 8.8%. The coloureds and Indian/Asians have about 3.1 and 0.1% respectively. About 54.7% of the Free State population still live in poverty. Personal annual disposable income in Free State is reported as R12,334 per capita, which is lower than the national average of R13,554 per capita (Bureau of Market Research [BMR], 2000).

Table 2.1: Population of the Free State by gender, age and district (2005)

Group	Gender	Age	Xhariep	Motheo	Lejwele-putswa	Thabo Mofutsa-nyana	Northern Free State	Free State
Black	Male	0 - 15	16595	92544	89942	118172	60651	377904
		16 - 64	31246	186938	189802	190648	127607	726241
		65 - 85+	1856	9516	7721	10940	6151	36184
	Female	0 - 15	16748	91476	90506	117903	61224	377857
		16 - 64	31298	210262	196337	231549	127968	797414
		65 - 85+	3196	17380	12336	21627	10927	65466
Coloured	Male	0 - 15	3760	5323	2123	525	1367	13098
		16 - 64	6647	11373	4198	1177	3053	26448
		65 - 85+	347	529	180	67	182	1305
	Female	0 - 15	3848	5245	1987	557	1344	12981
		16 - 64	6795	12066	4466	1192	2982	27501
		65 - 85+	493	795	232	86	250	1856
Indian/Asian	Male	0 - 15	8	169	90	233	56	556
		16 - 64	15	548	215	467	227	1472
		65 - 85+	0	15	3	8	3	29
	Female	0 - 15	8	154	65	196	60	483
		16 - 64	15	437	153	373	152	1130
		65 - 85+	0	17	12	9	9	47
White	Male	0 - 15	1251	8063	6040	3222	5472	24048
		16 - 64	3969	27752	18788	9569	18199	78277
		65 - 85+	822	3562	2548	1695	3402	12029
	Female	0 - 15	1246	7615	5970	3134	5331	23296
		16 - 64	3933	30778	19710	10203	19016	83640
		65 - 85+	1141	5702	3588	2381	4691	17503
TOTAL			135237	728259	657012	725933	460324	2706765

Source: Statistics, South Africa, (2005)

The living conditions of the Free State households have improved remarkably over the recent time. The number of households that have improved their livelihoods have increased. For example, about 29.2% of the households have access to formal housing; 31.3% have access to electricity for cooking; 60.1% have access to piped water; 80.9% have access to telephone facilities in their houses and or cell-phone; 52.7% have access to electricity for lighting. Only 4.9% have access to computers (NDA, 2006).

The province has the second smallest population and also the second lowest population density with about 20.9 persons per km^2. The province has a relatively high level of urbanisation (71.7% compared to 55.4% in South Africa). About 75.8% of the population live in urban areas while the remaining 24.2% live in rural areas. The province has an economically active population of about 1.1 million which is about 37% of the population in the province (NDA, 2006).

2.4 The climate

The Free State is a summer-rainfall region. It usually gets extremely cold during the winter, especially towards the eastern mountainous regions where temperatures can drop to as low as -9.5^{o}C. The western and southern parts are semi-arid. About 3.2 million ha is cultivated while natural veld and grazing cover 8.7 million ha. The area of land suitable for cultivation, which is not presently cultivated, is about 0.23 million ha. About 0.14 million ha of this is owned by the State (Free State Department of Agriculture, 2005). The climate significantly determines resource use and spatial distribution of production potentials in the province.

2.5 Farm resource and output supply potentials in the Free State

Resource endowment in the form of natural resources such as rainfall, soil quality, vegetation, topography, etc. determine resource use and output supply potentials in the province. The eastern part is semi-arid with an annual rainfall of about 700 mm; there is occasional hail, frost and snow. In the western parts, rainfall intensity is erratic and ranges between 80mm and 300mm per annum. Western parts have flatter landscape, which is dryer with grasslands. There are thunderstorms and flooding in the western parts. Water is a limited (scarce) resource in the central and western parts of the province (Strydom, 2003). Table 2.2 shows that from 1996 to 2003, the province had about 573mm average annual rainfall, which although it is more than the South African average of 486mm for the same period, it is lower than the world average of 860mm (Ricon, 2005, 2002).

Table 2.2: Average rainfall of the Free State and neighbouring provinces

Year	*Average annual rainfall (mm)*							
	Free State	**North West**	**Gauteng**	**Mpuma-langa**	**KwaZulu Natal**	**Eastern Cape**	**Northern Cape**	**National**
1996	717.59	599.26	887.4	1,034.49	1,082.09	675.27	280.93	605.6
1997	600.61	627.32	896.24	856.67	1,097.02	594.08	205.27	513.74
1998	613.68	549.2	658.35	786.64	841.98	623.17	184.47	473.59
1999	360.36	403	463.93	704.47	847.86	347.26	230.45	392.74
2000	635.02	584.31	913.55	1,099.20	1,126.58	716.25	276.35	611.91
2001	720.66	601.93	571.29	675.35	869.52	649.23	320.9	540.79
2002	552.45	428.73	490.53	585.41	747.22	611.36	232.03	425.25
2003	382.29	374.7	465.98	497.28	621.69	439.73	134.04	323.45
Average	572.83	521.06	668.41	779.93	904.25	582.04	233.06	485.88

Source: Ricon, 2005

Free State is one of the provinces where there is appreciable water resource development and a high rate of water use. The Free State has about 12 state dams and other rivers making the province the most water rich province in South Africa. The province lies between the Vaal River in the north and the Orange River in the south. Two main water catchment areas namely the Vaal and the Orange are within the Free State (Free State Department of Agriculture, 2005). Free State has, on average, medium-potential arable land (DWAF, 2002; WSAM, 2003; Prasad, Van Kopper and Strzepek, 2006).

Figure 2.2 shows the stratification of the Free State land area into agricultural land potentials. This distribution shows the type of resources available for agricultural purposes. The figure shows that of the about 13 million ha of land, only about 17% is of high potential agricultural land. About 17% is medium-potential agricultural land while about 42% is low-potential land. About 0.32% is irrigable and 21% is rangeland.

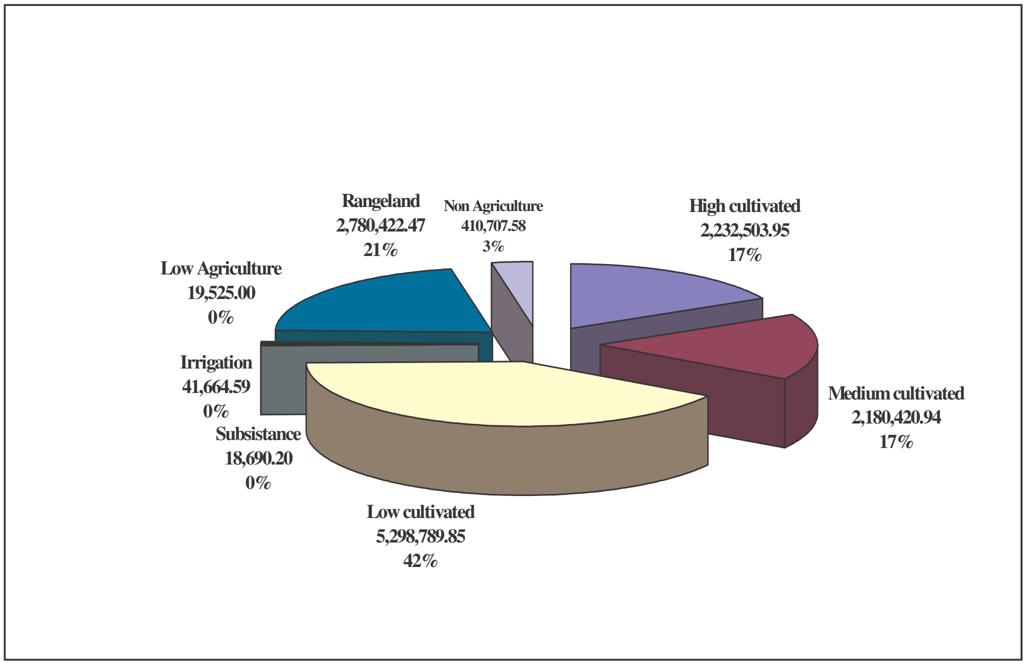

Figure 2.2: Distribution of Free State land strata
Source: Free State Department of Agriculture

The distribution of the land area that is used for non-agricultural purposes is shown in Figure 2.3. About 43% of this land is used for natural and wild life conservation. A substantial part is occupied by water in the form of rivers, lakes, etc. About 17% of the Free State land area is used for towns and cities while mines and rocks occupy about 10%.

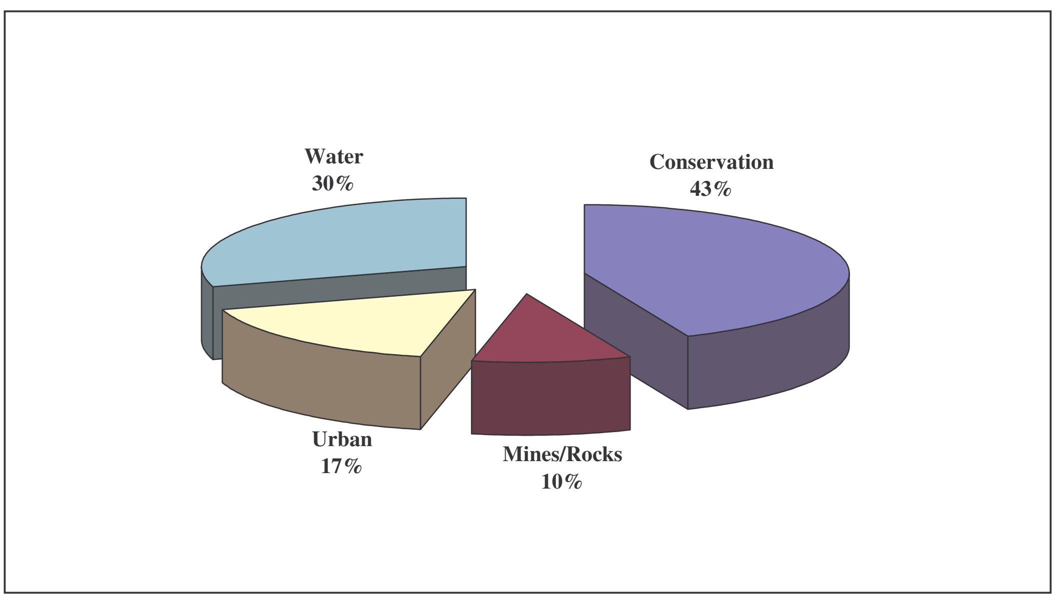

Figure 2.3: Distribution of non-agricultural land in the Free State
Source: Free State Department of Agriculture

2.5.1 Irrigated agriculture in the Free State

Relevant information on irrigated agriculture in the Free State was extracted from the Free State water register compiled by the Department of Water Affairs and Forestry (DWAF). Table 2.3 shows the volume and distribution of registered water use in irrigated areas among the districts of the Free State. The water use is differentiated into irrigation and livestock watering. The water users are the farmers who are the registered water users as at June 2005 in the water schemes in the Free State. About 5,878 farmers are registered water users who use a total of 1,169,210.78m^3 to irrigate a total area of 159,639.49ha; 131 farmers are registered to use a total of 323,820m^3 for watering livestock. Agricultural water use across the province differs from district to district.

Table: 2.3: Irrigated agriculture in the Free State

District	*Area irrigated (ha)*		*Registered Volume (1000m^3/annum)*		Number of water users
	Total	**Average**	**Total**	**Average**	
Lejweleputswa					
• Irrigation	23,901.18	17.12	302,686.51	215.89	1402
• Watering: livestock	-	-	860.75	9.26	93
Motheo					
• Irrigation	25,482.24	19.68	288,836.99	223.39	1296
• Watering: livestock	-	-	-	-	-
Northern Free State					
• Irrigation	8,480.61	10.59	89,611.80	110.77	808
• Watering: livestock	-	-	0.257.00	0.26	1
Thabo Mofutsanyana					
• Irrigation	6,391.27	17.90	47,184.42	132.17	357
• Watering: livestock	-	-	500.00	500.00	1
Xhariep					
• Irrigation	95,384.19	47.45	1,169,210.78	580,253.49	2015
• Watering: livestock	-	-	585.80	16.27	36
Free State					
• Irrigation	159,639.49	27.16	1,897,530.51	682.31	5878
• Watering: livestock	-	-	322.82	0.19	131

Source: Own computations based on the data from the National DWAF

Xhariep district has the highest number of registered users (2,015 farmers) who, on average, irrigate 47.45ha with an average registered volume of water of 585 million m^3 per annum. The district also has about 36 registered water users who use 585,800m^3 of water for livestock activities. Motheo also has a substantial number of water users (1,296 farmers). On average, about 19.68ha is irrigated with 223,39m^3 of water per annum. Total area irrigated in Motheo is 25,482.24ha. this gives an average of 19.68ha per farmer. These farmers use a total of about 289million m^3 of water.

1,402 farmers in Lejweleputswa district irrigate a total of 23,901.18ha with about 302,686million m^3 of water per annum. Another 93 registered water users use a total of 860,750 m^3 per annum for livestock watering. Northern Free State uses a total of 89,611,800m^3 of water to irrigate a total area of 8,480.61ha on an annual basis. Thabo Mofutsanyana has the least registered water users; the district comes last in irrigated agriculture in the province. Here, 357 farmers use 47184420m^3 of water to irrigate 6,391.27ha on an annual basis. However, only 1 farmer in the district uses 500,000m^3 per annum for livestock watering.

2.6 Previous agricultural policies and development strategies

According to Bayley (2000), South African agricultural industry was under government control for about 60 years. Van Rooyen *et. al.* (1995) report on this long history of the government's intervention in the form of commodity, factor and technology policies. These policies were implemented under different legal frameworks that affect access to and use of resources, finance, capital, labour and marketing of agricultural products. One of the objectives of the previous agricultural policies was 'self-sufficiency' in food, fibre, beverages and raw materials for local industry. Non-tariff barriers were also in place to enhance industrialization. Generally, the state intervention in the marketing of agricultural products was justified on the inelastic demand for agricultural produce, the adverse climate, the lack of information and the risk inherent in a liberalised market (Van Rooyen *et. al.,* 1995). A number of legal frameworks were put in place to foster these policy objectives.

Natives' Land Act 27 of 1913

The Native Land Act 27 of 1913 made it illegal for blacks to purchase or lease land from whites except in reserves. The law abolished a number of tenancy forms such as sharecropping. This resulted to racial segregation and simultaneous marginalisation of the black farming sector. Subsequently, large-scale commercial agricultural uses about 87% of the total agricultural land. The Act restricted black occupancy to less than 8% of South Africa's land. Most smallholder farmers were converted into farm labourers. Smallholder farming is located mostly in the former homelands and is an impoverished sector dominated by a low-input, labour-intensive form of production farming (Brand, 1992; Kirsten, 1998; Vink & Kirsten, 2003).

Export subsidies Act of 1931

The Export Subsidies Act of 1931 is one of the legal frameworks that provided subsidies to enhance export volume production. Subsidies, marketing infrastructure and a number of tax concessions were available to large-scale commercial (mainly white) farmers. These policies heavily favoured the increase in production by large-scale owner-operated farms. Both individual farmers and industries received subsidies from the government in one form or the other. Some subsidies to the industries were to keep consumer prices as low as possible while others were to subsidise the marketing control agents in the form of handling and storage costs in order to keep the selling prices as low as possible (Van Rooyen *et. al.,* 1995).

The large-scale commercial sector became capital-intensive, intensified in large-scale commercial production and strongly linked to global markets. These farmers contribute about 4% of the country's GDP, employ about 10% of the formal labour force and contribute 8.4% of the country's total export earnings (NDA, 2005).

Import and Export Control Act of 1963

The Import and Export Control Act of 1963 was established to ensure that some goods can only be imported in the Republic of South Africa with an import permit issued by the Director of Imports and Exports. The permit allows imports from any country (Van Rooyen *et. al.,* 1995).

Agricultural Marketing Act 26 of 1937 and Cooperative Societies Act of 1939

These Acts were established to facilitate orderly marketing of agricultural products. However, it did not cater for the smallholder farmers in the homelands. According to Bayley (2000), marketing legislation allowed farmer-dominated control boards. The control boards determined who produced what and at what price. This eventually resulted in the dominance of a small number of large-scale agro-processing companies. The Acts have been amended and consolidated to the Agricultural Marketing Act 59 of 1968. The Marketing Act was operated under different schemes, which regulated the domestic market, controlled the imports, exports, demand and supported research on different agricultural produce.

2.6.1 Large-scale farms in the Free State

On average, most established commercial farmers are reported to have high management aptitudes. These aptitudes are, in turn, reported to have positive correlations with their farm characteristics. These characteristics and resource levels range from long histories of financial success, high turnover, economic viability, good socio-economic standing, capital-intensive agricultural production and good marketing facilities (Burger, 1971; Callow, Van Zyl, Santorius von Bach & Groenewald, 1991; Nel, Botha & Groenewald, 1998; Van Schalkwyk, Groenewald & Jooste, 2003).

Commercial, large-scale white-owned farms dominate South Africa's agricultural industry. These farms contributed about 95% of value added and utilise about 87% of the agricultural land in the country. Maize is the most widely grown crop, followed by wheat, oats, sugarcane and sunflowers. This highly skewed distribution in resource use and output supply potentials were blamed on an acute lack of markets, capital and education among black agricultural producers in the so-called homelands which is commonly attributed to the previous apartheid policy (Brand, 1992; Bromberger & Antonie, 1993; World Bank, 1994; Percival & Homer-Dixon, 1995; Kirsten, 1998).

The South African farm industry structure and the characteristics of commercial farms are typified in the Free State province. Large-scale commercial farmers produce nearly all the marketed outputs and utilize about 98.2% of the land in the province. Farmers in the Free State make significant contributions to both regional and national production levels. The Free State farmers are engaged mainly in major farm production enterprises such as maize, sunflower, large and small stock farming and horticulture. Agriculture in the province contributed, an average of 9.2% between

1990 and 2002 and 6.1% between 1995 and 2004, to the province's GDP. Also, Free State agriculture contributes, on average, 20.1% to the commercial employment in the province. A considerable portion of the maize produced in the Free State is exported to other parts of the country and neighbouring countries. A percentage of the remainder is processed for animal feed (Free State Provincial government, 2005; NDA, 2005).

At the provincial level, agriculture in the Free State contributed 4.6% to the Gross Geographic Product of the Province in 2004. At national level, Free State agriculture contributed 9.2% to the South African agricultural GDP (Statistics, South Africa, 2005). In general, Free State is the third largest custodian of cattle in South Africa after Kwazulu-Natal which follows Eastern Cape. About 16.5% of South African cattle are reared in the Free State. Free State province has about 20.6% of the national sheep flock after Northern Cape followed by the Eastern Cape. Free State has the second lowest number of goats in South Africa with about 1.1% of the total. In the same vein, Free State is a marginal producer of pigs with about 6.6% of the national pig herd (NDA, 2004).

Tables 2.4, 2.5 and 2.6 show the contribution of commercial agriculture in Free State to the South African agriculture performance. The figures in the tables show the financial performance and dominant agricultural production of commercial farms from the latest 2002 census of commercial agriculture (Statistics South Africa, 2005).

Table 2.4 shows that the Free State contributes about 31% of gross farming income from field crop production and about 16% from animal and animal products. The market value of farm assets, farming debt and interest paid on loans by the commercial farmers in the Free State show the prominent place of the Free State province in the South African agricultural economy. The farmers in the Province have about 13% of asset market value. However, of the national farming debt of about R31billion, Free State province was responsible for 16.4%.

Table 2.4: Financial outlook of the Free State and the South African commercial farm industry (2002)

	Free State	South Africa	Free State as % of South Africa
Gross farming income (R'000):			
• Field crops	5,067,205	16,476,933	30.75
• Horticulture	620,318	14,228,909	4.36
• Animals and animal products	3,410,581	21,222,618	16.07
• Other products	27,475	1,400,592	1.96
Market value of assets (R'000)	12,477,269	98,428,255	12.68
Farming debt (R'000)	5,060,522	30,857,891	16.40
Interest paid (R'000)	540,289	2,958,464	18.26
Farming expenditure: (R'000)	7,720,547	45,038,908	17.14
• Current	7,343,664	42,092,135	17.44
• capital	376,883	2,946,773	13.13
Total paid farm workers	115,478	940,820	12.27
• Full time workers	57,607	481,375	11.97
• Casual and seasonal workers	57,871	459,445	12.60
Total employees remunerations (R'000)	650,483	6,215,582	10.47
• Full time workers	580,888	5,252,251	11.06
• Casual and seasonal workers	69,595	963,331	7.22

Source: Own computations from the Statistics South Africa (2005) report

Farming debt in the Free State was about R2.1m and R2.7m for 1998 and 1993 respectively. This implies that the Province paid about 18% interest on capital in the year 2002. Farmers in the Free State province had the largest ratio of farming debt to the market value of assets at about 40.6%. Free State is the second largest employer of paid farm workers in formal agriculture. It employs about 12% or 115,478 paid farm workers. Out of a national total expenditure of about R45 trillion, Free State province contributed about 17.14%. The province is a major producer of field crops and animals and animal products to the tune of about 31% and 16% of the South African field crop and livestock sub-sectors respectively.

Table 2.5 breaks current expenditures into principal items. Stocks and poultry feed take a big share of expenditure at 12.76% followed by fertilizer, maintenance and repairs to structures, fuel, interest paid on loans, seed and planting materials. Expenditure on contracts is also relatively high at 5.05% of total current expenditure. These are major items of variable costs that directly affect the production at farm level.

Table 2.5: Current expenditure of commercial farms in the Free State province in Rand and as percentage of total South Africa (2002)

Cost items	Current expenditure (R'000)	% of total
Seed and planning materials	536,868	6.95
Stock and poultry feed	985,086	12.76
Fertilizers	864,246	11.19
Fuel	734,006	9.51
Packing materials	117,534	1.52
Transport	131,989	1.71
Veterinary services	37,801	0.49
Combating pests and diseases in crops	295,601	3.83
Combating pests and diseases in livestock	100,261	1.30
Contractors	390,073	5.05
Security	14,807	0.19
Maintenance and repairs of buildings, machinery, vehicles, etc.	770,071	9.97
Electricity	122,152	1.58
Licence fees	25,526	0.33
Insurance premiums	301,035	3.90
Interest	540,289	7.00
Water purchased	28,250	0.37
Rental	281,153	3.64
Protecting clothing for farm workers	10,720	0.14
Depreciation	473,580	6.13
Rates paid to regional services	17,541	0.23
Other farming expenses	564,578	7.31

Source: Own computations from the Statistics South Africa (2005) report

Table 2.6 presents a summary of the dominant agricultural activities of commercial farms in the Free State Province as a proportion of total South Africa agricultural activities. Free State is a major producer of the prominent field crops, chicken eggs, beef cattle, mutton-sheep and diary milk.

Table 2.6: Dominant agricultural activities of the commercial farm type in the Free State province (2002)

Crops	Area (ha)		Production (ton)		% of total South Africa production
	Dry-land	**Irrigated**	**Dry-land**	**Irrigated**	
Maize	708,057	38,515	1,987,580	243,151	45.54
Sorghum	27,848	860	57,308	3,751	46.77
Wheat	221,150	22,036	436,266	102,143	36.65
Sunflower seed	126,604	2,033	158,868	3,236	44.63
Ground-nuts	20,146	1,375	27,390	2,871	42.76
Soya bean	10,776	322	14,287	481	15.56

Livestock	Number on farm	Number sold	% of total South Africa
Dairy cattle	139,482	15,414	12.54
Beef cattle	950,188	608,534	22.31
Sheep	1,845,051	812,354	16.60
Goats	24,339	5,572	2.40
Pigs	30,437	57,972	4.63
Chickens	17,559,432	37,182,485	22.70

Source: Own computations from the Statistics South Africa (2005)

The table, showing the 2002 production levels supports the general production potentials in the Free State. About 46% of the maize output is produced in Free State. About 47% of sorghum is produced in the Free State while the Free State commercial farmers produce 37% of wheat, 45% of sunflower seeds, 43% of groundnuts and 16% of soya beans. Animal and animal products are also substantial in the Free State. About 13% of dairy cattle and about 14% of total milk and cream; 22% of beef, 23% of broiler chicken, 11.33% of chicken eggs, 17% of sheep mutton and about 24% of wool production comes from the Free State. The province is a marginal producer of goat and pig meat.

Information from the Farm Information Centre of the Free State Department of Agriculture is presented in Table 2.7 to show the distribution of livestock among the districts. The Table shows that most of the cattle in the province are located in the Northern Free State and Thabo Mofutsayana followed by Lejweleputswa. Xhariep has the least of the Free State cattle herd.

Table 2.7: Distribution of Free State livestock number among the districts as at February 2004

District	**Cattle**		**Sheep**		**Goats**	
	number	**% of total**	**number**	**% of total**	**number**	**% of total**
Northern Free State	674,472	30.06	1,785,552	30.21	4,022	5.73
Lejwele-putswa	452,347	20.16	308,399	5.22	28,576	40.72
Motheo	264,370	11.78	333,272	5.64	3,779	5.38
Thabo Mofutsan-yana	663,756	29.58	1,307,129	22.11	6,092	8.68
Xhariep	188,791	8.41	2,176,556	36.82	27,714	39.49
Free State	2,243,736	100	5,910,909	100	70183	100

Source: Farm Information Centre, Free State Department of Agriculture

Figure 2.4 shows the contribution of commercial agriculture to the Free State Gross Domestic Product (GDP). The figure shows that while the Free State GDP is on steady increase from 1995 to 2004, the contribution of agriculture to the GDP is not stable over the period. Figure 2.5 shows the contributions of the district municipalities to the Free State GDP in 2004. Motheo district contributed most to the Free State GDP. This is the central district where the provincial capital is located, which could have made it to benefit from the government and service sectors. This is followed by the Lejweleputswa district, which has a vibrant mining industry. Northern Free State district has a vibrant manufacturing industry. Thabo Mofutsanyana is considered one of the most fertile agricultural regions in the Free State, however, it is also the part of the Free State where poverty is concentrated. The lowest contribution comes from the Xhariep. The district heavily relies on agriculture. Agriculture contributed 14.5% of this district's GDP in 2004. The district is more prone to drought than the other districts.

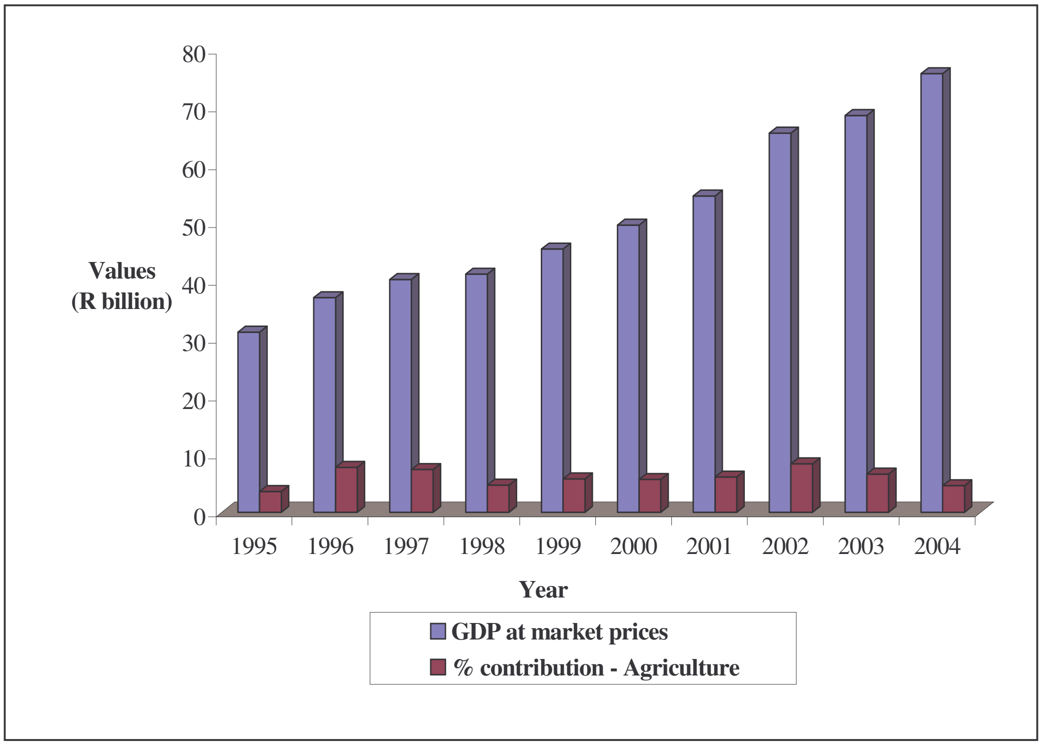

Figure 2.4: Free State gross domestic product and agriculture's contribution
Source: Own computation from Statistics South Africa (2005)

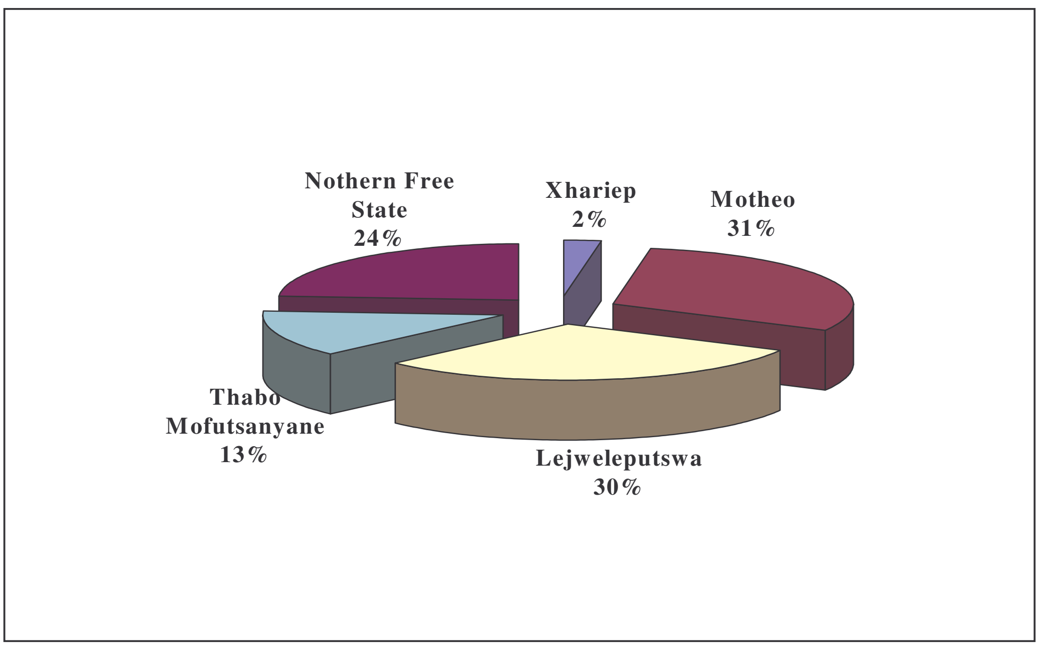

Figure 2.5: District contribution to the Free State GDP in 2004
Source: Own computation based on data from Free State PDA

2.6.2 Smallholder agriculture in the Free State

Statistics South Africa undertook a nation-wide rural survey in 1997 to determine the extent to which rural households in the former homelands had access to land and to income-generating activities. 68,496 households were sampled in the former homelands (Qwa-qwa and a portion of Bophuthatswana at Thaba Nchu) of the Free State. The survey (Rural Survey, 1997) was reported in June 1999 by Statistics South Africa (Statistics South Africa, 1999). Information on access to land and subsistence farming in the rural areas of Free State were extracted from the report and are presented in Tables 2.8 and 2.9 to paint a picture of smallholder agriculture in the Free State.

Table 2.8 shows land access among the smallholder farmers in the rural parts of the Free State. About 48.8% of households surveyed in Free State did not have access to land for farming purposes and about 51% did not have access to land for animal grazing. About 95% of those that had access to grazing land had it through communal access. About 31% of the surveyed households had permission to occupy the land on which they lived while about 39% did not have permission to occupy the land on which they lived. The remaining households either did not know and or did not specify. About 98.2% of the households has not moved since 1913. The majority of the households, 69.4% that had access to land had access to Local Authority and or State land for farming.

Table 2.8: Land access in smallholder agriculture in the Free State

	Number	%
➢ Access to land for farming:		
• Yes	33,415	48.8
• No	35,081	51.2
➢ Access to land for animal grazing:		
• Yes	14,332	43.0
• No	16,891	50.7
• unspecified	2,121	6.4
➢ Types of land access for animal grazing		
• Communal grazing land	13,633	95.1
• Land for own use	699	4.9
➢ Method of gaining access to land:		
• Inheritance	4,224	8.3
• Purchase	282	0.6
• Lease	173	0.3
• Local/state land	35,538	69.4
• Others	10,966	21.4
➢ Whether households have permission to occupy the land they live on		
• Yes	21,138	30.9
• No	26,673	38.9
• Don't know	1,527	2.2
• unspecified	19,157	28.0
➢ Whether households have been moved since 1913		
• Yes	1,228	1.8
• No	67,268	98.2

Source: Own computations from the Statistics, South Africa (1999)

Table 2.9 shows some characteristics of smallholder agriculture in the rural parts of the Free State. Of the households in the survey, 48.79% were engaged in some farming activities. About 97.8% of the households that were engaged in crop farming had access to less than 10 ha of arable land. The majority, 77% were engaged in farming activities in order to produce enough food for the households to eat while about 20% were engaged in farming to earn a living. About 72% of the households that kept livestock had milk cows; 72% had other cattle; about 27% had sheep and lambs; 22.3% had one or a combination of horse, donkey and mule while 17% had pigs. 80% of the households that kept livestocks realised between R501 and R5000 as annual gross income from sales of livestock over the 12 months that preceded the survey. About 27% of the households planted maize and vegetables such as onions, tomatoes, pumpkin, etc. About 22% planted fruits. About 31% of households that planted crops realised a gross income of between R1 and R100; 37% realised between R101 and R500 while about 31% realised more than R500 from sales of crop products over the 12 months that preceded the survey.

Table 2.9: Farming activities among the smallholder agriculture in Free State

	Number	*%*
➢ Household with some farming activities:		
• Yes	33,345	48.7
• No	35,151	51.3
➢ Distribution of arable land among households that have access to land:		
• Less than 10ha	22,943	97.8
• Equal or greater than 10 ha	516	2.2
➢ Type of animals kept by households		
• Milk cows	12,169	77.2
• Other cattle	11,331	71.8
• Sheep and lambs	4,250	26.9
• Goats and kids	557	3.5
• Pigs	2,610	16.5
• House/donkey/mule	3,510	22.3
• Other livestock	803	5.1
➢ Gross income from sales of livestock		
• Less than or equal to R500	757	10.8
• Between R501 and R5000	5591	80.0
• Greater than R5000	640	9.2
➢ Crops, vegetable, fruits and other crops grown:		
• Maize	11,735	27.0
• Wheat	1339	3.1
• Sunflowers	977	2.3
• Folder crops	334	0.8
• Potatoes	4919	11.3
• Vegetables	11,837	27.3
• Flowers	1463	3.4
• Trees for timber	1060	2.4
• Fruits	9742	22.4
➢ Gross income from sales of livestock		
• Between R1 and R100	846	31.1
• Between R101 and R500	1027	37.7
• Above R501	850	31.2

Source: Own computations from the Statistics, South Africa (1999)

2.7 Current South African agricultural policies and development strategies

Though the previous policy measures enhanced large-scale agricultural production and self-sufficiency in a number of agricultural commodities, it is characterised by imbalance in resource use among races and lacks competitiveness in marketing and trade. For example, the policy of self-sufficiency benefited producers considerably with improved revenues and prices but at the expense of consumers. In addition, the GATT negotiations and trade agreements commit the government to adopt reform in marketing and trade of agricultural produce. These are among other reasons that justify reform in the South African agricultural sector (van Rooyen *et. al.,* 1995).

Subsequently, a number of policies and development strategies are in place and a number of others are being proposed since democracy began in South Africa. These are policies and development strategies that were meant to restructure the South African industry and enhance competitiveness in the agricultural sector. The strategic plan for agriculture include sustained profitable participation in agriculture by all stakeholders, increasing and maintaining commercial production, building international competitiveness and avoiding or reversing the imbalance in access to land and other resources in the sector. The South African vision, for a new agriculture, as stated in the white paper on agriculture, reads:

> *"a highly efficient and economically viable market-directed farming sector, characterised by a wide range of farm sizes, which will be regarded as the economic and social pivot of rural South Africa which will influence the rest of the economy and society"*

The current government is committed to redress the imbalance in the farming industry. From the mid-90s the South African government has invested huge amounts of money on the acquisition of land for previously disadvantaged people (World Bank, 1994; Makhura, 1994; NDA, 1995, 2004a). According to Lebert (2001), land reform was viewed as a necessary government intervention to improve household food security in South Africa. It was also expected to drastically restructure the agrarian economy. Hence, the government has put in place an number of legal frameworks for land reform between 1994 and 1999.

2.7.1 Land redistribution

Land redistribution is one of the main land reform strategies which government adopted in order to redistribute wealth in the South African economy. The policy thrust is to achieve a more equitable distribution of property and income. The government is involved in the land market by assisting the poor and disadvantaged people in land acquisition for residential and productive purposes. The government adopted a principle of willing-seller, willing-buyer land market approach.

Provision of Land and Assistance Act 126 of 1993

In 1993, the Provision of Land and Assistance Act 126 was enacted. This is a legal framework that enables the poor and disadvantaged people to be qualified for a maximum of R16,000 grant from the government. The grants are to be used to purchase land directly from willing-sellers including the State. The land redistribution programme is being implemented through a number of sub-programmes. Some individuals are settled as groups but with individual production activities. Groups and commonage production also exist. According to Lebert (200l) land is relatively expensive and unavailable in small grant size parcels. This involved the encouragement of group settlement as compared to individual settlement. Another problem was that the implementation of land redistribution was low with respect to the target rate of land transfer.

Subsequently, there was a policy change, which developed into an integrated programme of land redistribution for agricultural development strategy, which was adopted to assist black agricultural entrepreneurs to become commercial small-scale farmers. Under the new policy, the SLAG was replaced with LRAD. Through the LRAD, a land redistribution beneficiary is entitled to a grant of between R20,000 and R100,000 to purchase farmland and operational stocks. Another way in which LRAD is different from SLAG is that it is intended to redistribute white-owned agricultural land to blacks. The policy target has also changed from rural poor and landless populace to productive emerging black commercial farmers (DLA, 2002).

The programme has not fully yielded the intended benefits because according to Lebert (2001), the new policy has the potential to miss the intended beneficiaries in the rural areas who may be too poor to afford the minimum contribution of R5,000 to qualify for grants under the LRAD.

2.7.2 Agricultural trade and market reform

Deregulation started in the early 1980s and went up until the early 1990s when the agricultural sector was opened to the world market for free trade and competition with limited government intervention. Most of the control boards have been closed before

1998 and fixed prices on agricultural produce were abolished. These were replaced by other marketing mechanisms such as tariffs, import duties, etc (Bayley, 2000). Tariffs were to replace all non-tariffs barriers after 1994 when South Africa consented to the Marrakech Agreement. Virtually all tariffs are below the bound rates of this agreement. The average tariff cascades from relatively high rates on consumer goods to moderate on intermediate goods and low on capital goods. State funding to agriculture have been on the decline since 1994.

The list of goods subject to import permits has been progressively reduced and changed from a list of goods subject to import permit under the previous government intervention to a list of goods that do not require import permit (Van Rooyen *et. al.,* 1995).

2.7.3 Government supports and services

A number of government services have been transformed between 1994 and 1997. For example, on water use, higher priority has been afforded to human water use and the environment. Preferential access are been granted to smallholder farmers. The riparian rights have been terminated. There is implementation of integrated catchments management system. Subsidies on water price are also to be removed (Vink and Kirsten, 2003). Subsidies on wheat and maize have been reduced to zero by 1992 and 1993 respectively.

The recent government's efforts to redress the skewed distribution have led to a new dichotomy, namely, established and developing commercial farm types. Wethu (2005) reports that as at September 2005, a total of 3.1 million ha had been transferred through the various land reform programmes of which 1.3 million ha (about 43%) is through the Land Redistribution for Agricultural Development (LRAD) programme. LRAD is a sub-programme of the Land Redistribution Programme through which the Ministry of Agricultural and Land Affairs hopes to transfer land at the rate of 2.2 million ha per year from 2006 to 2015 in order to reach the target of transferring 30% of farmland from commercial agriculture by 2014. Summarily, the two farm types, large-scale and small-scale farmers, have been the focus of policy attention in the South African agriculture sector in recent times.

2.8 Small-scale agriculture in the Free State

Table 2.10 shows the impact of the land redistribution programme in the Free State. The land redistribution programme is being implemented under a number of sub-programmes namely commonage, FWSE, LRAD, Tenure reform, and others.

Table 2.10: Land redistribution and tenure in Free State as at March 2003

Year	*Number of projects*	*Household*	*Female Household*	*Area of land (ha)*	*Area of land per project*	*Area of land per household*	**Number of household per project**
1996	19	950	10	18,394.45	968	19.36	50
1997	21	609	176	11,035.98	526	18.12	29
1998	93	1437	303	57,189.20	615	39.80	15
1999	14	689	29	10,458.33	747	15.18	49
2000	2	789	3	1,854.03	927	2.35	395
2001	109	614	212	27,747.56	255	45.19	6
2002	162	926	359	48,884.31	302	52.79	6
Unspecified	75	1061	17	19,809.63	264	18.67	14
Total	495	7075	1109	195,373.50	395	27.61	14
Grant type:							
Commonage	34	1,477	0	42,419.65	1,248	28.72	43
FWSE	2	129	0	888.60	444	6.89	65
LRAD	61	384	120	24417.74	400	63.59	6
LRAD(LB)	238	1,414	468	62,140.10	261	43.95	6
SLAG	115	2,777	518	53.741.98	467	19.35	24
Tenure	18	2	0	8.00	0	4.00	0
Other	27	892	3	11,757.43	435	13.18	33
Total		7,075	1,109	195,373.50	395	27.61	14

Source: Department of Land Affairs (2003)

Land redistribution began in 1994 with the Settlement/Land Acquisition Grant (SLAG) but later in 2001 LRAD was introduced to increase the amount of black commercial farmers. The project delivery involves the DLA and Land Bank. It was only in Kwazulu-Natal that four projects were delivered in 1994. Free State DLA only delivered 19 projects in 1996. In almost all the provinces, delivery dragged until 1997. It increased drastically as 93 were delivered in 1998. There was a set-back afterwards till 2000 when only two projects were delivered. After then it has been on the increase. DLA attributed the inconsistent and slow progress in project delivery to the planning, legislative and policy-development stages, which the project implementation had to pass through at that time. Also, the drop in 2001 and 2002 was attributed to the change in political leadership and management in the DLA. The change subsequently led to legislative review when SLAG was replaced with LRAD. Between 1996 and March 2003, a total of 7,075 households of which 1,109 were female headed have been beneficiaries of land redistribution and tenure reform. In this period, 195,373.5ha of land were transferred. This amount to 395ha per project on average.

Table 2.11 shows the distribution of land redistribution projects among the districts. The projects under private land reform and LRAD reform are also presented in the Table. The table shows the distribution of farming activities among the beneficiary farmers in different districts of the Free State province. Most projects were delivered in Motheo with about 1,468 projects followed by Lejweleputswa with 879 projects. Agricultural production among the LRAD farmers follows the general production in the corresponding districts.

Table 2.11: Land reform beneficiaries per district council in Free State as at 1st January 2006

	Number of beneficiaries					
Land reforms:	**Xhariep**	**Motheo**	**Lejweleputswa**	**Thabo**	**Northern Free State**	**Free State**
LRAD land reform	470	1,240	879	775	467	3,831
Private land reform	44	228	25	158	73	528
Private and LRAD	514	1,468	904	933	540	4,359
Agricultural activities:						
Beef cattle	421	1,023	575	457	230	2,706
Dairy cattle	17	117	234	95	1	464
Small stock	388	538	432	133	38	1,529
Poultry	0	13	2	0	0	15
Crops	191	253	580	359	114	1,497
Vegetables	55	76	330	18	54	533

Source: Farm Information Centre, Free State Department of Agriculture (2006)

Compared to the established commercial farmers the developing farmers lack farm resources such as access to market, credit and management abilities. The few that are progressive do not operate at competitive levels (Makhura, Goode & Coetzee, 1998). Their farming operations, which are generally below optimum levels, are usually attributed to their lack of experience and long-time confinement to subsistence operation. The constraints range from inadequate technology, low entrepreneurial skills, lack of marketing infrastructure and information to transferral of information, among other things. Specifically, most of them lack the knowledge to implement production strategies such as forward pricing of inputs, diversification of enterprise and renting of land; marketing strategies such as development of new markets, better timing of access to markets, hedging of future contracts, forward contracting and spread of sales throughout the year; and financial strategies such as maintaining costs and credit reserves to meet unexpected cash flow difficulties, maintaining financial stability, etc. (De Villiers, 2004).

For example, in a study that evaluates empowerment policies, strategies and performance within the agricultural sector of the Free State province, Swanepoel and Stroebel (2004) report that Free State province has an articulate and intentional framework for empowerment. However, they note a number of problems that characterise such projects including insufficient implementation and lack of experienced officials to assist in settling farmers because of lack of understanding of essential concepts such as commercialisation, coordination, beneficiaries, mainstream economy, small farmer development, etc. Many projects are small in scope, which could limit the project's impact and adaptation to the competitive industry, and there is a lack of monitoring and post-settling training for developing farmers. Also, studies by Gouse, Pray, Kirsten, & Schimmelpfennig (2005) and Raney (2006) show that these farmers are not competitive in the agricultural input market because the adoption of insect-resistant white maize varieties by these farmers is constrained by the cost of these high technology seed.

Additionally, questionable ethics and values and low levels of management capacity reported among emerging farmers impact on their business practices, making it impossible for them to establish agricultural cooperatives among themselves whereas agricultural cooperatives are a viable means of sharing risk in an industry characterised by risk and uncertainty (DBSA, 1997; NDA, 1995). For example, in a study of joint ventures of the Hereford Irrigation Schemes comprising emerging small-scale irrigation farmers, private investors and government, Tapela (2005) observe the failure of such ventures with evidence of decreasing farm income and increasing debt among farmers. The study suggests that ventures in the context of Integrated Sustainable Rural Development Programme (ISRDP) and LRAD may be faulty in concept and implementation.

2.9 Challenges to both farm types

The preceding discussion makes it obvious that the changes in agricultural policy and development strategies will affect the resource use and output supply response among the large-scale and small-scale farmers and for difference agricultural commodities. The response is expected as a result of changes in number of farming units, trends in marginal revenue and associated risk in the farm industry.

Table 2.12 shows the trend in the number of farm units in the Free State farm types. This typifies the trend throughout South Africa. The trend is attributable to a number of factors. The effect of government-assisted land acquisition to settle small-scale commercial black farmers is evidenced in the growth in the number of farming units. The claims that established commercial farmers feel marginalised in a more liberal market with the withdrawal of government support could be attributed to the decreasing number of farm units in this category (World Bank, 1994; Makhura, 1994; NDA, 1995, 2004a). Jooste *et. al.* (2003) reported that trade liberalisation and market deregulation put pressures on the farmers.

Table 2.12 Trends in the number of farm units

Established commercial farms			Developing farms		
Period	**Farming units**	**Area (ha)**	**Period**	**Farming units**	**Area (ha)**
1983	9,436	9,716,000	1996	19	18,395.45
1985	10,040	9,758,000	1997	40	29,430.43
1986	9,880	9,716,000	1998	133	86,619.63
1987	10,610	11,039,000	1999	147	97,077.96
1988	10,387	10,725,000	2000	149	98,931.99
1993	10,252	11,321,000	2001	258	126,679.55
1996	10,272	11,342,502	2002	420	175,563.86
1998	10,926	11,496,000	2003	495	195373.49
2002	8,531	11,690,029	-	-	-

Sources: DLA, 2003; Statistics South Africa, 1993, 2005

It was mentioned earlier that farming debt and its growth are a major concern in the Free State and South African agriculture. Figure 2.6 shows the trend in farming debt, gross farm income and farming expenditure for commercial agriculture in the Free State Province. Farming debt increased steadily from 1983 to 2002.

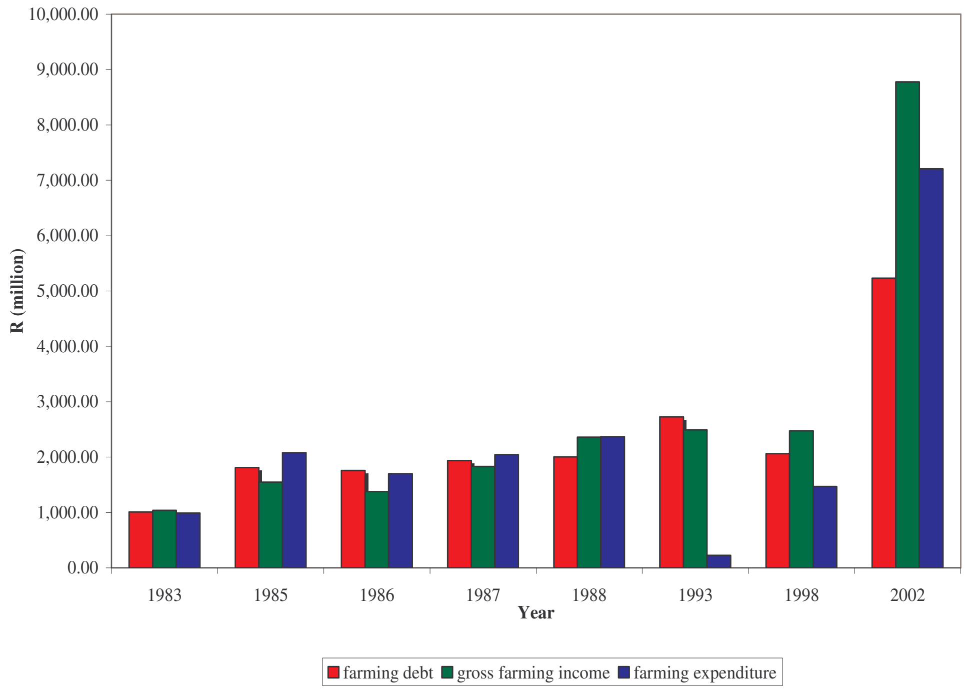

Figure 2.6: Trend in farming debt, gross farm income and farming expenditure in the Free State commercial agriculture

Source: Own computations from the Statistics South Africa (2005) report of the 2002 census

The trend can be related to the decreasing number of farming units among established commercial farmers because farms may fold up when they cannot make profits. The relative indebtedness of commercial farmers has increased sharply for the last 2 decades because of drought, high nominal and real interest rates, deregulation of markets and declining real land values (Ortmann, and Machethe, 2003).

In the same vein, it seems that developing agriculture is not competitive in agricultural production. For example, Lebert (2001) in a review of land reform between 1994 and 2001 surveyed 2000 households of land redistribution beneficiaries to examine the quality of their livelihoods. The report shows that over two-thirds of land reform beneficiaries used land for farming, growing about 25 different crops. About 38% were realising income from either sales or own consumption from agricultural activities. The study also shows that of the 2,000 households, an average income of R3,500 per annum was estimated. Also, about 50% of the communal projects were not operating while many projects were not showing economic potentials. Only about 15% of the projects were realising a median income of R10,000 per annum per individual beneficiary.

Jordaan and Jooste (2003) sampled and interviewed 55 out of 114 emerging farmers in the Qwa-qwa area of Free State to identify problems and challenges confronting the emerging farmers. According to the authors, about 55,000ha of land was expropriated on which emerging farmers were settled. The farmers also have access to extension agents at a ratio of about 1 to 20. The project is one of the pre-democracy government's efforts in establishing commercial farmers in the former homeland. The project is one of the intensive large-scale, centrally managed agricultural development projects that were established in the late 1970s and early 1980s.

The farmers were reported successful but the cost of maintaining and supporting them was high. However, after 1994 the democratic government discontinued with the project on the premise that only few farmers were benefiting from the project. The farmers were unable to get production finance for crop production. The authors conclude that the Qwa-qwa farmers have proved to be profitable and sustainable farmers.

However, nearly half of the settled farmers were insolvent and unable to repay the loans granted to them for production. The financial asset ratio of 0.44 to 1 was recorded among the sample emerging farmers. The farmers have a poor liquidity status that portends higher insolvency. They also report that certain farmers hold the belief that mortgage payment is not a priority to them because default payment was not deemed to engender title deeds. This report though not strongly supported by the authors portends lack of free land market and posses a threat to the land reform process. Bad weather during 1998 and 1999, carry-over debt, bad market prices, high input costs, lack of support systems and inability of farmers to negotiate production capital were reported causes of financial problems among the Qwa-qwa emerging farmers.

Bayley (2000) argues that reform in the South African agricultural market is increasing the level of price instability for both producers and consumers. And that the reform is vulnerable to significant political pressure. Bayley (2000) therefore suggests that for the advantages of deregulation to be achieved and to be sustainable, there is a need for the policy behind deregulation to be open, transparent and predictable such that the outcomes should be stable in terms of prices for commodities. There is also a need for market access for the developing farmers.

CHAPTER 3
LITERATURE REVIEW

3.1 Introduction

According to Tomek and Robinson (1990) empirical studies of farm supply response show that changes in prices typically, though not always, account for a small proportion of the total changes in supply that occur over a period of several years. This is to acknowledge that short-run changes in supply are often caused by other factors such as weather. In addition, long-run changes in supply are often attributed to improvements in technology and programmes that reduce risks in agriculture. These are factors that cause higher changes in output even at constant prices. It is therefore necessary, in analysing resource use and output supply response, to not only estimate potential changes in the supply that may result from changes in price but also changes in supply that may result from changes in factors that shift the supply curve. Therefore, a brief theoretical consensus on such factors and how farmers respond to them is discussed in the following section.

3.2 Changes in supply

Other factors that shift the supply curve seem to have more profound, lasting and irreversible changes in output supply. Therefore, studies of supply response should not be limited to predicting traditional supply changes. Traditional supply response is referred to as changes in supply as a result of changes in outputs price; it is stated that such a response is reversible (Tomek and Robinson, 1990). However, another type of supply response is named 'supply relation' which is more general and specifies the output response to price changes when other factors are not held constant. This involves both movement along the supply curve and a shift in the supply curve. This categorisation is reasonably based on the hypothesis that when prices change, there are likely to be correlated changes in supply shifters e.g. technology, risk, etc.

Furthermore, a number of such factors have been proved by both theoretical and empirical analyses to affect the supply, even at a given price level. According to Tomek and Robinson (1990), principal factors that cause shifts in supply curve, among others, include:

1. the level of yield, price or revenue risk and farmer's risk attitude;
2. technical progress;
3. institutional constraints such as area control, land reform, insurances, drought relief, etc.
4. input costs; and
5. farm industry structure (e.g. number of producers).

The theory underlying some of these factors that are relevant to the following sub-sections of this study is elaborated below.

3.2.1 Optimum resource use and output supply

From Figure 3.1, the Neoclassical theory of firms on perfectly competitive markets assumes that firms have perfect information i.e. when firms commit resources to production, firms know exactly what prices they will receive in the input and output markets and that given the technology they employ, they know the output they will obtain from the resource used. However, in the short-run, the firm maximises profit subject to diminishing marginal productivity as input use increases. At optimal resource use (activity level x_o), the Marginal Cost (MC) of a unit of output is equal to its market price P. When such MC curves are aggregated, it gives an industry supply curve, S. This total supply curve is the horizontal summation of individual supply curves. It is the total quantity produced by all producers at each possible price (Silberberg, 1990).

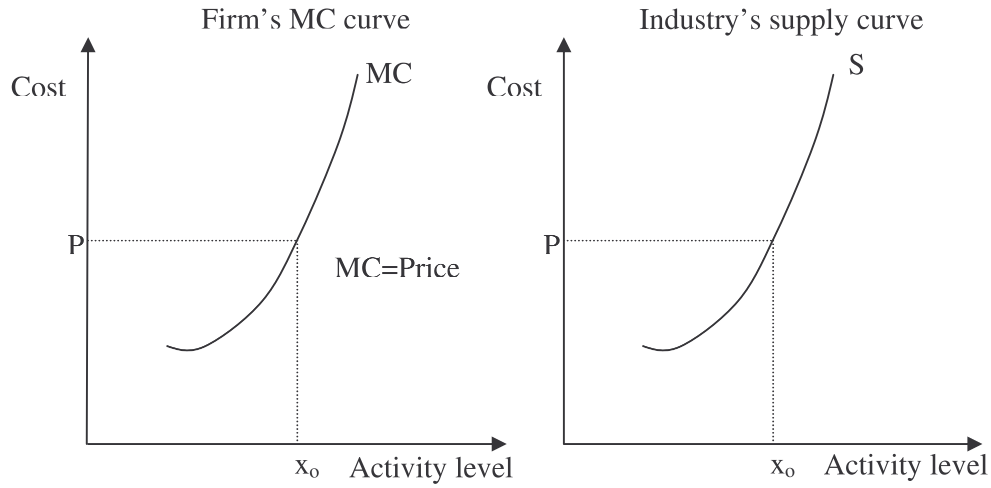

Figure 3.1: Neoclassical theory of firms on perfectly competitive markets

3.2.2 Farmers' response to risk

To understand how farmers respond to risk and estimate their degree of risk aversion, one can employ the Von Neumann-Morgenstern expected utility approach as this approach is based on utility and expectations; postulating that decision-makers take risk into account when taking a production decision (Von Neumann and Morgenstern, 1947; McCarl, 2004). This approach assumes that the distribution of stochastic variables (e.g. price, yield, marginal revenue, etc.) is normal and that the absolute risk aversion coefficient is constant (Paris and Arfini, 2000; McCarl, 2004). A risk-averse individual prefers the expected outcome to have certainty as compared to facing a fair lottery. This is based on the premise that marginal utility of profit diminishes as profit increases. This may imply that the utility lost of the random profit below the expected profit is greater than the utility gained if the random profit is above the expected profit.

Therefore, this approach can be used to measure how risk affects the utility of farm profit and how farmers respond. Hence from Figure 3.2, introducing risk into the production model such that the decision criteria for determining the optimal activity level changes MC equal to the price to MC less than or equal to the price. One would therefore expect farmers to reduce their activity level for more risky activities if they are risk-averse; otherwise the farmers are risk loving if they increase their activity level for more risky activities i.e. it is expected that risk will shift the supply curve both at the farm and the regional levels.

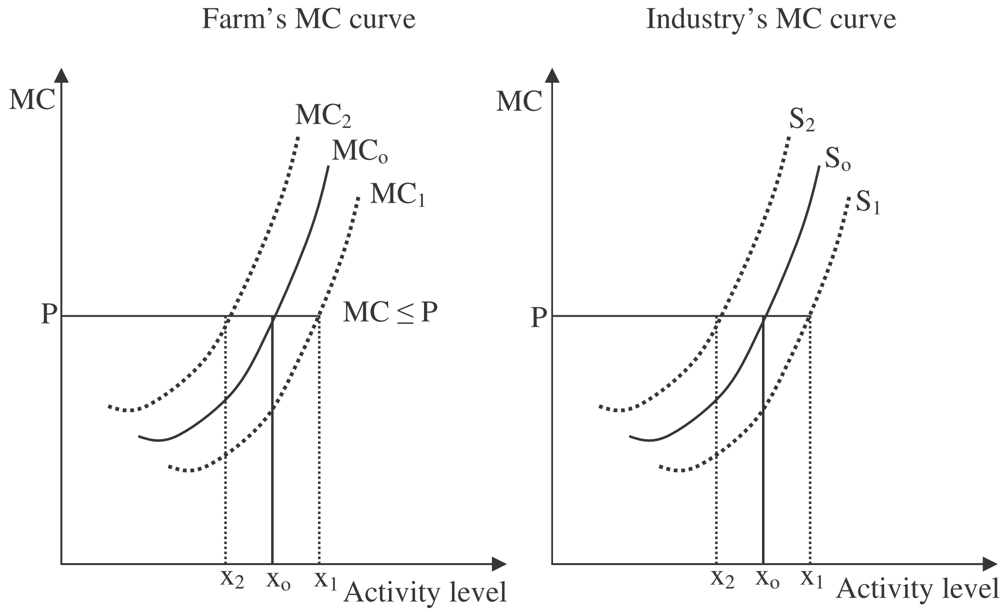

Figure 3.2: Farmers response to risk and the effect of this on regional supply

According to Sandmo (1971), a firm is expected to have a concave utility function if risk averse. The more concave the function of utility of profit, with respect to the origin, the greater the degree of risk aversion. This implies utility increases with profit but at a decreasing rate. The Von Neumann-Morgenstern utility expectation implies that

$$E(U(GM)) = E(\pi) - C(x_p) - \theta x'_p \, Cov_\pi x_p \qquad 3.1$$

Where π = revenue. This implies that the expected utility of gross margin E(U(GM)) is equal expected revenue E(π) from which total cost $C(x_p)$, if known with certainty, is deducted along with a risk premium, $\theta x_p^{'} Cov_\pi x_p$. Cov_π is the variance-covariance matrix of the marginal revenue. Parameter θ is an estimate of absolute risk aversion. A risk premium is usually incorporated into the objective function of optimisation models such that the certainty equivalent of gross margins is maximised as

$$\frac{\partial E[U(GM)]}{\partial x_p} = -C(x_p) - 2\theta Cov_\pi x_p = 0 \qquad 3.2$$

Therefore, with risk, the certain activity level would be less with the risk premium. This implies from Figure 3.2 that risk shifts the MC curve to the left i.e. reducing the activity level from x_o to x_1.

According to neoclassical economic theory, a farm maximises profits where MC of a unit of output equals the market price for that output in the Short-run i.e. producers are subject to diminishing marginal productivity as resource use increases (Varian 1984; Silberberg 1990).

However, when risk is considered as it happens in reality, the MC functions incorporate the area response elasticity that relates to changes in the crop area, not only to activity MR but also to the risk of each activity, such that farmers maximise profit subject to resource and technical constraints, market competitiveness and the activity revenue risk level. Therefore, Figure 3.2 represents how farmers may respond to risk in their production and marketing activities. In the real world, there is diversity in portfolio theory and planning under risk. One of the reasons that justify activity diversification is risk and the risk attitude of producers. Therefore, the MC curve does not always equal P.

Therefore, risk shifts the farm's MC and corresponding industry supply, S to the left i.e. MC_2 and S_2 respectively. However, where financial solutions are available in the form of institutional arrangements such as futures markets and options a risk-averse farmer may look risk loving when the farmer transfers the risk to the institutions in the game of profit making (Boussard, 2003). Thereby moving the farm level MC and corresponding industry supply S to the right i.e. MC_1 and S_1 respectively.

3.2.3 The effect of changes in production costs on resource use and output supply

Market deregulation, trade liberalisation and removal of government supports in the industry may increase the intensity of shocks to the prices farmers receive and the prices they pay for inputs. Therefore it is necessary to allude to the relevant aspects of the theory of the farm. The theory of the firm consists of a number of economic theories which describe the nature of the firm including its behaviour and its relationship with the market (Berle and Means, 1932; Hall and Hitch, 1939). In this study, relevant economic theories include the theory of production dealing with the structure of production factor pricing and the theory of the firm dealing with why firms exist.

According to Berle and Means (1932), the theory of the firm states that ownership of a typical firm is spread over a wide range of shareholders such that the control is made by managers who own very little equity themselves. Hall and Hitch (1939) in their book on price theory and business behaviour further state that businessmen made decisions by rule of thumb rather than in the marginalist way. These two assertions imply that perfect competition is not an adequate model of how firms behave (Nodoushani, 1999).

According to Salvatore (1983), the theory of production states that production decisions are concentrated on what goods to produce, how to produce them, the costs of producing them, and optimizing the mix of resource inputs used in their production. This production information can then be combined with market information on demand and marginal revenue to determine the quantity of products to produce.

In that essence, the critical assumption behind the equilibrium level of resource use and output supply is profit maximisation. Although not all farmers start out with or have a profit maximising objective, this assumption is deemed essential to exploit the theory of the firm and furthermore it will lead to more accurate predictions of business behaviour in this study because entrepreneurship and the theory of the firm are central to market economy and can be incorporated into the modelling framework (Foss, 1997, 1999; Foss and Klein, 2002; Foss and Klein, 2005; Casson, 2004, 2005a, 2005b).

Economists conventionally assume that firms try to make profit and yet controversy abounds on this issue partly because the word profit is ill-defined (Knight, 2002). Most firms that announce their profit compute it as a residual i.e. left over after costs incurred have been deducted. Actually, economic profit is impossible to measure because most firm operators do not account for implicit costs and/or ignore returns to family labour. In addition, a farmer who operates with his own capital may not account for the return to capital as interest he or she would pay were he or she to borrow the capital.

Economic profit is the difference between revenue and opportunity cost of all resources used. This includes the implicit costs and returns and therefore makes it difficult to measure. Hence, it is assumed that it does not exist when entry into an industry is easy. This is because when there is surplus, new firms enter, bidding up input costs and bidding down the outputs prices until economic profit is eliminated. Therefore, in the long-run equilibrium profit should not exist.

The assumption in this study is that farmers are out to maximise profit. It seems plausible to assume that farmers stay in the farming business because they make a profit and that those that exit the industry do so because they fail to make profit. However, the question still remains - do farm firms, like any other business firms, try to maximise profit? The answer to this question is that when costs are sufficiently and broadly defined, rational farmers try to make profit.

Moreover, to capture the South African agricultural and land reform policy measures, the assumption of profit maximisation is also appropriate since the policy thrust is to raise a number of small-scale farmers at a commercial level. Apart from that, in the context of this study let us suppose a farmer cultivates a relatively small piece of land with the objectives of:

(i) producing a crop for subsistence, and

(ii) selling the excess output in order to have money to buy what he or she could not produce on the farm.

Yet, it is arguable that if the price rises exogenously, the farmer's opportunity costs increase then the farmer may partially embrace the goal of profit maximising. This alludes to the Kirzner (1997) theory of alertness to opportunity in the theory of the firm.

On the other hand, for the existing commercial farmers, the alternative assumption is that farm firms try to survive because the new market environment is more liberal than it used to be. In the long-run, this assumption appears more realistic to farmers at all levels of operation. In the South African context, the sustainability of the new entrant farmers is a measure of the achievement of wealth redistribution and industry restructuring goals. Also, the survival of the commercial farmers is important for employment, regional and national food security with national economic efficiency in resource development and use. Basically, if the survival of the established commercial farmers and the sustainability of developing farmers require profit, the two assumptions are equivalent. Moreover, the assumption that firms try to survive under certain conditions leads to the assumption that farms try to make profit.

Interestingly, the assumption of survival reveals similarities between small scale and large-scale farmers. Both face the same supply curve for resources; the same production function and the same type of demand curve for output. For instance, many small-scale farmers are settled to achieve wealth redistribution. However, they buy resources such as farm supplies and other operating capitals. They produce primary produce e.g. maize and they must have enough money to pay hired labour, irrigation water, land, interest rates, etc. in order to farm the land and be sustained as commercial farmers.

Therefore, the basis is that farmers use optimal level of resources to produce optimum levels of output in order to maximise profit. The optimum level of resource use and output supply to maximise profit is a mathematical problem if the production, supply curve for the resources and the demand curve for the outputs are known. However, when not known, profit maximisation output is determined by trial and error. However, because of the dearth of data on MC and MR for the typical production activities, the concept of profit maximisation through the PMP approach where MC is derived from the average cost is used. This implies the farmers use an optimum level of resource to produce an optimum level of output that maximises profit in order to incur the least opportunity cost for resources (Parris and Howitt, 1998). The use of a farm profit maximisation approach is valid because it helps to answer questions such as: how well firms that maximise profit serve the public interest? It also has some predictions about the effects of government control and intervention (Salvatore, 1983).

3.2.3.1 How farmers respond to cost increases

It is also interesting to note how farms respond to changes in costs when maximising profit. The optimisation principle dictates that the profit maximising level of output is that level at which the marginal benefit to the farm will just equal the marginal cost of that unit. The marginal benefit, to the firm, is the extra revenue from producing another unit of output. This extra revenue is marginal revenue (MR) and depends only on the demand curve. The MC is more complex because it depends on both the production function and the supply of resources. However, it plays a leading role in the economist's story of the firm. Once a minimum total cost curve is determined, the MC curve can be determined from it. To discuss it further, one must compute the total cost curve as in Figure 3.3 for the output.

Fixed costs are costs that do not vary with output for example, rent. However, when such costs increase they shift the MC from MC_o to MC_2. In a perfect competitive market, where producers are price takers, farmers can only respond to such changes in MC that result from changes in fixed cost by reducing the activity level from x_o to x_2.

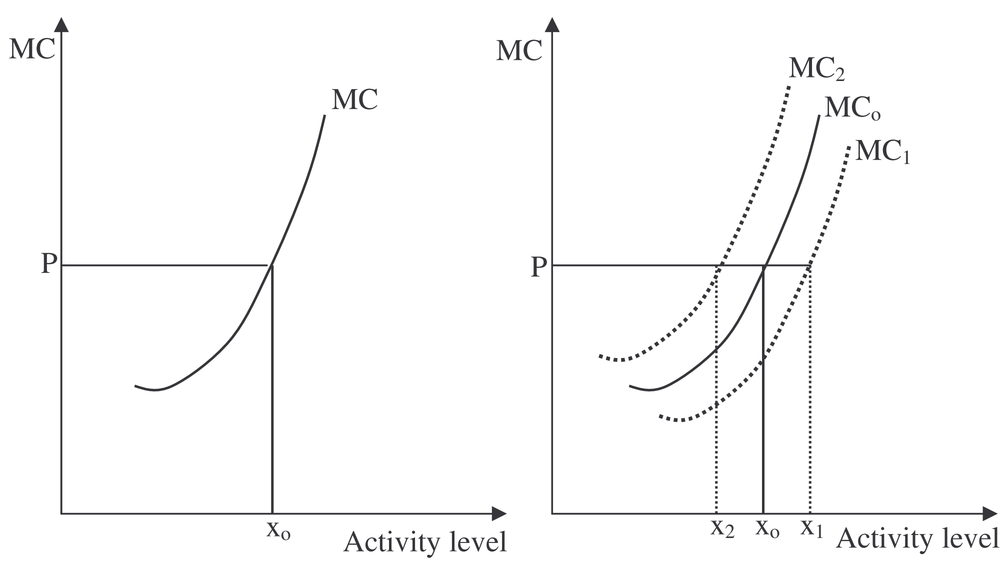

Figure 3.3: Farm's MC curve and response to changes in cost in a perfect competitive market

In the same vein, if there is a decrease in fixed cost such that the MC_o curve moves to MC_1 the producers could increase the activity level from x_o to x_1. This follows the marginal decision rule that producer expands activity levels if and only if the price is greater than the MC_o (Salvatore, 1983).

Therefore, fixed cost, though not varying by activity levels, has a major impact on the activity level decision of firms. For a real-world firm, fixed cost includes rental payments, insurance payments, depreciation, etc. If fixed cost increases sufficiently, there would be no level of output or activity level for which there exists a profit. If such losses get big enough and become permanent, the firm may find that the best way to minimize losses is to shut down completely.

In the Free State farm industry context, considering differences in the activity levels of the two farm types, they could have different average cost (AC) curves. Therefore policy that affects fixed cost may have different effects on the AC that each farm type will face because, for low levels of production, fixed costs are major determinants of AC whereas for high level of production, variable cost (VC) dominates (Piana, 2003).

The profit maximising level of activity level is where MC equals MR. MC depends on the supply curve of the resource. Increase in costs usually decreases the profit and the firm usually considers a reduction in the level of such activity. Another possible response from a farm is investing in better technology that will restore the MC back to the equilibrium level MC_o and maintain the activity level, or further improve the technology and productivity, to move MC to MC_1.

In the short-run, the amounts of some inputs can be changed, while others cannot. Generally, all inputs including land can be changed in the long-run. In the short-run, (when at least some costs are fixed), the producer may stay in production if it appears that revenue will at least cover variable costs. However, if variable costs cannot be covered, continued production, even in the short run, only makes things worse. In the long-run (when all costs can be varied), a farmer may continue production only if all costs can be covered. Anything short of that usually results in cash flow deficits and the loss of net worth. Therefore, both fixed and variable costs should be modelled when simulating the impact of changing costs on production decision because both fixed costs and variable costs are usually considered when deciding whether to continue production. Therefore, observed changes in technology progress in an industry may be incorporated in simulating the effects of increasing costs in the industry.

3.3 Agricultural sector models

A number of factors that affect resource use and or output supply response can be analysed with the aid of an agricultural sector model especially when farm-level parameters are well incorporated into such models. Agricultural sector models are used as tools for analysing quantitative economic problems in the agricultural sector of an economy. Most of these models are developed to analyse policy impacts on agriculture and therefore provide implications or suggestions for policy decisions. Based on implementation and structure, agricultural sector models are traditionally divided into econometric models and programming or mathematical models. Each of these modelling approaches is described in the sub-sections that follow.

3.3.1 Econometric models

Econometrics is the application of mathematics and statistics to empirically measure a relationship postulated by economic theory (Greene, 2002). The theoretical basis of econometric models is the maximisation of producers' profits and or consumers' utilities, given certain constraints. The assumption of profit and utility maximisation is inherent in the econometric sector models. Econometric models are quite flexible and different functional forms and sets of different explanatory variables can be tested. It is easy to find, in the literature, some generally accepted statistical tests and other validation procedures on which to base the inference. Econometric models are also flexible in the sense that they can capture dynamic patterns in a system when lagged variables are introduced into such models.

However, one may have serious estimation problems because of the inconsistency of the parameter estimates due to lagged variables and heteroscedasticity. There are other problems related to the statistical quality of the data which are encountered in econometric modelling (Pindyck and Rubinfeld, 1991; Just, 1993; Lamb and Diebold, 1996; Greene, 2002).

Bauer (1998) highlights the advantages of econometric models as follow:

i. use of statistical methods for parameter estimation;
ii. use of generally accepted calibration and validation procedures;
iii. flexibility of specification and possibility of testing various behavioural assumptions;
iv. continuous response to changes in exogenous variables; and
v. integration of dynamic lags.

However, the disadvantages of econometric models include the following:

i. when modelling an agricultural sector of large dimensions, there is the difficulty of estimating the parameters of large simultaneous equation systems; and
ii. there is limited use of *a priori* information if possible at all.

In addition, there is no economic evaluation of fixed factors and internal flows (Helming, 2005). There are, among others, some reasons which make programming models to be preferred to or needed to complement econometric models. In the next section more details on programming models are presented.

3.3.2 Mathematical or programming models

An agricultural model is an abstract, a quantified framework for organising kinds of information about the structure and functions of an agricultural sector (Burrell, 1995). Agricultural sector models using the mathematical programming approach are characterised as 'logical' models. They describe the nature of agricultural production; the models are used to investigate the implications of the multi-input and multi-output nature of agricultural production, joint factor use and own-production of intermediate inputs by the causal links and behavioural responses within a sector (Weber, 2003).

The mathematical models maximise consumer and or producer surplus subject to production and resource constraints (Hazell and Norton 1986). This approach became increasingly popular in modelling the agricultural sector since the 1980s. Programming models that simulate competitive markets often use cross-sectional data or smoothed data from a period of 2 to 3 years as a reference year. In addition to official statistical data, mathematical models can directly use different kinds of technical data or an *a priori* or data from experts. For example, data on production costs of different production activities and other farm-level information can be used directly to allocate costs on different products.

When empirical information is available on price-supply response (elasticity), explicit marginal cost function can be set up which can reveal more information on the specific properties of a production activity. Therefore, some *a priori* information can be used directly in mathematical models. Production technology, support systems, fixed production factors, resource constraints and capacity levels can also be modelled directly. Physical linkages between crop and animal production can be modelled explicitly together with production quota.

It is consistent with standard economic theory to compare different outcomes when running the mathematical models for different policy scenarios. In addition, when comparing results of different policy scenario outcomes with the base year outcome it is possible to make conclusions concerning the effects of agricultural policy on production volume, production allocation and farm income. It is also possible to analyse the efficiency of different agricultural policy regimes, for example, the impacts of different support payments on farm income. The results of programming models when maximising producer and or consumer surplus represent rational economic behaviour. Thus, the models can be used to forecast future changes in agriculture, given some specific policy parameters.

Mathematical modelling approach offers several methods of analysis, which are not easily captured in econometric models; such methods are theoretically appealing. For example, shadow prices of some explicit resource constraints and physical capacity provide information that may be needed by decision makers. Such information can be easily obtained from programming models.

The main characteristics of programming models of the agricultural sector are as follow:

i. detailed description and representation of agricultural technology;
ii. differentiation of the production sectors and explicit consideration of various interactions;
iii. use of *a priori* information for model specification;
iv. economic evaluation of fixed factors and the internal commodity flows; and
v. explicit incorporation of many policy instruments like physical production limits, foreign trade policies such as export and import quotas, tariffs, input subsidies/rebates and domestic price policies.

However, the programming modelling approach is not without problems. Despite the apparent advantages highlighted above, there are problems that should be acknowledged and taken into careful consideration when developing programming models for policy analysis. The disadvantages of programming models are briefly described in the following subsections.

3.3.2.1 Normative optimisation

Programming models are strictly based on neo-classical equilibrium theory as it assumes perfect rationality, i.e. that the producers maximise profit or consumers maximise utility. Moreover, perfect competition is assumed in the basic standard form of optimisation of consumer and producer surplus (Hazell and Norton, 1986; Heckelei and Britz, 2003). Individual producers and consumers are assumed too small in size to influence prices. This is a disadvantage to programming models because in reality farmers do not have all the information to make a profit maximising decision.

In addition, perfect competition implies efficient markets where economic agents trade as long as no trade transactions increase anybody's profit or utility without lowering the utility or profit of the other trade agent i.e. efficient market outcomes are pareto-efficient (Andersen, 1994). However, markets of agricultural products may have some internal frictions (like inventories or long-term delivery contracts between suppliers and the food industry), which prevent an immediate response in the economy due to policy variables. Therefore, the static nature of programming models does not allow time-dependent issues like lags in the production process. Rather, it is assumed that consumer and producer surplus is maximised instantaneously i.e. economic agents are able to respond immediately (or at least quickly enough before any consequent changes in parameters) to changes in market conditions while keeping other parameters constant.

In reality, many parameters are changing constantly and simultaneously (Tomek and Robinson, 1990). On the other hand, producers cannot respond immediately to changes because some factors of production are fixed in the short-run. Different agents may have different lags in adapting to changing conditions while a neo-classical model assumes simultaneous response of all agents. Due to the lag in response to changing conditions, other changes may occur during the lag. Thus, the resulting actual response may depend on the specific sequence of parameter changes. Consequently, the actual interplay of different economic agents may be different from the model outcome. However, difficulty in specifying system dynamics is common to all economic models based on static equilibrium and it's not only specific to mathematical models.

3.3.2.2 Aggregation problems

Different decision makers in a region, sector or nation are usually represented by a single 'representative decision maker'. More than one representative decision maker can be included in the model at the expense of additional data requirements. Aggregation problems occur in sector-level optimisation models since natural and economic conditions usually vary considerably from one location to the other or even from one farm to the other (Bauer and Kasnakoglu 1990).

This is the case in South Africa, which is like any other economy with a quite heterogeneous soil quality in relatively small regions or even on individual farms. The history of farms may be different. Thus the production planning and production equipment i.e. production costs, may vary considerably even on farms of the same size and type. Given the natural and economic conditions, individual farms may specialise in production, which is allowed by their resource constraints and preferences. Resources, like some particular types of land, owned by some groups of farmers, cannot be made easily available to other farmers, as is assumed in sector-level mathematical programming models.

In a sector model with representative farms and Leontief technology (fixed input-output-relations in production), one is assuming that average cost is also equal to marginal cost. This is rarely the case, because marginal behaviour cannot be inferred by using only aggregate data. If this is attempted, the outcome of a sector-level optimisation model is not likely to match real data (Heckelei, 2002).

To minimise these problems, regional aggregation of a sector model should be done in a way that farms and areas with similar production structures and natural conditions (indicated by crop yields) are combined in order to form homogenous regions (Hazell and Norton, 1986). Unfortunately, this is not always possible because most data available are usually regional data prepared for the purpose of administration and governance (Paris and Howitt, 1998). It may be difficult and costly to acquire data on different areas in a region. In practice, some aggregation error seems inevitable in modelling. However, all possible efforts have to be made in order to analyse homogenous regions or farm types.

3.3.2.3 Problems in parameter estimation

Parameter estimation is problematic not only in econometric but also programming models. For example, signs of elasticity parameters may depend on the length of time series data used in estimation. This is problematic, since the price elasticity of demand for example must be negative in the case of downward sloping demand functions used in optimisation models. In addition, the price elasticity of supply should be positive in upward sloping supply functions. In many modelling exercises, the model parameters have been set using expert knowledge or adopting parameter estimates from modelling exercises in some other countries (see for example, Apland and Jonasson 1992). This is understandable because of estimation problems or because of the lack of resources available for parameter estimation. However, taking parameters directly from other studies and countries should not be encouraged as a general practice.

3.3.2.4 Problem of model validation

A programming model of an agricultural sector usually has a large number of interdependent equations and variables, often in thousands, so it is not always obvious how the model should be validated. Unlike econometrics, the programming approach is lacking generally accepted principles, criteria and guidelines for model testing and validation. However, some tests have been used in evaluating the behaviours of optimisation sector models (Hazell and Norton 1986). For example, one may compare shadow prices of capacity constraints in a model to the actual prices of investment goods, as well as prices and quantities of inputs and products in a model to the actual prices and quantities observed in an agricultural sector. The right level of shadow prices and the value of the applied inputs can be considered an indication of the consistency of a model.

Also, the validity of agricultural sector models are most often been evaluated by comparing production outcomes of the model to the observed ones. In static equilibrium analysis, it is possible to check that the production quantities in a model solution are close to the actual ones. At times, production quantities of some commodities may be close to the observed ones and quantities of some other commodities are not. How to evaluate the overall model validity remains a problem. In the case of small volume products, one may accept even relatively large deviations from the observed production values, if the production quantities of high volume products in the model are close to the observed ones. In short, one may accept larger deviations of production quantities from the observed ones of small volume products than in the case of large volume products. Thus, a greater weight may be given to large volume products in evaluating model validity in terms of production volumes.

There is however no consensus on mathematical-based agricultural sector modelling as regards to the statistic to be used in evaluating the fit of a model. Some simple measures like mean absolute deviation (MAD) or percentage absolute deviation (PAD) have been suggested as well as Theil index used typically in econometrics

(Hazell and Norton 1986). In the case of agricultural sector models consisting of many regions, one may perform tests on each region separately, but the fit is usually better on the aggregate level than on the regional level. This is understandable since there is tendency for overspecialisation of production between regions in an optimisation model (Hazell and Norton 1986; Bauer 1998).

According to Hazell and Norton (1986), an additional complication of regional sector models is how to evaluate the model fit when there are considerable differences in fit in different regions. One specification of a model may have a better aggregate fit while the fit of individual regions may be rather poor. Some alternative specification may have a better fit in individual regions while the aggregate fit may not be that good since the production levels in individual regions may all be slightly biased in the same direction. Thus, one may have difficulty in deciding which model specification to use.

It may be the case that the model is not properly specified i.e. some important structural dependencies are lacking, and the base year data cannot be replicated by varying the chosen validation parameters. However, difficulties in model calibration may not be an indication of inadequate or wrong specification. It may be difficult to replicate actual base year data using the model even if the model is properly specified. This may be due to fact that the base year data do not correspond to an economic equilibrium. These problems however, are common for both econometric and programming models and for all models based on static equilibrium reasoning.

In calibrating an optimisation model, some model parameters are changed in such a way that the model outcome is close to actual data in terms of production quantities. The choice of free parameters for calibration is somewhat arbitrary (Heckelei, 2002). One may for example add some linear or non-linear terms to the cost function, add risk aversion parameters to the objective function, crop rotation constraints or in extreme cases, simply change some yield or cost function parameters in an arbitrary way. One may also introduce some *ad hoc* flexibility constraints, i.e. artificial constraints on the variable in the model. Such calibration methods substantially affect the model response (McCarl and Spreen, 2004).

However, the implications of such assumptions and manipulations are usually not very well stated (Bauer and Kasnakoglu 1990). Worse still, in the absence of generally accepted calibration and validation procedures, and given the limitations of econometric methods in generating the required model parameters, arbitrary and non-explicit adjustments in model parameters may become routine. *Ad hoc* parameter or data manipulations also make the life of models very short and difficult to update. Such modelling and validation practices do not increase the validity of agricultural sector model but deteriorate the trust of policy makers in model-based economic and policy analyses (Howitt, 2005a). As a consequence, even more problematic and less analytical subjective views on policy effects may replace modelling efforts in actual decision-making.

However, there are already procedures (though with much computational requirements) to overcome these problems which make mathematical modelling approach more popular in recent times. Basically, most recent attempts to overcome the problems of the mathematical programming modelling approach involve integrating econometric methods in programming modelling. However, in the meantime, for a decade or so ago, one of such procedures that has been very useful in overcoming some of these shortcomings in programming modelling is the standard positive mathematical programming (PMP) approach by Howitt, (1995a, b). It allows incorporating *a priori* information from econometric models into mathematical models. It will be worthwhile to digress a bit and review the scope in programming modelling approach.

3.3.3 The scope in programming models

There are two main scopes in analysing policy effects with mathematical modelling approach namely, the computable general equilibrium (CGE) framework and the partial equilibrium (PE) framework. The CGE models are used to model the commodity markets and supply-demand relationships in an economy. The models are often aggregated at an economy-wide level and used to represent the overall function of a national economy. The inputs are sometimes modelled to be transferable across the sectors but at times may be modelled as fixed. The prices of all products are determined simultaneously (Pindyck and Rubinfeld 1991). Perfect competition

results in optimal allocation of resources and maximisation of total welfare in an economy. The effects of a number of possible policies are evaluated with CGE models.
In comparison, the level of coverage in the PE models is on a sub-sector or a product in an economy. The demand and supply of agricultural products at sector-level could also be analysed with PE models. This modelling approach is partial because other sectors of the economy are considered not to have an effect on the sub-sector or the product in question; however, the analysis is in details for the sub-sector or product in question.

In the South African context, agriculture is a small sector of the economy in terms of the value added and its effect on another sector may be very small. Therefore, PE models would be able to give a succinct indication of the effect of changes in policy on the sector. Another advantage of PE models over the CGE models is that PE models are relatively simple in structure and results can easily be understood and interpreted. Dynamic and stochastic elements can also be easily incorporated into PE models. In addition, PE models can allow more adequate incorporation of physical resource constraints (Banse and Tangermann, 1996).

While the GE framework is very suitable for analysing the impacts of policies directed to agriculture, the PE models examine in greater detail policies directed to specific commodities and inputs. In a multi-input multi-output PE model of agriculture with joint factor use, producers allocate resource endowment to maximise their profits. In such a model, the question of how alternative policy settings influence economic decisions is a question of how policy affects the economic incentives like input and output prices (Weber, 2003). Thus, the same economic model can be used to analyse a whole range of alternative policy measures. More specifically, static PE analysis focuses on the principal agents affected by the policy in question (Banse and Tangermann, 1996). Therefore a PE analysis of land reform may try to justify the sustainability of such projects by comparing the marginal cost of production with prevailing products revenue

Hertel, (1985) compares the advantages and disadvantages of GE and PE analyses. It was reported that GE analyses are much more difficult to conduct for policy analysis because of high data requirements and the degree of sub-sector specificity required. The PE analysis may be modelled at farm-level. Such farm-level models are often used to describe the agricultural production at farm-level. The models are often specified in terms of production technologies. Substantial detail about the potential effects of a policy variable can be evaluated at farm-level using farm-level models. Such models can be made more realistic by incorporating risk and risk attitudes of the farmers in the specification (Hazell and Norton 1986).

To understand a similar, though possibly relatively small, effect of policy changes, sector-wide PE models could be aggregated from farm-level models that represent representative farms that specialize in the production of certain commodities of interest. Farm-level models are often developed to analyse the short-term effects of agricultural policies on a farmer's or farm type's cropping pattern and income. Such information is useful in policy decision-making and development strategies in an economy (Ala-Mantila, 1998).

3.4 The preferred modelling approach - PMP

PMP is a method for calibrating models of agricultural production and resource use. The approach involves using non-linear yield or cost functions. The idea of PMP is that a sufficient number of non-linear relationships are added to an LP model in order to calibrate the model exactly to the base year data.

The addition of non-linear terms improves the diversity of the optimal solution. Adding some non-linear terms to the objective function, typically the risk aversion coefficients, can improve the model calibration. There are however, often an insufficient number of independent non-linear terms that can be added to accurately calibrate the model (Howitt, 1995a, b, 2005a). The ability to calibrate the model with complete accuracy depends on the number of non-linear terms that can be independently added. Thus, by introducing a sufficient number of non-linearity, PMP procedure calibrates the models exactly to the base year in terms of output, input use, objective values and dual values on model constraints (Howitt, 1995a).

Because non-linear terms in the supply side of the profit function are needed to calibrate a production model, the task of PMP is to define the simplest specification needed in an exact calibration. PMP uses the observed acreage allocations and outputs to infer marginal cost conditions for each observed crop allocation. This inference is based on those parameters that are accurately observed, and the usual profit-maximising and concavity assumptions of standard micro-economic theory.

Given certain commodity prices, the modelled optimal activity level may exceed (or be less than) the observed level in the base year. At the observed level of production it turns out that according to the profit maximisation hypothesis – a portion of the production costs is not covered by the model. These costs can be recovered exactly using the PMP approach. One may use for example, a quadratic cost function of the form:

$$C = \alpha x + 0.5\beta x^2 \qquad 3.3$$

where C is the non-linear part of the total production functions, x is the production activity level and α and β are parameters, in the calibration procedure. The first derivative of this function is

$$\frac{\delta C}{\delta x} = \alpha + \beta x \qquad 3.4$$

This is at the point of the observed production level. Assuming that α is zero, parameter β is given by

$$\beta = \frac{\rho}{x^*} \qquad 3.5$$

where x* is the base year production activity level and ρ is the dual of calibration constraint. Parameter β can be subjected to econometric analysis to explain changes of the cost structure over space and time.

3.4.1 Calibration in PMP

PMP is a model calibrating and specifying approach (Howitt, 1995a, b). The standard PMP calibration approach according to Howitt (1995a,b) is implemented in three stages. The first stage is the construction of linear programming (LP) models with calibration constraints using all the available information to derive a vector of shadow prices, λ of the limiting allocable resources and the differential marginal cost vector, ρ of vector of realized resource allocation or output levels. The structure of the constrained LP is of the form:

$$\text{Maximize } \pi = Px - cx \qquad 3.6$$

Subject to: $Ax \leq b$ $[\lambda]$ (structural constraints) 3.7

$x + \varepsilon \leq x^*$ $[\rho]$ (calibration constraints) 3.8

$x \geq 0$ (non-negativity assumption) 3.9

Where π is the objective function to be maximised over a vector of decision variables, x. P and c are MR and direct allocatable variable cost respectively. A is the matrix of technical coefficients involving limiting inputs levels. Parameter b is the vector of availability of limiting allocable inputs, and x* is the vector of observed activity levels. The vector of shadow prices, λ is associated with the allocable input of the structural constraints while the vector of differential marginal costs, ρ is associated with the calibration constraints. The parameter ε, epsilon is a small number used to calibrate the model. The primary intent of this stage is to obtain an accurate and consistent measure of the marginal cost (MC) associated with the vector of observed activity levels, x*. The MC vector is given by

$$MC = c + \rho \qquad 3.10$$

In state 2, the dual values, ρ is used to construct non-linear (NLP) programming models using a specification that is linear in the parameters that reproduce the base year solutions without calibration constraints. Parameter ρ is a measure of the value of the residual cost that is needed to calibrate the model to the observed activity level or resource use. The NLP model is often hypothesized to be a quadratic functional form in activity levels. The objective function, 3.6 becomes

$$Max \ \ \pi = px - \alpha x - 0.5\beta x' Qx \qquad 3.11$$

Where Q matrix is symmetric and positive semi-definite. The MC becomes

$$MC(x) = \rho - c = \alpha x + Qx^{*} \qquad 3.12$$

Stage 3 involves assembling an NLP model that uses the recovered variable function, which is capable of reproducing the primal and dual solutions of the first stage LP model without the calibration constraints. This model is then used to simulate the impact of agricultural policy changes. The system of equations 3.6 – 3.9 becomes:

$$Max \ \ \pi = px - \alpha x - 0.5\beta xQx \qquad 3.13$$

Subject to $Ax \leq b \quad [\lambda]$ (structural constraints) 3.14

$x \geq 0$ (non-negativity assumption) 3.15

The calibrating model exactly reproduces the base year activity levels i.e. the primal and dual solutions of the NLP model is exactly equal to the primal and dual solution of the constrained LP model (Paris and Arfini, 2000).

3.4.2 The shortcomings in PMP

The weakness of the PMP calibration approach is that the costs implied in the non-linear cost function cannot be explicitly attributed to specific production factors (Bauer and Kasnakoglu 1986). Consequently, the model does not contain the actual explanatory variables of the non-linear cost function. Thus, the derived non-linear costs function may be valid only temporarily. For this reason, it is not advisable to use the PMP approach in any long-term analysis. The calibrated model may however, yield quite a reasonable policy response in short-term analysis, if the actual cost factors affecting the non-linear cost function remain unchanged.

Also, one may test between different functional forms of the non-linear cost function. The second derivatives i.e. curvature properties, greatly affect the response behaviour of the model (Heckelei and Britz 1999). Different functional forms have different curvature properties, and the response to exogenous changes may depend crucially on the chosen functional form. The specification problem of non-linear cost function parameters becomes ill-posed (i.e. the number of parameters to be specified is greater than the number of observations).

Paris and Howitt (1998) propose a Maximum Entropy (ME) based method to estimate the parameters. ME estimation removes the need to decide on *a priori* restrictions on the parameters compared to the traditional econometric approach which allows different functional forms of the objective function. ME estimation also makes it possible to use more than one observation on activity levels in the specification of the parameters, thereby broadening the information base for the specification. Inclusion of more than one observation of each activity level and thus marginal costs (through first derivatives) creates an opportunity to infer curvature properties of the non-linear cost functions from the differences in marginal costs. However, in the dearth of data, if there is only one observation, the curvature properties are arbitrary and the model behaviour depends on the chosen function forms.

Heckelei and Britz (1999) have developed a method that uses a cross-sectional sample in order to derive changes in marginal cost based on observed differences between regions with different crop rotations. These differences in first derivatives comprise information about the second derivates, which are relevant for simulation analysis. Therefore, the PMP approach requires a careful specification of the model structure as well as of the input and output coefficients, otherwise all the errors in model structure or data are incorporated in the non-linear cost function (Bauer and Kasnakoglu 1986). In the actual analysis, the non-linear cost function is assumed to stay constant. Thus, in the case of inadequate specification of the model or data errors, the resulting response to exogenous changes will be misleading.

The PMP approach became very popular in country-specific agricultural sector modelling from the 1990s and has been applied even in relatively large European Union-wide models (Heckelei and Britz, 2000). This is because of the features of

PMP approach as discussed earlier. Basically, it is useful in overcoming the problems of structural model specification and validation.

One main critique of PMP calibration approach is that adding calibration constraints to LP models in the standard PMP approach is an *ad hoc* mechanism even though it has economic justification. This *ad hoc* mechanism is attributed to, among other problems, lack of enough information upon which the PMP simulation behaviour derives. This is because the PMP approach uses only one year's data (Heckelei, 1997, 2002). Heckelei (2002) pointed out that one-year observation data does not give information on the second order properties of the objective function.

The argument is that changes in economic incentives and the resulting behaviour need to come from observed behaviour in the form of other exogenous information on technology or behavioural response as reflected in changes in activities levels before the parameters estimated for simulation could be valid. The standard PMP approach results lead to underdetermined parameter specification problems by generating NLP models to specify marginal behaviour from average behaviour (using only one observation data). The most appealing method would have been to use a sufficient number of observations to derive marginal behaviour (Paris and Howitt, 1998). However, the problems of lack of data persist not only in developing countries but also in developed countries. Moreover, the PMP approach is designed to use only one-year data (Howitt, 2005).

However, efforts have been put into proffering solutions to this shortcoming. For example, there are three approaches to overcoming the underdetermining of the parameters in the PMP framework, namely, an *ad hoc* procedure with some parameter set *a priori* (Howitt, 1995a); the use of supply elasticity from econometric studies and the use of Maximum Entropy (ME) criterion (Paris and Howitt, 1998; Heckelei and Britz 2003; Heckelei, 2002).

Heckelei (2002) and Heckelei and Britz (2003) proposed that because of the lack of sufficient observation, which may necessitate the use of the PMP approach, the use of PMP approach should be limited to the calibration method and that the one-year base data should be combined with the exogenous information, specifically supply elasticity. This is a means of incorporating necessary econometric criteria into the PMP approach. In spite of these shortcomings, the increasing popular use of the PMP approach to calibrating aggregate agricultural supply programming models stems from its strengths.

3.4.3 The strength of PMP calibration approach

The popular and increasing use of PMP is evidenced in more than 40 published PMP models at farm, region and sector levels. This is because of its strengths (Howitt, 2005b). It allows the use of minimal data sets, among other benefits. The approach calibrates programming models to observed activity levels; it also gives a more realistic smooth aggregate supply response function when compared to the traditional linear approaches. The PMP approach uses the dual values of the calibration constraints in stage 1 to capture potentially incorrect specification of technology in marginal models, data errors, aggregation bias, representation of risk behaviour, price expectations, non-linear constrains, etc.

Also, there are a number of approaches to calibrating PMP models. There is the cost-based approach where non-linear costs and constant yields are assumed to calibrate the models. In addition, there is the supply-based approach where non-linear supply and constant costs are assumed. The third approach assumes that both costs and supply are non-linear (Howitt, 2005a). The other approach is to add risk terms as non-linear terms to the model. The principle is to add the appropriate non-linear terms of the model to capture the plausible marginal behaviour of the farmers.

The PMP approach is used to overcome validation problems of optimisation models as well as excessive specialization in activity levels. While linear or non-linear sector models with few non-linear relationships usually produce drastic and discontinuous responses, the PMP models yield smooth responses to exogenous changes (Howitt 1995a; Gohin 2000). A number of studies have used one or a combination of these methods.

3.5 Empirical models and their applications

This section gives a brief review of empirical programming models and their applications. Most of the PMP based studies report responses from farmers in the form of changes in area grown to crops, cropping patterns, demand for farm labour and other farm resources, environmental conservation, etc. with respect to various policy variables such as prices, transfer payments, government intervention, new market environment, etc. Results from these studies often necessitated policy reform to achieve specific economic and political objectives such as food security, rural development, farm industry restructuring, etc. For instance, the European member states often fine-tune their Common Agricultural Policy (CAP) instruments according to their specific policy goals (Judez, Chaya, Martinex and Gonzalez, 2001; Schmid and Sinabel, 2003). Also, Agriculture and Agri-Food Canada (1998) uses the Canadian Regional Agricultural Model (CRAM) to analyse the 1985 U.S. Food Security Act, direct government programs, Canada-US Trade Agreement, Multilateral Trade Negotiations, Western Grain Transportation Act, etc. (Agriculture and Agri-Food Canada, 1998). Specific empirical studies are discussed in the paragraphs that follow.

Barkaoui, Batault and Rousselle (2000) analysed the impact of the 1999 Berlin Agreement on the cereals and oilseeds supply in European countries. They simulated the Europeans field crops supply. The agreement involves a drop in the cereal intervention price and suppression of subsidies between cereals and oilseeds and the establishment of non-specific area payment. They used the mathematical programming modelling approach. However, in their analyses they modified the standard PMP propositions. They used Farm Accounting Data on 60,000 farms. They developed a model for each of the 36 regions using simple Cobb-Douglass yield functions with integrated endogenous prices and technical progress. The functions determine the yield for each activity. The parameters are corrected according to the observed cost and the results of the yield function. Barkaoui *et al.* (2000) kept yield constant and assumed the variable cost is a function of the acreage harvested. They introduced technical progress, which is not often included in the short-term model. Their simulation indicates that the 1993 CAP reforms could make farmers maintain constant yield and adapt the variable inputs. Their results show that farmers maximise gross margin by maximising margin per hectare for each production activity and optimised crop allocation. Their results also indicate that the European models project a potential 21% increase in cereals land allocation with a 16% decrease in oilseeds land. This is expected to have a considerable impact on the food balance sheets among the member states. The results call for setting the price for cereals below or close to the world market price otherwise subsidies will be needed for export production to occur.

Paris and Arfini (2000) incorporated price risk into the PMP models for Italian agriculture assuming that each farmer considers price considerably different from year to year based on their risk aversion. The analysis involves extending the Paris and Howitt (1998) methodology to the perceived poor Italian Network Farm Account Data to estimate a cost function for a sample of homogenous farms. They state that most of the data available for research have poor statistical properties and the decision is whether to discard the data altogether or to make the best use of such data despite the poor quality. They used least squared and maximum entropy (ME) methods to specify the PMP model in order to exploit incomplete information contained in the Italian Network Farm Accounting Data. They constructed a typical farm by using technical, income level and environment criteria even though not every farm within a farm type cultivates every crop within a typology.

The assumption is that a farm within each farm type could produce every crop within a farm type but not for reasons of preference. This is termed the self-selection rule that characterises every farm sampling. This is important in fitting cost function for this farm type. The other characteristic of such a cost function is that it should be frontier cost function with respect to every farm in the farm type. The ME method gives a more stable crops substitution and response effects. The results suggest that farmers may have the ability to maintain the current level of net revenue in spite of substantial reduction in prices because of increase in the compensation for some crops.

Judez and Miguel (2000) simulate the effect of CAP of the EU between 1993/94 to 2006/07 on the representative farms in Navarra. They compare results of the models with a different base year on the areas grown to some important crops under the most important types of farming. They used the PMP modelling approach to develop models of the Comarca III of the Navarra agricultural sector by estimating representative farmers with principal component analysis. They used data on their crop yields, family aid, hired labour and variable costs. Their results suggest that the measures of Agenda 2000 would only increase the gross margin of farmers because of the increase in compensatory payments for crops, except for sunflower. The Agenda 2000 measures would not change land distribution for crops among small farms. The farmers would substitute cereal for sunflower. However, the difference between the simulated results of different base years is very little and the base year chosen was not considered a threat to the simulation results.

Schmid and Sinabell (2003) estimated the farm labour demand and producer surplus in response to the complete and partial adjustment to CAP reform 2003. CAP Reform 2003 involved decoupling direct transfer payment from production. They used model simulation of the type PMP models with linear approximation technique to mimic the non-linear PMP approach. They estimated the producer surplus and labour demand. They compared the results of the three different scenarios to a reference situation and computed percentage deviation.

The model indicates that at complete implementation, the reform will reduce demand for labour by 2% until 2005 relative to the reference scenario. Farm output volume will decline by 10% for beef but insignificantly for other crops. Variable cost will reduce for both livestock and crop production. Hectares of arable land will decrease by 4% and crop output is expected to decrease by the same proportion (4%). This shows a shift in the production pattern and resource use from labour intensive to relatively extensive production. However, at partial level, there will be only a marginal effect on farm income. There will be slight increase of 1% in arable crops. The decline in beef production will be minimised to 8%. There is further decrease in variable costs and the effect on labour demand is relatively low, 1%. The conclusion was that adjusting CAP reform will slightly reduce agricultural employment, have only a minor positive effect on aggregate farm income and lead to less intensive farming practice that will reduce crop and beef outputs. The authors quantified the trade-offs (in the Austrian agricultural sector) in adjusting and fine-tuning the CAP reform in accordance with their specific policy goal.

Since the CAP reform allows member states considerably leeway to design their own CAP version that will meet their own version of agricultural policy. Therefore, the European member states fine-tune the CAP instruments according to their specific policy goals even at some cost for example, there is trade-off between aggregate farm income and farm employment. Thus, the study recommends adjustment strategies such as minimum prices, direct production incentives, direct payment, extensification premium, additional premium, etc. Furthermore, farmers were always encouraged and protected through adjustment with measures such as incentives to enhance production decision, rural development programmes, technical improvement, credit and finance facilities in kind, stabilising agricultural income, guiding agricultural production towards consumer interest, i.e. local consumption pattern and changes in quality of farm products, making the production process more environmentally friendly and responding to animal welfare, modifying market regimes and special assistance.

Hennessy and Breen (2003) assessed the Mid-Term Review (MTR) of the Luxemburg Agreement on farm activity and income in Ireland. They projected the likely farm-level adjustment to the trade policy changes and estimated the farm-level effects of policy changes, i.e. estimated the effect of projected prices, costs and policy changes on the profitability of the various enterprises in a static sense. They used linear programming (LP) to calibrate the maximum profit to farms post-adjustment (decoupling). They used econometric models to estimate labour allocation. They used data on input and output prices following the policy changes by the dynamic PE model of the agricultural sector. They used budgetary modelling at farm-levels. They then simulated the farmers' response to the changing profitability to show the labour allocation between agriculture and other employment, exit from dairy production, switches in farm enterprise specialisation and the decision to become a 'sofa farmer'.

Their results show that the quantity projected in the scenarios is much higher due to the decreasing profitability of dairy farming. At base line, about 2% of dairy farmers were projected to exit per year; about 35% were projected to exit following the adjustment. This decrease in farm numbers results in increasing the average quota per farm by the year 2012. Furthermore, more farmers are likely to work off-farm as the returns to farm labour decline considerably in scenarios. The proportion of part-time cattle farmers is projected to increase to 60%, about ten more than at base line. There is deterioration in returns to farm labour relative to off-farm labour. A complete shift to part-time cattle farming will occur because of the farmers' age structure. With the Luxemburg Agreement, farmers' income decrease than what it is in base period.

Judez, Martinez, Chaya, de Miguel and Miguel (1998) studied the effects of the Common Market Organisation (CMO) for wine and the measures envisaged in Agenda 2000 for arable crops on a representative farm in Castilla la Mancha. They analysed the possible short- and long-run effects of certain agricultural policies under the CMO reform for cereals, oilseeds, and protein crops and wine on the decision of the representative farm. They used PMP techniques of multi-period models with a quadratic specification of the variable cost function. They reported that a reduction in the area under vine results from the implementation of the reforms because of economic profitability. While other crops changed slightly, there was an increase in land allocated to cereal, especially barley, and a reduction in land grown to oleaginous crops as a result of CMO measures.

Drynan, Perich, Betterhan and Whelan (1994) examined the effect of alternative policies and price changes on the production of milk in New South Wales. They examined long-term changes in the industry structure. They used sub-regional programming models of spatial equilibrium linear activity analysis. The model was based on farm-level activities of representative farms. They divided New South Wales into four regions. They used production costs and production patterns to divide each region into three farm types using data from the 1984/85 and 1985/1986 dairy industry surveys. The first farm type are quota farms producing a high proportion of marketed milk, producing a low proportion of manufactured milk, incurring high feed cost and high total cost. The farm type 2 exhibits a seasonal pattern of output producing more milk in the winter months than the other farms and having a comparative advantage in the production of winter milk. Farm type 3 has a strong seasonal pattern of production with less milk in winter and more in late spring, summer and early autumn.

The model was developed to indicate changes that could occur in the industry in the long-term. The model also covers a calendar year and was divided into four time-periods to capture the effects of seasonality. The programming modelling approach was used because past regional supply data were not readily available for econometric analysis. Furthermore, programming modelling was preferred because it is flexible enough to incorporate complex linkages between the supply response opportunities under alternative policies. Non-transferability of quotas leads to inefficiencies and high cost of production. External effects (increased competition from Victoria Free Trade in the industry between Australia and New Zealand) lead to reform in New South Wales. Subsequently they called for a less regulated industrial structure to increase the social welfare.

3.6 Knowledge gleaned from the literature review

Econometric and mathematical programming models are often used for policy evaluation. The latter often involves using programming models to analyse the economic behaviour of producers. Mathematical programming modelling is flexible enough to incorporate the complex linkages and a supply response opportunity under alternative polices. It enables the relatively simple manipulation of variables in order to determine how the system would behave in different situations.

Econometric models are data intensive while programming models are computationally intensive. However, because of the dearth of data and the wealth of physical structural data, policy models of resource use and agricultural production are often specified as programming models. Programming models are also favoured because time series data are not usually available on a disaggregated basis and the assumptions needed for cross-sectional analysis are not usually acceptable to policy makers with regional constituencies. Most mathematical models application started with the LP modelling approach.

However, LP modelling formulated to maximise a linear objective function subject to a set of linear constraints and limited to normative application is disadvantaged because it uses a corner and stepwise response until an optimal feasible solution is achieved. Positive Mathematical Programming (PMP) is a recent mathematical programming approach developed to obviate this limitation. It is used to solve the classic problem of mathematical programming. It involves calibrating LP or other variant models to actual behaviour by adding calibration constraints or risk terms. It involves maximising a non-linear objective function subject to a set of constraints by replacing base year data with non-erratic behaviour and few data are needed as compared to the econometric approach.

The processes of programming modelling include model specification, calibration and policy optimisation. Programming models are always by nature inherently short-run because of the resource constraints. However, long-run scenarios can be achieved if resource constraints are relaxed. Methodology to recover cost function of a given farm type must consider self-selection of crops with the farm type.

Criteria for model selection include data availability, a computational requirement. However, there is subjective trade-off between the realism of model specification or solution and the predictability of the models' data and computational requirements. The model must be simple enough for the policy-maker but must also be tractable and able to reproduce base year data. Also, research situation determines model selection and specification.

After choosing mathematical modelling approach, policy scenarios are tested by using realistic values for policy parameters or some other macroeconomic variables or technical parameters in the model. The models are solved for the policy and macro economic scenarios. A new set of cropping patterns, resource allocation and supply are obtained as potential effects of changes in policy variables, technical parameters or macroeconomic effects. The outcomes of base run and policy run are compared and conclusions are made on the possible effects of alternative agricultural policy, macro economic effects and other changes made on the basis of this comparison.

The farm-level or simple farm management model could be used to predict the response of individual farmers, which can be aggregated to regional and even national supply response. Essentially, these models involve a comparison of (expected) gross margins among the competing crops and a decision rule to change the cropping pattern by preferring the most profitable crop that is allowed by the agronomic constraints, assuming that the marginal cost is constant until the next resource constraint is binding. This approach is expected to yield a considerable true farm-level decision pattern and also provides plausible prediction. When aggregated over the region from the census of agriculture, it provides the secondary sector model with base values.

Results from the application of programming models often results in suggestions for general or specific policy reform and manipulation to achieve specific economic and political objectives. Evidence from developing Central American countries indicates that liberalising foreign trade and deregulating domestic markets is not associated with improved agricultural performance, as opposed to the frequent argument that trade liberalisation and deregulation of domestic markets in developing countries results in increased incentives for agriculture. This implies that trade liberalisation is not sufficient to stimulate agricultural exports. A nation could be more productive and thus wealthier by increasing the quantity of resource availability, discovering new technology, increasing division of labour and specialisation, improving the allocation of existing resources and increasing the rate of use of the existing resources.

CHAPTER 4

A MODEL OF RESOURCE USE AND OUTPUT SUPPLY RESPONSE FOR THE FREE STATE

4.1 Introduction

In this chapter, justification for the research method and modelling approach is discussed. Specifically, the choice of the PMP modelling approach is further justified. The risks in revenues and the farmers' risk attitude are estimated with Expected-Variance Risk analysis. The model is specified with risk and farmers' risk attitudes to improve the model's calibration and validation. Also, *a priori* supply response, estimated by other researchers who used econometric models, was used to specify the model's supply response behaviour. The model's features and characteristics are also explained. For farm typologies, the commercial large-scale farmers are broadly aggregated to a large farm type. The LRAD farms are again broadly aggregated to the small farm type. The detailed mathematical specification and calibration procedures are also discussed and presented.

4.2 Justification for the mathematical programming approach

Previous studies on South African agricultural supply response (Lubbe, 1992; Van Schalkwyk & Groenewald, 1993; Schimmelpfenning, Thirtle & Van Zyl, 1996; Abbott & Ahmed, 1999; Townsend, 1999; Meyer, 2003,2006) and resource use (Van Schalkwyk & Groenewald, 1992; Poonyth, Van Zyl, Vink & Kirsten, 2001) are not only few but also have used deterministic analysis with econometric models. These models are data intensive and forecasting from such studies may be difficult (Pindyck & Rubinfeld, 1991; Just, 1993). Estimates from such analyses usually have large variation across crops, regions, and time periods (Lamb & Diebold, 1996). This implies that policy recommendations from such models cannot be explicit because of other policy variables which may not be modelled in econometric analyses.

Some other studies, also few, have evaluated the impact of policy changes on South African agriculture in an *ex post* manner (Jooste, Aliber & Van Schalkwyk, 1998; Dushmanitch & Darrock, 1990). To bridge the gap in knowledge that programming analysis can fill, Britz, Jooste, Louw and du Plessis (2001) developed regionalised mathematical programming models for the South African livestock feed sub-sector. Oyewumi (2005) used a mathematical programming model to simulate the potential effects of tariff rate quota implementation on the South African livestock industry.

The choice of this methodology was based on, among other criteria, the criteria highlighted by McCarl (1992) for using a programming approach as opposed to an econometrical method. The criteria which justify the use of this methodology are as follow:

(i) there is not enough data on historical behaviour on which to extrapolate the actions or reactions motivated by the policy/market changes; and

(ii) it is obvious that the South African farm industry's objective of restructuring and the inherent profit-maximising behaviour of farmers will be constrained by farm-level resource constraints which the econometric approach cannot easily capture.

Another factor suggests the use of this approach. When there are significant differences in the structural characteristics of farms, especially the farm sizes as typified in the Free State farm industry, the PMP modelling framework is preferred to capture the differences in the farm structures. This helps to elicit the impacts of various farm characteristics on the adjustment to market and policy variables (De Frahan, Buysse, Polome and Van Huylenbroek, 2005).

This study therefore explores the advantages of the programming approach and tries as much as possible to minimise its negative consequences on the research outcomes. The methodology allows one to construct a synthetic representation of supply response based on an assumed objective and sets of constraints. The approach is a forward-looking analysis that supports the identification, prediction, prescription and comparison of alternative policy impacts on the production of primary products. This modelling approach is a programming approach that is a more normative in analysis;

however, it specifically explains and projects behaviours by using supply elasticity reported from econometric studies through calibration of the model. This approach is also necessary because behavioural functions, according to Heckekei (2005), cannot capture the bio-physical, market and political variables that bear on farmers' decision and behaviours.

4.3 The features and characteristics of the model

Taking yield as endogenous in response to the technology of production, regional aggregate farm income is a function of farming system or technology, (rain-fed or irrigated), number of farm units in each farm type, levels of resources used or production level of each agricultural production activity, efficiency level of farm units and yield risk. At farm level, the choice of the farming system (technology), activity level and combination of activity levels is considered as profit maximising choices for individual farm types given the farm-level resource limits and the risk of each production activity.

A static comparative partial equilibrium (PE) mathematical programming model that represents Free State regionalised farm-level resource use and output supply response (SAROS) is developed in this study for the analysis. The model represents the base level resource use and output supply given the revenue risk and resource constraints. The farm type's risk attitudes that allow the base activity levels is generated and incorporated into the model. The model is calibrated to the observed activity levels and *a priori* supply elasticity estimated by other researchers that used econometric models. The model has elements of both macro-economic and policy variables. This allows the application of the model to examine the potential and possible effects of changes in policy and macro economic variables. The unique characteristics of the model are explained in the sub-sections that follow.

4.3.1 Farm typology and aggregation

The main question in agricultural policy analysis with respect to the impact on farmers is what is a typical farm? In this study the question is what does a typical Free State farm unit look like? Historically and by a number of ramifications, and for one of the research questions (examining the effect of equity policy on efficiency), one can assume that there are two farm types. The farm types are the established commercial large-scale farm units herein aggregated at the regional level and called large farm type, and developing, LRAD, small-scale farm units, herein aggregated at regional level and called small farm type. The further question is what do typical large farm and typical small farm look like?

For the purpose of identifying 'typical' large farms, the number of farming units, as at the end of 2002, as reported in the NDA (2005) report of the 2002 census of commercial agriculture were used. These farm units were characterised by the level of farm resource endowments. A number of studies report that South African farmers differ in experience, technology, capital assets and market access (Burger, 1971; Callow, Van Zyl, Sartorius von Bach & Groenewald, 1991; Makhura, Goode & Coetzee, 1998; Swanepoel and Stroebel, 2004; Nel, Botha & Groenewald, 1998; Van Schalkwyk, Groenewald & Jooste, 2003; Makhura, Goode & Coetzee, 1998; Gouse, Pray, Kirsten and Schimmelpfennig, 2005; Tapela, 2005; Jordaan & Jooste 2003; Raney, 2006). Therefore, the typologies were based on the differences in technical production coefficients and coefficients of the objective functions (revenue, risk aversion, yield). Also, each of the farm types is weighted by a rough number of farm units in each farm type.

Large farms have a larger proportion of the agricultural land in the region. Small farms rely on government-assisted land acquisition. This tenure arrangement is viewed to have implications for the farmers' incentives and reaction to shocks/vagaries and harshness or government incentives or disincentives in the industry. Besides, these tenures have a tendency to affect access to other resources such as institutional credit facilities, irrigation water, etc. which directly or indirectly impact on their respective productivity (Hazell & Norton, 1986).

Also, there are not enough resources to gather data on the number of farm units engaged in each production activity, the principle of self-selection is adopted whereby each farm type is assumed to be engaged in production activities which were observed at the base level (Paris and Arfini, 2000). For example, large farms are typically engaged in all the activities considered, whereas small farms would not typically engage in some production activities e.g. soya beans, sorghum and sunflowers.

Therefore, a weighted average analysis was performed to estimate the data on farm resource endowment, production capacities, etc. with respect to these 2 policy-related farm types in the region. Therefore, a regional 'typical' farm type is the unit of analysis in this model, and each farm type has a number of farm units as this is another policy interest (to have a large share of the population represented in the farm industry). A weighted average analysis was performed with the large farm type having 8,531 units and 495 units for the small farm type. The characteristics of the two farm types are reported in Chapter 5.

The principle of self-selection (Paris and Arfini, 2000) was assumed such that farm units within the two farm types are homogenous from a technical, income-level, resource limits and institutional arrangement viewpoint. The assumption is that every farm unit in each farm type could have produced every crop in the given farm type but did not for reasons of preference. This is termed a self-selection process which is of a general occurrence in agriculture and common to most farm samples. Paris and Arfini (2000) argue that this assumption is necessary when estimating cost functions for a farm type. Therefore by self-selection, each farm unit and/or each farm type could engage in the production of a number of crops and animal products given the objective of profit maximisation. In a nutshell, SAROS is a 'typical' farm and 'typical' activity analysis model.

It is acknowledge that this typology is broad because it is arguable that each of the farm types have varying farm sizes, among other things, which could influence substantially, their level of resource use and output supply response. In addition, it is acknowledged that there are differences and peculiarities among the various agro-climatic zones within a region. It is possible that farm resources such as arable land, grassland, etc. are concentrated in different areas of the region. This implies that the assumed 'typical' regional farm type does not necessarily have access to the assumed pool of resources.

Statistical analysis such as principal components and the clustering analyses used by Judez and Miguel (2000) to come up with representative farms in Navarra could have been used. However, the constraint is that most data available are regional which cannot easily be disaggregated into homogenous production zones within the region. One could also be compelled to aggregate at regional level since in terms of the constitution, agricultural functions fall within the competence of provincial governments, i.e. agricultural functions are regionalised yet agriculture has national characteristics as an integrated section (NDA, 2004). Most policy measures are implemented at regional level. This conforms to one of the objectives of this study i.e. to analyse the possible effects of policy and market changes on regional farm resource use and output supply.

The differences in resource use and output yields between these farm types are subjectively based on reports from the literature which yet lack empirical estimates of such differences. However, it may suffice to limit this typology to large farm and small farm types for two reasons:

i. These are the major farm types at the centre of policy making in restructuring the South African economy and farm industry in particular. Thus, a typical farm type as a farm unit with its resource endowments given policies such as land reform and other wealth redistribution and economic reform strategies such as trade liberalisation and market deregulations is what is sought in this study.

ii. The resource endowment among farms typically categorises them into these two farm types. A number of distinct characteristics that could affect the magnitude of the policy effects on their production decision were categorically presented in chapter 2 of this thesis.

Therefore, the aggregation of farms at the regional level and typology into two farm types are justified because the coefficients of the objective function, the technical coefficient matrix and the proportionality of the right hand side vectors, i.e. resource endowment, are different (with insignificant exception). However, the aggregation and typology, though broad, satisfy the three sufficient conditions of Day (1963) for avoiding aggregation bias. The three conditions are (i) identity of the technical coefficient matrixes of the groups to be aggregated, (ii) proportionality of the coefficient of the objective function, and (iii) proportionality of the right hand side vectors i.e. resource endowment.

In a nutshell, South African farmers are grouped into two groups by level of technology, experience, efficiency level, level of capital assets, and operating capacity. This typology is self-classifying as the established commercial large-scale farmers (large farm) and the developing small-scale farmers (small farm).

4.3.2 Enterprise analysis approach

Crops and livestock production activities for which more consistent data were available are used in the modelling approach. It is assumed that the farm types compete for the same domestic and foreign markets. They have limited land and irrigation water at farm-level. The region also has limited casual farm labour supply. Crop interdependence is a phenomenon in economic theory whereby change in the price of a product affects the supply of a related crop. This is a problem to farmers as decision makers. The problem is that most often there is insufficient data in most developing countries, even South Africa, to estimate the elasticity between these crops (Hazell & Norton, 1986). This problem is addressed in this study by estimating the covariance of production revenues. Also, risk in each enterprise's revenue is incorporated, and this is expected to capture the substitution effects among the enterprises given their levels of risk.

Also, it is obvious from agricultural production practice that even some crop-specific enterprises yield more than one income-generating output. A good example is egg-layer production where the major output is considered to be eggs and culled hens as another income-generating product. This phenomenon was incorporated in this model. Beside the revenue from the major income-generating output of an enterprise, other income-generating outputs were considered as by-products and valued per activity unit (ha for crop production and animal for livestock production). The revenue from the by-products is added to the marginal revenue of each production activity.

4.3.3 Model constraints

The model features constraints due to resource availability and distribution; short-run asset fixity among the farm types; government intervention in the sector to redress the skewed distribution in the farm industry; and farmers' behavioural response to revenue risk. Fixed inputs in the model are farm land, irrigation water and regional casual labour. The land is differentiated by land quality namely dry land, irrigable land, and grazing land. These fixed inputs are valued by the opportunity costs or the rental values of the resources at regional level. At this stage, capital was not a constraint and hence assumed not binding in this model.

4.3.4 The market behaviour of farmers

From history, profitability has been the most widely used criterion in farm budgeting and planning as macro-economic and policy variables change; yet, liquidity or cash flow has become increasingly important in light of the financial crisis in agriculture. This implies that cash flow statues of production activities could give more information on farmers' response to cost increase. However, if profit is well defined, according to Van Blockland (2005), as what is left after paying all the operating expenses, depreciation, overhead, taxes, interest rate, etc. then profit is a good measure of a farm's financial performance.

The core of SAROS is an optimisation block of maximised total farm profits from agricultural production at farm types levels and aggregated to the regional level. Farm profit is defined as expected revenue minus direct allocatable variable cost, policy-related costs, and the cost of bearing risk. Farm profits and costs are differentiated by different farming systems (rain-fed and irrigated). The basic underlying assumption is that farmers' behaviour can be described by the maximisation of the profits from individual production activities. Profits are maximised simultaneously across the two farm types to take into account the relationship between market effects and farmers' behaviour. Simultaneous optimisations of farm profits assume an optimal allocation of agricultural inputs and outputs across farm types so that profit from agriculture at the regional level is maximised. This optimal allocation of inputs and outputs is achieved when marginal cost (MC) are greater than or equal to marginal revenue

(MR) from all agricultural production activities in the model. Therefore, the profit-maximising behaviour of the farmers depends on the prices, yield, marginal revenue elasticity of supply, yield, risk of each crop, risk attitudes of the farmers and resource constraints. The demand for agricultural commodities are assumed constant in this study.

4.3.5 Farming system

Crops in the model are specified such that it is produced through two types of farming activities (rain-fed and irrigated) with type- and region-specific input-output coefficients. Producers may switch between the different farming systems or technologies of crop production activities depending on relative costs and yield differences. Therefore, the model allows the practice that farm type and regional specific crop supply can be fulfilled through rain-fed and or irrigated crop production.

4.3.6 Inputs and outputs

In SAROS, agricultural inputs and outputs are linked to agricultural production activities through the input-output technical coefficients. In the region for each farm type, there are 6 arable cropping activities, mainly grains. Each cropping activity is categorised into rain-fed and irrigated crop productions so that 12 cropping and 6 livestock production activities are distinguished. Arable cropping activities include white maize, yellow maize, sorghum, soya beans, wheat and sunflower. Livestock activities include beef cattle, dairy cattle, mutton sheep, swine, chicken broilers and laying hens for egg production (Table 4.1). To easily manage this model, each of the production activities produces one specific crop or livestock output per activity. Some of the important commodities in the Free State are not included in this model because of lack of consistent data on such commodities. Also, where a production activity has more than one output, the major output is treated as the product while others are treated as by-products. The revenues on such by-products were valued on Rand per ha or animal basis and added to the main product's marginal revenue.

Table 4.1: Cropping and livestock activities and corresponding outputs (excluding by products)

Production activities	Outputs	Inputs
Crops:		
White maize	White maize grains	Seeds, fertilizers, herbicides, pesticides, fungicides, irrigation water, casual labour, contract on harvesting, contract on spraying chemicals, insurance, arable and irrigable land
Yellow maize	Yellow maize grains	
Sorghum	Sorghum grains	
Wheat	Wheat grains	
Soya beans	Soya beans grains	
Sunflower	Sunflower seed	
Livestock		
Beef-Cattle	Beef	Day old chicks, replacement animals, feed, vaccine and vitamins, sanitations, electricity, water, trays, gestation examination, shearing pasture, bedding materials, insurance and housing or building structure and grazing land
Dairy-Cattle	Fresh milk	
Pigs	Pork	
Mutton-Sheep	Mutton	
Broiler-chicken	Chicken	
Layer-chicken	eggs	

4.3.7 Model data

The model was developed to adjust for inflation and time-trend effects in the data used. The nominal time series on producer prices were adjusted for inflation by the producer price index for output at regional level to arrive at the real producer prices. The real producer prices were normalised to the base year period. The stochastic time series data on real marginal revenue for the output of each production activity were derived by multiplying each real price by the yield. Also, the model was coded to de-trend each of the series (real prices, yield and revenue) by fitting a linear time trend regression for each series. This renders the real prices, real cost, yield and marginal revenue to expected real and stationary values.

Marginal revenue for crop production activities equals yield (in ton/ha) times price (in R/ton). The marginal revenue for livestock production (beef cattle, mutton sheep, pork) equals the off-take rate (in %) times the animal slaughter weight (in ton) times the auction price (in R/ton). The marginal revenue for chicken broilers is 1 minus mortality rate times live weight times price. The marginal revenue for dairy milk is the annual volume of milk production per cow times the price per litre; the marginal revenue for laying eggs is 1 minus the mortality rate times the average number of eggs produced per year (230 eggs) times the price of eggs.

4.3.8 Model calibration and specification

Linear programming models have the tendency to overspecialise and consequently may not reproduce the observed activity levels. Overspecialisation results from the way standard LP's are defined. This situation is not realistic in nature because of technical difficulties and some other factors that may constrain producers from overspecialising. Overspecialisation could be avoided in many ways namely by adding more constraints to the models.

However, in aggregated models, the number of empirically justified restrictions that could be quantified and added is relatively small compared to the possible number of activities (Heckelei, 1997). Another problem with adding many constraints is that it may not make the model react smoothly to the exogenous disturbances. The calibration of SAROS with respect to regional/farm type production activities is such that the model's basic solutions reproduce almost exactly the observed 2004 farm type activity levels. The model is calibrated using the PMP approach (Howitt, 1995a, 1995b). To minimise or avoid the problem of parameter underestimation in standard PMP approach, risk and risk-averse attitudes of farmers were estimated and incorporated into the model. The model was also specified with *a prior* supply elasticity from econometric models by other researchers. Details of the mathematical specification and calibration of the model are presented in the section that follows.

4.3.9 The application of the model

In this study, the model is developed with macro and policy parameters and variables that may affect farm-level resource use and output supply. This allows the model to be useful in examining the potential effects of the possible implementation of some policy variables and possible changes in some macro-economic variables. Therefore, the model was applied to answer the research questions of the study.

4.4 Detailed mathematical presentation of the model

4.4.1 Incorporating risk into mathematical models

Overspecialisation problems may lead to another problem of overestimation of the value of fixed production factors like land, irrigation, water, etc. Examples of factors, among others, that often prevent overspecialisation in agricultural production include land quality, fixed production factors, risk attitude of farmers, etc. Early attempts to solve the problem of overspecialisation in mathematical programming include, among others, the imposition of upper and lower bounds on the decision variables. However, this approach may also restrict the response of the models to the policy variables. Another way of avoiding overspecialisation is to incorporate the non-linear terms, representing risk averse behaviours of the farmers, into the objective function (Hazell and Norton, 1986). However, the approach needs a formulation of the farmer's forecast expectation of yield, price or revenue and the risk averse attitude of the farmers. It is then assumed that farmers are maximising profit given the expected values of marginal revenue and variances of the revenues. The problem remains how to know and use the appropriate expectation models of the farmers because different price, yield or revenue expectation specifications lead to different equilibriums and model behaviour (Hazel and Norton, 1986).

Another difficulty is the estimation of the risk aversion coefficients of farmers, especially in price exogenous models with quadratic objective function. Ideally, risk aversion parameters should be formed as suitable aggregates. The solution has always been the use of risk aversion coefficients that give the best fit to the base year data. This however has shortcomings because the base year cropping pattern may not correspond to economic equilibrium, therefore the risk aversion parameters may become biased. This in turn creates substantial biased responses to exogenous changes since the risk aversion coefficients are kept unchanged when solving the policy scenarios. Another approach is to construct the base year data with at least a 2-year average of cropping patterns especially where prices are volatile. This will enable the use of risk-adjusted sector models.

In this study, risk is incorporated into the mathematical programming model with the assumption that the probability distribution of the risk parameter is known with certainty (McCarl and Spreen, 2004). This involves representing the distribution of the risk parameter and the response of the decision-maker in the form of a risk aversion parameter. A conservative way of modelling risk is to deflate the objective function revenue coefficients and inflate the cost coefficients. Expected-Variance (E-V) risk analysis is one of the techniques used to incorporate risk and risk attitude into the mathematical modelling framework.

4.4.1.1 Expected-Variance (E-V) risk Analysis

It is envisaged that a number of factors cause price, yield or marginal revenue risks. In any industry it is possible that changes in agricultural policy could result in changes in output prices, especially when the policy exposes the producers to external forces of demand and supply, coupled with import and export shocks. The current market reform and trade liberalisation in South Africa could impact significantly on the expected prices which, in turn, could impact on supply and again, on expected prices in such a cycle. Therefore, there could be variations in expected revenue from year to year.

In this study, the expected revenues and variances in revenues were estimated from past yields and output price data. The data used are time series data from 1994 to 2004. The data on prices obtainable are at current prices; therefore they were adjusted for inflation before the revenues were calculated from yield and real prices. This gives real revenues of the production outputs.

4.4.1.2 Probability distribution of yield, price and marginal revenues

Although little or nothing is known about how yield, price and revenue expectations are formed amongst farmers at farm level, it is acknowledged that a simple de-trending procedure might be too simple to describe the farmers' expectations about risk in those variables. However, time-budget constraints led one to this assumption, as is often the case with a number of modelling analyses such as these (Heckelei and Britz, 1998; McCarl 1996; Zen *et. al.,* 2003).

According to McCarl (1996) and Sprot (2004), the most common way of forming a probability distribution from a set of non-stationary data is to use a regression analysis to remove the systematic trends in the series. The residuals from regression may then be used to form the probability distribution of such series. Such data may then be extrapolated to the time period of interest. This procedure is necessary because weather and other phenomena fluctuate in time and so also the crop yields, animal off-take rates, mortality rates, and output prices. It was postulated that some of these fluctuations may be as a result of deterministic randomness (Sprot, 2004). If such randomness is examined, then it may be possible to improve short-term predictability and enhance the understanding of the system in question.

Therefore, in this study it is assumed that farmers base their expectations on the distribution of past revenue i.e. their activity levels are derived from prices, yields and marginal revenue expectations. Additionally, in handling the data it is acknowledged that time series on prices and yields may not be stationary due to trends inherent in the series. While Hazell and Norton (1986) suggest that each series of yield and price should be de-trended separately, McCarl (1996) points out that this approach assumes that the yield and price are independent. There are justifications for both views. The bottom line is that merely because 2 series are trending together, one cannot assume that the relation is causal. Often, both series will be trending because of other unobservable factors. When such factors are unobservable, one can control for the trend by directly de-trending the series by using linear, exponential or quadratic models.

However, the opinion is that given the market mechanism, aggregate yield and real price are dependent. The real revenue was then calculated from the multiplication of real prices by yield to arrive at real revenue. SAROS was coded to fit linear regression functions for each price, yield and marginal revenue over the time period to control for the time trends in the series. It also calculates the deviation (risk) in prices, yields and marginal revenues for each production activity as the difference between observed prices, yields and marginal revenues and that calculated by the linear regression for prices, yields and marginal revenues, respectively. The absolute deviations in prices, yields and marginal revenues in relation to the simple linear regression of prices, yields and marginal revenues over time are formulated as:

$$D\_Price_{p_t} = o\_Price_{p_t} - (\kappa_p + \sigma_p T) \quad 4.1$$

$$D\_Yield_{p_t} = o\_Yield_{p_t} - (\kappa_p + \sigma_p T) \quad 4.2$$

$$D\_Reve_{p_t} = o\_Rev_{p_t} - (\kappa_p + \sigma_p T) \quad 4.3$$

where D_Price is the deviation of observed output prices from the expected output prices in year t for product p. D_Yield is the deviation of observed yields from the expected yields. D_Rev is the deviation of observed marginal revenues from the expected marginal revenues. O_Price is the observed output prices. O_Yield is the observed yields. O_Rev is the observed marginal revenues. Parameters κ and σ are the intercept and slope respectively, of the regressions. Variable T is the time in years. The de-trended real revenue was arrived at by adding the residual from the trend regression to the trend values for the pivot year (2005), so that de-trended series are given by:

$$de\_Price_{p_t} = \kappa_p + \sigma_p T_{2005} + D\_Price_{p_t} \quad 4.4$$

$$de\_Yield_{p_t} = \kappa_p + \sigma_p T_{2005} + D\_Yield_{p_t} \quad 4.5$$

$$de\_Rev_{p_t} = \kappa_p + \sigma_p T_{2005} + D\_Rev_{p_t} \quad 4.6$$

where de_Price is the de-trended, normalised series of prices in year t. Variable de_Yield is the de-trended, normalised series of yield in year t. Variable de_Rev is the de-trended, normalised series of marginal revenue in year t. These equations were used to extrapolate the years 1994 to 2004 to arrive at de-trended, normalised series.

The time series of the de-trended values of the activity output yields, real prices and real revenues were used to formulate the expected values of the series and a matrix of variance and co-variance of output revenues. The equations are presented as follow:

$$E(Price_p) = \frac{1}{n}\sum_n de\_Price_{p_t} \quad 4.7$$

$$E(Yield_p) = \frac{1}{n}\sum_n de\_Yield_{p_t} \quad 4.8$$

$$E(\mathrm{Re}v_p) \quad = \quad \frac{1}{n}\sum_{n} de\_\mathrm{Re}v_{p_t} \qquad 4.9$$

$$Cov(\mathrm{Re}v_{p^{'}p}) = \frac{1}{n}\sum_{t}\Big((d\_\mathrm{Re}v_{p^{'}_t} - E(\mathrm{Re}v_{p^{'}}))\cdot(d\_\mathrm{Re}v_{p_t} - E(\mathrm{Re}v_p))\Big) \qquad 4.10$$

Where n is 1, 2, …, t. $E(Price_p)$ is the expected value of price; $E(Yield_p)$ is the expected value of Yield; $E(Rev_p)$ is the expected value of marginal revenue for production activity p. Variable $Cov(Rev_{p'p})$ represents the matrix of variance and covariance of the activity marginal revenues. The expected prices and marginal revenues were used in the model at regional level because there were not enough data to identify the differences in prices received by the farm types. However, the enterprise budgets and agricultural information database show the yield difference at farm type level. Therefore, the regional expected yields and revenues were adjusted to farm type level yields by a factor as already used in the construction of enterprise budgets at farm type levels. Subsequently, the expected prices, yields and marginal revenues and variance and covariance matrix of the marginal revenues were incorporated into the relevant equations of the model.

4.4.2 Model calibration – PMP approach

SAROS is calibrated to observed activity levels in the base year using the PMP approach (Howitt, 1995a, 1995b). The PMP approach calibrates the model in three stages. In the first stage, the cost functions in the objective function are represented as linear cost functions. Also, activity levels are constrained to observed activity levels by adding calibration constraints. In the second stage, the parameters of the marginal cost functions are derived so that they are partly based on the duals of the calibration constraints. In the third stage, the linear cost functions are replaced by the quadratic cost functions. These stages are implemented in this study. The stages are presented in the succeeding sections.

4.4.2.1 Stage 1 of the PMP calibration approach

In the first stage, the cost functions in the objective function are represented as linear cost functions. The activity levels are constrained to observed activity levels by adding calibration constraints with other (resource) constraints. The objective function of the calibration constrained linear programming (LP) model is written as follows:

$$\begin{aligned} \textit{Maximise} \quad \Pi = & \sum_f \sum_t \sum_c E(\mathrm{Re}\,v_{ftc}) X_{ftc} - \sum_f \sum_t \sum_j \sum_c c_{jc} \omega_{ftjc} X_{ftc} \\ & + \sum_f \sum_s E(\mathrm{Re}\,v_{fs}) X_{fs} - \sum_f \sum_j \sum_s c_{js} \omega_{fjs} X_{fs} \\ & + \sum_f (b_{f_{land}} - \sum_p \omega_{land} X_{f_{land}}) \cdot k_{land} \cdot tc \end{aligned} \qquad 4.11$$

Subject to the constraints represented in equations 4.12 to 4.25.

Where the indices f, t, c, l, j, … represent sets.

Π = regional farm income (Free State as a case study),

f = vector of farm types (commercial and developing farm types)

t = vector of technologies (rain-fed land and irrigated)

p = vector of production activities

c = vector of crop activities; c is a subset of p

s = vector of livestock activities; s is a subset of p

j = vector of variable inputs

l = vector of land qualities (which is a set of arable land, grazing land, dry non-irrigable land and irrigable land)

X_{ftc} = matrix of level of crop activities under technology t by farm type f in the region (ha)

X_{fs} = matrix of level of livestock activities by farm type f in the region (number)

b_{fland} = amount of farm land available under each farm type f (ha)

k_{land} = average land rent by quality in the region (R/ha)

tc = transaction cost of land rent (%)

ω_{land} = land requirement (1 for cropping activities) and carrying capacity of grazing land for livestock activity s in the region (ha/head).

The first expression in the first line of equation 4.11 represents the revenue less the total direct costs of crop production activities. The choice of farming system (rain-fed and irrigation cropping) per activity level is determined endogenously within the model. The second expression in the second line of equation 4.11 represents the revenue less the total direct costs of livestock production activities.

The area of land that is not used for production activities is determined endogenously. It is modelled in such a way that the area not used in production activities is affected not only by the prices of activity products, but also the possible marginal revenue of renting out such land. Therefore, line three of equation 4.11 gives the possible revenue from land that is not used in production activities but could be rented-out. This assumption is to capture the likely impact of the levying of agricultural land tax. It is defined as the amount of total land under each farm type, less the land used for production (crop and livestock) multiplied by agricultural land rent, and multiplied by the transaction cost factor in the land rental market.

The values of the total cost are different at different technology levels for each farm type in each region. Furthermore, the yield and subsequently the revenue per activity level is different at technology and farm type level which accounts for the possible differences in the management capability and the farm sizes among the farm types in the regions.

Where $E(Rev_{ftp})$ is the expected revenue from production activities, p (p = 1, 2, …) by a farm type f, using technology t. The production activity p is categorised into cropping activities c and livestock activity s. The categorisation is necessary to capture the two possible dimensions of cropping activities (rain-fed and irrigated). This is necessary to evaluate the use and demand for irrigation resources (irrigable land and irrigation water) in the production of a particular field crop. $E(Rev_{fl})$ is the expected revenues (R/head) from livestock products, s by farm type f in the region.

The variable c_{jc} is defined as the unit cost of input j for production activity p in the region. The variables a_{ftjc} and a_{fl} are defined as inputs j per cropping activity c under farm type f by technology t in the region and input j per livestock activity s under farm type f in the region, respectively. The objective function of the calibration constrained LP model 4.11 describes variable costs as the linear function of prices and quantities. The second terms in each of the first two expressions were expressed as linear variable cost functions.

Maximising the objective function 4.11 is subject to non-negativity constraints, calibration constraints and resource constraints. The farm resource balances (arable land, irrigable land, grazing land and the irrigation water quota) are defined and explained below:

Fixed inputs at regional level

Fixed inputs included in SAROS are arable land differentiated into an irrigable portion and a non-irrigable portion, the grazing land, the irrigation water quota (the irrigation water quota is fixed on an annual basis) and hours of casual labour in the region.

To capture the distribution of land quality in each region and by each farm type, the fixed inputs constraints were specified in the following way. The constraints on farm resources include a block of 6 equations as follow:

i. maximum arable land available (rain-fed and irrigated cropping);
ii. maximum irrigable land available for irrigated cropping;
iii. maximum irrigation water available;
iv. maximum grazing land available;
v. maximum farmland available for cropping and grazing; and
vi. maximum hours of casual labour.

Maximum arable land

$$n_f \sum_f \sum_t \sum_c X_{ftc} \leq b_a \qquad \text{for all a} \qquad [\lambda_{ba}] \qquad 4.12$$

Where n_{rf} is the number of farm units in each farm type. Parameter b_{ra} is the arable land constraint in the region. This is to limit the area grown with crops on rain-fed and the area grown with irrigated cropping to the total arable land in the region. The parameter b_{ra} is the total amount of arable land available in the region. The variable λ_{bra} represents the shadow value of arable land at regional level.

Maximum irrigable land

$$n_f \sum_f \sum_c X_{ft1c} \leq b_i \qquad \text{for all i} \qquad [\lambda_{bi}] \qquad 4.13$$

The equation 4.13 is a subset of equation 4.2. It accounts for the irrigable land constraint so that the level of irrigated cropping does not exceed the portion of irrigable land available. The variable b_r is the regional level of irrigable land available. The variable λ_{bi} is the shadow value of irrigable land at regional level.

Maximum irrigation water

$$n_f \sum_f \sum_c \omega_{ftc} X_{ftc} \leq b_w \qquad \text{for all f, t} \qquad [\lambda_{bw}] \qquad 4.14$$

The equation 4.14 represents the regional irrigation water constraint. It ensures that irrigation water use at regional level is less than, or equal to, the regional irrigation water availability regardless of the amount of irrigable land. The parameter ω_{ftc} is the crop-water requirement per ha of cropping activities under the farm type in each region. The variable is not differentiated by farm type because all farm types are expected to follow the crop-water agronomic requirement. The variable λ_{bw} is the shadow price of irrigation water at regional level.

Maximum grazing land

$$n_f \sum_f \sum_l \omega_{fl} X_{fl} \leq b_g \qquad \text{for all f,l} \qquad [\lambda_{bg}] \qquad 4.15$$

Equation 4.15 represents the constraints of grazing land at regional level. It ensures that the grazing activities (live stocking) do not exceed the level of grazing land available. The parameter ω_{fl} is the grassland carrying capacity for animals. The variable b_g is the grazing land constraints. The variable λ_{bg} is the shadow price of grazing land at regional level.

Maximum farm land

$$n_f (\sum_f \sum_t \sum_c X_{ftc} + \sum_f \sum_s a_{fs} X_{fs}) \leq b_l \qquad \text{for all l} \qquad [\lambda_{bl}] \qquad 4.16$$

Equation 4.16 is the combination of the total land (arable and grazing) in the region. It represents the constraint that total cropping and livestock activity levels do not exceed the total farm land available in the region. The variable b_l is the total land constraint in the region. The variable λ_{bl} is the shadow price of farm land at regional level.

Maximum hours of casual labour

$$n_f \sum_f \sum_p \omega_{labour\,p} X_{fp} \leq b_{labour} \qquad \text{for all f, p} \qquad [\lambda_{blabour}] \qquad 4.17$$

Equation 4.17 represents the constraints of hours of casual labour at regional level. It ensures that the level of casual labour used in hours per annum does not exceed the level of hours of casual labour available. The parameter ω_{labour} is the labour requirement for production activities. The variable b_{labour} is the available hours of casual labour in the region. The variable $\lambda_{blabour}$ is the shadow price of casual labour at regional level. It is acknowledged that labour may flow in from other regions. However, this may not be a serious shortcoming in the model because, for the present use of the model, casual labour was not binding in any simulation.

Fixed inputs at farm type level

The farm size at farm type level is highly differentiated. Therefore, to capture the land resource limits at farm level, the same set of equations 4.12 to 4.16 is specified at the farm type level. The equations are identical to the ones at regional level. The versions of the constraints at farm type level on fixed inputs are as follow:

Maximum arable land

$$\sum_t \sum_c X_{ftc} \leq b_{fa} \qquad \text{for all f, c} \qquad [\lambda_{brfa}] \qquad 4.18$$

The variable b_{fa} is the arable land constraints to farm type f in the region.

Maximum irrigable land

$$\sum_{c} X_{ftc} \leq b_{fi} \qquad \text{for all p} \qquad [\lambda_{bft}] \qquad 4.19$$

Equation 4.19 is a subset of equation 4.18. It accounts for the irrigable land constraint so that the level of irrigated cropping does not exceed the portion of irrigable land available. The variable b_{bf} is the farm type level of irrigable land available. The variable λ_{bf} is the shadow price of irrigable land at farm type level.

Maximum irrigation water

$$\sum_{c} a_{ft1c} X_{ft1c} \leq b_{fw} \qquad \text{for all f, t, p} \qquad [\lambda_{bftw}] \qquad 4.20$$

Equation 4.20 represents the irrigation water quota constraint of irrigation water use at farm type level, which demonstrates that the levels of irrigation water use are less than, or equal, the farm type annual irrigation water quota, regardless of the amount of irrigable land. The parameter ω_{t1c} is the crop-water requirement per ha of cropping activities. The variable λ_{bftw} is the shadow price of irrigation water at farm type level.

Maximum grazing land

$$\sum_{s} a_{fs} X_{fs} \leq b_{fg} \qquad \text{for all f, s} \qquad [\lambda_{bfg}] \qquad 4.21$$

Equation 4.21 represents the constraints of grazing land at farm type level. It ensures that the total level of grazing activities (livestocking) does not exceed the level of grazing land available. The variable b_{fg} is the grazing land constraints. X_{fs} is the level of the number of animals, given the limited grazing land. The variable λ_{bfg} is the shadow price of grazing land at farm type level.

Maximum farm land

$$\sum_t \sum_c X_{ftc} + \sum_s a_{fs} X_{fs} \leq b_{fl} \qquad \text{for all f, p} \qquad [\lambda_{bf}] \qquad 4.22$$

Equation 4.22 is the combination of the total land (arable and grazing) limited to each farm type. It represents the constraint that total cropping and livestock activity levels do not exceed the total land available in the farm type. The variable λ_{bf} is the shadow price of land at farm type level.

Non-negativity assumptions

$$X_{ftc.}, X_{fs} \geq 0 \qquad 4.23$$

Equation 4.23 satisfies the non-negative assumptions that no negative activity level is observed.

The calibration constraints

$$X_{ftc} \leq X^*_{ftc} + \varepsilon \qquad \text{for all f, t, c} \qquad [\lambda_{ftc}] \qquad 4.24$$

$$X_{fs} \leq X^*_{fs} + \varepsilon \qquad \text{for all f, s} \qquad [\lambda_{fs}] \qquad 4.25$$

The calibration constraints (equations 4.24 and 4.25) put upper limits on activity levels based on observed levels in the base period (X^*_{ftc}, X^*_{fs}) with very small numbers (0.0001), ε. The shadow prices of the calibration constraints, λ_{ftc} and λ_{fs} in the calibration equations 4.24 and 4.25 give the increase in the objective function if the constraints are less restrictive and the level of activities increase marginally.

The way constraints 4.24 and 4.25 are incorporated into the optimisation model is admittedly *ad hoc,* even though incorporating them has economic justification. The economic justification is to account for the realistic incidence of diversification in production planning. Diversification is a risk-minimising strategy. Incorporating the constraints makes the PMP approach ‘force’ the optimisation model to incorporate more activities and it does that if the data are consistent (Howitt, 1995a, 2005a).

In the second stage of the PMP calibration approach, the duals of the calibration constraints obtained in the first stage, were used to specify non-linear terms to replace the linear terms of the cost terms. Replacing the linear cost functions with non-linear cost functions will improve the model’s simulation behaviour if the model’s simulation behaviour remains linear. This implies that adding a non-linear term improves the calibration and simulation behaviour of optimisation models. Therefore, incorporating a risk term into the PMP model as a quadratic term based on expected utility function, will improve the model calibration and simulation behaviour.

4.4.2.2 Model calibration with risk terms

Risk analysis has a long-standing history in agricultural sector modelling (e.g. Hazell and Norton 1986). Agricultural production faces two main interlinked sources of risk, namely, yield risk, due to uncertainties of the production process (weather, diseases etc.) and market risk, due to price uncertainties which are partly related to yield risk. There are a number of techniques for risk analysis. MOTAD and E-V are most common. MOTAD may be preferred because it has few computation requirements. However, E-V has the advantage of more precise results, because it does not undergo the linearisation process (Zen *et. al.,* 2003). As Hazell and Norton (1986) suggest, the E-V risk analysis may be carried out by adding the covariance of the per-activity revenues weighted with the risk aversion attitudes of the decision makers.

Considering the risk-averse nature of farmers, the Hazell *et. al.,* (1983) techniques of modelling risk and risk attitude with E-V analysis were adopted. The variance and covariance of the revenue of each production activity weighted with the risk aversion parameter θ, are incorporated into the objective function. It is assumed that there is no risk in the cost. Therefore, the risk term represented by the $Cov(Rev_p)$ and the risk aversion attitudes were introduced into the objective function of A.11 and it becomes:

$$\begin{aligned}
\textit{Maximise} \quad \Pi = & \sum_f \sum_t \sum_c E(\mathrm{Re}\,v_{ftc}) X_{ftc} - \sum_f \sum_t \sum_j \sum_c c_{jc} \omega_{ftjc} X_{ftc} \\
& + \sum_f \sum_s E(\mathrm{Re}\,v_{fs}) X_{fs} - \sum_f \sum_j \sum_s c_{js} \omega_{fjs} X_{fs} \\
& + \sum_f (b_{f_{land}} - \sum_p \omega_{land} X_{f_{land}}) \cdot k_{land} \cdot tc \\
& - \sum_f (\theta_f (\sum_t X_{ftc} + X_{fs})' Cov_{rev_p} (\sum_t X_{ftc} + X_{fs}))
\end{aligned} \qquad 4.26$$

The restrictions are the same as in equations 4.13 to 4.25. According to Heckelei and Britz (1998), in order to integrate the model into a quadratic programming framework as was done in developing SAROS, the E-V term may be simply added to the objective function as in 4.26. Because the principal mathematical layout of an EV-Risk terms and a PMP approach with a quadratic objective function are identical, the integration of an E-V analysis into the objective function 4.11 becoming the objective function 4.26, is straightforward.

However, in using E-V risk analysis, the risk attitude of the decision makers should be quantified and incorporated into the quadratic term of the model. The risk aversion coefficient θ may be evaluated in micro applications in cooperation with decision makers. Its value is often used as an instrument of model calibration in macro-economic or aggregate models (Hazell and Norton, 1986). However, in recent times, the PMP approach offers a more straightforward way of calibration (Howitt, 1995, 2005a). Additionally, as for PMP, the introduction of a quadratic term in the objective function leads to a smoother response in the model in simulation runs.

However, incorporating the risk term into the PMP approach is to explore the possibility of an E-V Risk analysis contributing to the objective function in 4.26 in explaining the observed production activity levels and also in making the simulation of behaviour more realistic. One of the approaches to estimate θ according to McCarl and Spreen (2004) is to estimating θ so that the difference between the observed production plan and the model solution is minimised. This approach was used by Brink and McCarl (1979) and Hazell, Norton, Parthasarathy and Pomareda (1983). The approach involves estimating θ to have a minimum absolute deviation (MAD) from the observed production plan. The MAD is formulated as:

$$MAD = \frac{\sum_c \sum_t \left| X^*_{ftc} - X_{ftc} \right| + \left| X^*_{fs} - X_{fs} \right|}{\sum_c \sum_t + \sum_s} \qquad 4.27$$

where X* represent the base activity level and x is the optimum, model solution. However, this approach would be redundant in the PMP framework. This is because the PMP calibration constraints already yield MAD from the observed production plan. Therefore, there is a need to define another measure of improvement in the PMP model calibration, if the risk term is incorporated into such a model. Such measures should give an indication of the calibration that is caused by incorporating the risk term and the risk aversion parameters. Heckelei and Britz, (1998) suggest and used such a measure in the E-V risk analysis of German agriculture with the PMP calibration approach.

4.4.2.2.1 Measure of fit

In evaluating the effect of incorporating risk and risk attitudes into the PMP model as shown in 4.26, Heckelei and Britz (1998) demonstrate that this may be done by simulating over a range of θ and observing whether the duals of the calibration constraints are decreasing with the increasing level of θ, given the same set of constraints. Heckelei and Britz (1998) define the measure of improvement in the model calibration as the F value where F is given by:

$$F = \frac{\sum_p X^*_p \left| \lambda_p \right|}{\sum_p X^*_p c_p} \qquad 4.28$$

where p represents the activity levels in the model; F is a ratio of non-observed cost to the observed cost; X^* represents the base activity level. Parameter λ is the dual value of the calibrating constraint on activity p.

In order to incorporate risk aversion parameters, θ into the PMP framework, the model was re-formulated as a quadratic programming model of the form 4.26 above. The explanatory power of the PMP model with the θ was measured by using MAD and F measures combined. The quadratic programming model was solved using CONOPT3, a non-linear programming optimisation solver. Sensitivity analysis was performed to estimate optimal θ for each of the farm types. The θ were sequentially altered between runs over a range of reasonable θ until optimal θ that reproduced the base activity levels were obtained i.e. given MAD and decreasing F. The optimal θ slightly improved the model calibration.

For the commercial farm type, the initial MAD was 0.0352 and the value of F decreased from 1.2115 when θ was 0 to 1.1984 when θ was $3.0x10^{-7}$. Increasing θ above $3.0x10^{-7}$ resulted in an increase in MAD. Therefore, the optimal level of θ for the commercial farm type was estimated at $3.0x10^{-7}$. For the developing farm type, the initial MAD was 0.0004 and the value of F decreased from 0.7063 when θ was 0 to 0.6506 when θ was $2.0x10^{-5}$. Increasing θ above $2.0x10^{-5}$ led to an increase in MAD. Therefore, the estimated level of θ for the developing farm type is $2.0x10^{-5}$. These estimates were incorporated into the objective function 4.26 before proceeding to stage 2 of the PMP calibration approach.

4.4.2.3 Stage 2 of the PMP

In this stage, the general idea of the PMP is to use the PMP duals (λ_{ftc} and λ_{fs}) to specify non-linear cost functions. This specification method is one of the shortcomings of the PMP model calibration approach. The argument is that if the cost functions are specified in this way, the simulated price-supply response is not based on an empirical response. Different methods have been invented to overcome the parameter under-estimation in the PMP stage 2 (Heckelei and Britz, 2005). However, these methods are purely motivated by computational simplicity in the absence of data. Unfortunately, such *ad hoc* methods give a different simulation response. The last resort is to calibrate the PMP model to elasticities from studies that used econometric models (Heckelei and Britz, 2005).

In this study, we therefore used the supply elasticities estimated with econometric models by other researchers to specify the slope of the marginal cost curves for production activities as follow:

$$\beta_{ftc} = \frac{\sum_j c_{jc}\omega_{tjc} + \lambda_{ftc}}{\eta_{ftc} X^*_{ftc}} \qquad \text{for all f, t, c} \qquad 4.29$$

$$\beta_{fs} = \frac{\sum_j c_{js}\omega_{s} + \lambda_{fs}}{\eta_{fs} X^*_{fs}} \qquad \text{for all f, s} \qquad 4.30$$

Using equations 4.29 and 4.30, the intercept coefficients of the marginal cost functions were estimated as:

$$\alpha_{ftc} = \frac{(\sum_j c_{jc}\omega_{tjc} + \lambda_{ftc})\cdot(\eta_{fc} - 1)}{\eta_{fc}} \qquad \text{for all f, t, c} \qquad 4.31$$

$$\alpha_{fs} = \frac{(\sum_j c_{js}\omega_{js} + \lambda_{fs})\cdot(\eta_{fs} - 1)}{\eta_{fs}} \qquad \text{for all f, c} \qquad 4.32$$

where η is the *a priori* elasticities from econometric studies as presented.

4.4.2.4 Stage 3 of the PMP

In the third stage of PMP, the linear cost expressions in equation 4.26 were replaced by the quadratic cost expressions, using equations 4.29 to 4.32. The calibration constraints 4.24 and 4.25 were removed. The calibrated model with the objective function 4.33 was now used to simulate observed activity levels and elasticities used to specify the marginal cost functions. The results of the model calibration and validation are presented in Chapter 5. The final objective function of SAROS was specified as follows:

$$\begin{aligned} \textit{Maximise} \quad \Pi = & \sum_f \sum_t \sum_c ((E(\mathrm{Re}\,v_{ftc}) - (\alpha_{ftc} + 0.5\beta_{ftc} X_{ftc}))X_{ftc}) \\ & + \sum_f \sum_s ((E(\mathrm{Re}\,v_{fs}) - (\alpha_{fs} + 0.5\beta_{fs} X_{fs}))X_{fs}) \\ & + \sum_f (b_{f_{land}} - \sum_p \omega_{land} X_{f_{land}}) \cdot k_{land} \cdot tc \\ & - \sum_f (\theta_f (\sum_t X_{ftc} + X_{fs})' Cov_{\mathrm{Re}\,v_p} (\sum_t X_{ftc} + X_{fs})) \end{aligned} \qquad 4.33$$

The constraints remain the same without the calibration constraints 4.24 and 4.25. The model with objective function 4.33 is a non-linear primal, risk adjusted model of the Free State resource use and output supply response.

CHAPTER 5
DATA AND MODEL VALIDATION

5.1 Introduction

In this chapter, the data and sources of data used are discussed. The different approaches employed to validate the data are also presented. The model parameters and variables are discussed. The structural characteristics of the farm types with respect to the models' parameters and farm-level resource limits are presented and regional resource constraints are discussed in this chapter. The model developed in Chapter 4 is solved and the observed data and a priori supply response were cross-checked with the model solution in the process of model validation and calibration. At the end of the chapter, the observed and model solutions are presented. The model solutions and response behaviour show that the model calibrates in its capacity to reproduce the observed data and *a priori* supply response used to specify the model.

5.2 Data source and validation

Given the financial and time constraints, it was not possible to conduct a provincial farm survey to identify typical farm units within the large and small farm types. Data inputs into the models were sourced from different sources. The data used typify empirical data, which contain an amount of information, but lack statistical properties. Despite this, such data should not be discarded in the absence of a better source (Paris & Arfini, 2000). The solution to this kind of data problem is to use different sources to complement one another and a number of appropriate data-validating techniques e.g. modelling framework that maximises the use of such data. That is why the relationships between the production activities are handled by variable cost functions employing the latest techniques of the PMP modelling approach (Howitt, 1995a, Heckelei & Britz, 2000; Heckelei, 2002; Howitt, 2005a). The simulation behaviour was calibrated, as far as possible, to match the supply elasticities estimated, with econometric models, by previous researchers. Table 5.1 presents the description of the data used, the sources and the validation method.

Table 5.1: Description of the data used, sources and validation

Category	Data	Sources	Validation
Base year activity level	Area planted (ha) Number of animals Production levels: - Grains (ton) - Number of animals slaughtered - Volume of fresh milk production	National Crop Estmiate Committee (NCEC) Southern African Poultry Assosication (SAPA) Milk Producers Organisation(MPO) South Africa Statistics Global Agriculture Information Network (GAIN) of the USDA Foreign Agricultural Service - South Africa	• Reports of the recent survey on drought relief programme at district levels from the extension officers
Policy variables	Land transfer and Agricultural land tax0	• PDA • DLA	• Experts
Enterprise budget	Yields and resource requirements	• Combud enterprise budgets	• Cost and returns records of the cooperatives in the province • Where market prices are not readily available for input, an economist at the PDA was consulted to estimate the economic (opportunity) cost of the resource • SAPWAT, PLANWAT 2.0 software
Regional farm resource availability	Farm land Farm labour Irrigation water Number of farm units	• Umhlaba Wenthu reports • Statistics SA • DLA	• National Register of Water Use • Census of commercial agriculture 2002
Farm land resource strucutre at farm-type level	Farm land Farm labour Irrigation water Number of farm units	• DLA • DWAF	• SAPWAT software
Times series	Crops yield, animal off-take rate mortality rate,Producer price index Price indices of farming requisites	• SA Statistics	• SAMIC, • SA Feedlot Association • SAPA, MPO, SAFEX, Grain SA
Land quantity and quality	Arable land, irrigable land, grazing land	• SA Statistics • DLA	• Deparment of Land Affairs
Elasticity and total productivity Factor	Own price elasticity of supply Total factor Productivity Growth	• Literature (BFAP) • Literature – CEPA	• Literature • Experts from the PDA

5.2.1 Enterprise budgets

Enterprise budget data on yields and farm resource requirement per unit of production activities were sourced from the Combud Enterprise budgets. The Combud Enterprise budgets are compiled, published and updated on a regular basis by the Provincial

Department of Agriculture (PDA). The Combud Enterprise budget contains estimates of costs, returns and input-output technical coefficients of crop and livestock productions of homogenous farming areas with respect to scale of operation and technology.

These data were validated with records of agricultural production activities of some cooperatives in the region. The data also included average area planted with grain crops, the production costs, yields and revenues under rain-fed and irrigation cropping systems. Data on costs, prices and input levels from 2000 to 2004 were summarised into a typical enterprise budget. The cooperatives whose records were used to validate the enterprise budget data included Senwes, FS Co-op, NWK, Kameeldoorn, NWK Mareestane, NWK Soetmelksvlei, NWK Delareyville, and the GWK Beperk.

Since most of the previous surveys were conducted on established commercial farmers, the Extention Officers that attend to developing farmers were consulted in adjusting the Combud enterprise budget data to reflect the costs and returns observable among the developing farm type.

Where market prices were not readily available, an economist at the PDA was consulted to estimate the economic (opportunity) cost of the resource. Estimates of irrigation water requirements from SAPWAT software and estimates of farm and crop irrigation requirements from PLANWAT 2.0 software were used to validate the irrigation water requirements for each of the cropping activities[3].

5.2.2 Farm resource availability

Data on regional and farm-level resource availability were sourced from the Free State Provincial Department of Land Affairs. The data were crosschecked with the data collected from the Farm Information Centre of the Free State Department of Agriculture. The data extracted from the national register of water use from the Department of Water Affairs and Forestry (DWAF) and the report of the census of commercial agriculture 2002 by Statistics SA were used to validate data on resource

[3] The assistance of Pieter Van Heerden is gratefully acknowledged for making the software available for use in this study.

availability and production levels. The data on land quality (arable land, irrigable land and grazing land) for developing farmers were specifically sourced from the Free State DLA database of the LRAD projects.

5.2.3 Time series data

Time series data on crop yields, animal off-take rates, mortality rates, producer price indexes and the price index of farming requisites were sourced from the publication of Statistics SA. Consistent data for the period of 11 years, (1994 – 2004) were used in this study. Regional price data were not available for some crops; national price data were adjusted to a regional price equivalent with assistance of experts from organisation such as Grain South Africa (Grain SA), South African Futures Exchange (SAFEX), Provincial Department of Agriculture (PDA), South African red meat industry (SAMIC), South African Poultry Association (SAPA), Milk Producer Organisation (MPO), etc. The data on prices and yields were used to formulate probability distributions of yields, prices and marginal revenues for the production activities.

5.2.4 Own-price supply elasticities estimates

Other data used in this study include the estimate of own-price elasticities of supply. These data were sourced from research reports of studies that used econometric models. Though scanty and available for different times, the most consistent source is the elasticities estimated by the Bureau of Food and Agricultural Policy (BFAP), from the University of Pretoria. Other sources were used to validate these elasticities estimates. In addition, data on total productivity factor (TPF) of South African agriculture were sourced from the literature.

5.2.5 Policy variables

Information on current policy variables and the proposed policy variables were sourced from the experts at the PDA. The information includes the proposed agricultural land tax and rate of land transfer in the province.

5.3 Regional and farm-level farm resource availability

Table 5.2 presents the estimates of resource availability at regional and farm level. As previously explained in Chapter 4, the weighted average gives an indication that based on the data available - reports of the 2002 Census of Commercial Agriculture – (Statistics South Africa, 2005), there are roughly 8,531 commercial farm units. In addition, there are roughly 495 farm units of the small farm type, as at end of year 2003. Reports of the censuses of commercial agriculture in the Free State Province show that for the past 18 years, the number of active large farm units in the Free State has trended downward from 9,436 in 1983 to about 8,531 in 2002. This is a decline of about 129 farm units per year. The database of Free State DLA on the LRAD projects gives an indication that the number of farm units in the small farm type increases by about 68 farm units per year.

Table: 5.2: Average structural characteristics of representative farm types

Farm type	Large farm type	Small farm type	Total at regional level
Number of farm units	8,531	495	
Changes in the number of farm units per year (number)	-129	740	
Resource availability:			
Farm land (ha)	1,370.30	394.69	11,885,402
Arable land (ha)	496.05	82.89	4,272,833
Rain-fed (ha)	484.64	75.76	4171965
Irrigable land (ha)	11.41	7.13	100,868
Potentially irrigable land (ha)	-	-	29,222
Grazing land (ha)	874.25	311.81	7,612,573
Irrigation water (m^3)	305,381.29	37,984.54	2,602,933,358
Available casual labour (hour)	-	-	149,164,800

Source: Own computations based on data from DLA, DWAF, Statistics, South Africa

The proposition by the Ministry of Agriculture and Land Affairs is to speed up the rate of land transfer i.e. transferring land at the rate of 2.2 million ha per year from 2006 to 2015 in order to reach the target of 30%. Assuming that the average farm size of developing farm units will be maintained, the land transfer process may amount to establishing about 740 farm units per year.

Using weighted averages to estimate the distribution of farm resources in each farm type, an average of 1,370.3ha of farmland per farm unit per large farm type was taken. Of this amount, about 496.05ha is arable land, of which about 484.64ha is dry, non-irrigable arable land, with the remaining 11.41ha being irrigable. About 874.25ha is grazing land. There is 305,381.29m^3 of irrigation water available per farm unit per large farm type. For the small farm type, there is an average of 394.69ha of farmland per farm unit. Of this amount, about 82.89ha is arable land of which about 75.76ha is dry non-irrigable arable land and the remaining 7.13ha is irrigable. About 311.81ha is grazing land. There is 37,987.54m^3 of irrigation water per farm unit. Casual labour is assumed limited at regional level at an estimate of about 149,164,800 person-hours per annum. The region also has about 29,222ha of potentially irrigable land. The above was used as inputs in the resource constraints equations

5.4 Production activities

Table 5.3 presents the areas planted with field crops and the number of animal breeding stocks held by each farm type in the Free State Province at commercial level. The crop production activities were further broken down into farming systems/technology. This is to reveal how much irrigation water is being used in agriculture. This accounts for different yields and costs that result from different farming systems.

Each farm unit in the large farm type, on average planted about 77.36ha of white maize. Of this amount, about 75.04ha and 2.32ha was planted with white maize on dry and irrigated land, respectively. On the other hand, each farm unit within the developing farm type, planted on average about 3.64ha of white maize. Of this amount, about 3.53ha and 0.11ha were planted with white maize on dry and irrigated land respectively. The same explanation goes for other cropping activities for the different farm types.

Table 5.3: Base year activity level and supply

	Large farm type			Small farm type			Region	*Farm industry structure by activity level*	
	Activity level		**supply**	**Activity level**		**Supply**	**Supply**	**Small**	**Large**
	Farm type	**Farm unit**	**Farm type**	**Farm type**	**Farm unit**	**Farm type**		**farm type as % of total**	**farm type as % of total**
Crops	**(ha)**	**(ha)**	**(ton)**	**(ha)**	**(ha)**	**(ton)**	**(ton)**	**(%)**	**(%)**
White maize	659958.64	77.36	2,718,392.86	1801.80	3.64	6,055.29	2724448.14	0.27	99.73
Rain-fed	640159.88	75.04	2,546,554.15	1747.75	3.53	5,625.23	2.55E+6		
Irrigated	19798.75	2.32	171,838.71	54.05	0.11	430.05	172268.76		
Yellow maize	385004.15	45.13	1,617,418.45	3400.65	6.87	12,557.90	1629976.35	0.88	99.12
Rain-fed	373454.02	43.78	151,348.33	3298.63	6.66	11,723.93	1.52E+6		
Irrigated	11550.12	1.35	104,270.12	102.02	0.21	833.97	105104.09		
Wheat	190496.91	22.33	517,674.84	128.70	0.26	280.78	517,955.62	0.07	99.93
Rain-fed	180972.06	21.21	461,775.68	122.26	0.25	249.58	462025.26		
Irrigated	9524.85	1.12	55,899.16	6.44	0.01	31.20	55930.36		
Soya beans	12369.95	1.45	30,508.35				30,508.35	-	100
Rain-fed	9895.96	1.16	20,338.90	-	-	-	20338.90		
Irrigated	2473.99	0.29	10,169.45	-	-	-	10169.45		
Sorghum	42484.40	4.98	162,899.02				162,899.02	-	100
Rain-fed	42059.56	4.93	159,673.29	-	-	-	159673.29		
Irrigated	424.84	0.05	3,225.72	-	-	-	3225.72		
Sunflower seed	185037.06	21.69	269,343.05				269,343.05	-	100
Rain-fed	181336.32	21.26	257,267.24	-	-	-	257267.24		
Irrigated	3700.70	0.43	12,075.81	-	-	-	12075.81		
Livestock	**(herd)**	**(herd)**	**(ton/litre/unit)**	**(herd)**	**(herd)**	**(ton/litre/unit)**	**(ton/litre/unit)**	**(%)**	**(%)**
Beef cattle	443612	52	60,255.17	4950	10	336.18	60,591.35	1.10	98.90
Mutton sheep	1117561	131	29,999.96	11385	23	150.92	30,150.88	1.01	98.99
Pork pig	17062	2	10,233.02	495	1	259.77	10,492.79	2.82	97.18
Chicken broilers	49,010,640	5745	74,360.91	6435	13	8.14	74,369.05	0.01	99.99
Chicken eggs	1,868,590	219	515,194,400	2475	5	568,755.00	515,768,100	0.13	99.87
Dairy cattle	51,186	6	357,984,700	495	1	2,740,695.75	360,725,400	0.96	99.04

Source: Own computations

Likewise, the numbers of animal breeding stock are presented in the table. Each farm unit within the commercial farm type held on average about 52 cows, 131 mutton-sheep, 2 pigs, 5,745 broiler chickens, 219 layer chickens and about 6 dairy cattle in a year. Each farm unit within the small farm type on the other hand, held as breeding stock: 10 cows, 23 mutton-sheep, 1 sow, 13 chicken broilers, 5 egg layers (chickens) and 1 dairy cow. These figures were aggregated at the regional level to imply that on average, the large farm type produced at the base year, 2,718,392.86 tonnes of white maize and 1,617,418.45 tonnes of yellow maize grains, etc. On the other hand, the small farm type produced 6,055.29 tonnes of white maize and 12,557.90 tonnes of yellow maize, etc. These add up to a regional output supply of about 2,724,448.14 tonnes of white maize and about 1,629,976.35 tonnes of yellow maize. The dairy milk supply is given in litre and that of eggs in per unit.

In general, the figures show that the large farm type has a higher share of both crop and animal production. The base activity levels show that the large farm type contributes about 99.73% of white maize, 99.12% of yellow maize, 99.93% wheat, 100% each of soya beans, sorghum and sunflower, 98.9% of beef cattle, 98.99% of mutton-sheep, 97.18% of pig-pork, 99.99% of chicken broilers, 99.87% of layers-chicken and 99.04% of dairy cattle at commercial levels.

The distribution is a weighted average of the representative farm types. It is acknowledged that this approach may have some aggregation bias but was adopted because of lack of enough data on the specific number of farm units that are engaged in a specific production activity. However, this approach reproduces the base year data on area planted, number of animal breeding stock and output supply as reported by the Crop Estimate Committee of the National Department of Agriculture. The weighted averages were also validated in consultation with experts at the Free State Provincial Department of Agriculture.

Thus, it is assumed that if a farmer decides to engage in a combination of crops and livestock activities, given the revenue risk, government policies and other macro-economic variables that affect the production revenue, such as resource constraints, such a farmer may wish to maximise his expected profit given the resource constraints. Other cropping activities were not considered, such as horticulture, permanent tree crops, etc. in this study because of limited data and for simplicity.

5.5 Productivity growth in the South African agriculture

Table 5.4 shows the total factor productivity growth in the South African agriculture. These data were used to compute the average total factor productivity for the two farm types, to give an indication of the technical progress in the industry. The most recent estimates for the period of 1981 to 2001, by Avila and Evenson (2004) were used. From the base year activity levels and supplies, it is observed that despite that about 2.5% of land has been transferred so far and the fact that increases in costs outpace increases in revenues (Coetzee, 2003 a, b, c), the production has been on the increase for most agricultural products. This could be attributed to technical progress and changes in the cropping pattern in the industry. However, evidence exists that the established large-scale farms have been responsible for massive if not all of the production of the crop and animal products. Therefore an average productivity growth of 2.74% for crop production, and 1.91% for livestock production were imputed in the model for the large farm type while these estimates are subjectively halved to represent assumed TPF for the small farm type.

Total 5.4: Total Factor Productivity (TFP) growth in South African agriculture

Source	*Period*	*Activity*	*TFP (%)*
Thirtle, Sartorious von Back and van Zyl (1993)	1947-1965	Aggregate	0.00
	1965-1981	Aggregate	2.15
	1947-1991	Aggregate	1.26
	1981-1991	Aggregate	2.88
Van Zyl, Vink and Kirsten (2000)	1960-1980	Aggregate	2.05
	1980-1990	Aggregate	0.96
	1980-1996	Aggregate	1.19
	1990-1996	Aggregate	1.56
	1960-1996	Aggregate	1.66
Coelli and Prasada Rao (2003)	1980-2000	Aggregate	1.03
Avila & Evenson (2004)	1961-1980	Crops	4.11
	1961-1980	Livestock	3.05
	1961-1980	Aggregate	3.61
	1981-2001	Crops	2.74
	1981-2001	Livestock	1.91
	1981-2001	Aggregate	2.32

5.6 Estimate of yields among the large and small farm types

Table 5.5 presents estimates of grain yield, animal live and carcass weights that are observed on average among the large-scale commercial farmers and LRAD developing farmers. The estimates are the average at regional level as it is acknowledged that significantly different estimates are obtainable at different areas of the province where there are more significantly different production climates. As expected, large-scale commercial farms on average experience higher yields and off-take rates as a result of capital-intensive technology or specialization among other things.

Table 5.5: Estimates of expected yields per annum

		Large farm type		*small farm type*	
	Unit	**Expected Yield**		**Expected Yield**	
Crops		**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**
White maize	ton/ha	3.98	8.68	3.22	7.96
Yellow maize	ton/ha	4.05	9.03	3.55	8.17
Wheat	ton/ha	2.55	5.87	2.04	4.85
Sorghum	ton/ha	3.80	7.59	-	-
Soya beans	ton/ha	2.06	4.11	-	-
Sunflower	ton/ha	1.42	3.26	-	-
		Expected Yield		**Expected Yield**	
Livestock		**Live weight**	**Carcass weight**	**Live weight**	**Carcass weight**
Beef	ton/head	0.24	0.14	0.12	0.07
Mutton	ton/head	0.05	0.03	0.03	0.01
Pork	ton/head	1.31	0.60	1.14	0.52
Boilers-Chickens	ton/head	0.0022	0.0015	0.0018	0.0013
			Expected Yield	**Expected Yield**	
Layers-Eggs	egg/head		276		230
Dairy milk	litre/head		6993.80		5536.76

Source: Free State Provincial Department of Agriculture

5.7 Production, consumption and trade balance of selected products

Table 5.6 presents the Free State production, consumption and trade balance of crops and livestock products considered in this study. Free State is a major producer of most of these crops. In the same vein, the Free State produces substantial level of animal products. For livestock products, the percentage consumption has the same trend. Free State has a positive trade balance in all the crops considered. However, South Africa has a negative trade balance in most of the crops and livestock outputs, namely wheat, sunflower seeds, beef, dairy milk, mutton, pork, and broiler chickens.

Table 5.6: Base year regional production and consumption as a percentage of the national data

	Unit	Regional production, consumption and trade balance			National production, consumption and trade balance		
		Production	FS as % SA	FS consumption	FS as % SA	FS trade balance	National trade balance
Grains							
White maize	ton	2,724,448	36.53	260,357	5.42	2,464,091	2,661,255
Yellow maize	ton	1629,976	32.74	584,774	15.72	1045202	1,257,993
Wheat	ton	517,956	30.49	105,064	3.12	412,892	-1,667,600
Soya beans	ton	30,508	11.20	12,000	7.41	18,508	110,500
Sorghum	ton	162,899	43.67	7,980	5.76	154,919	234,500
Sunflower seed	ton	280,000	42.17	101,400	15.00	178,600	-11,990
Livestock							
Beef cattle	ton	60,591	8.55	50,477	6.99	10,114	-13,000
Dairy cattle	litre	301,061,300	14.26	96,242,768	4.41	204,818,532	-73,000,000
Mutton sheep	ton	30,151	20.37	13,792	7.66	16,359	-32,000
Pork pig	ton	10493	7.83	8,827	5.67	1,666	-21,790
Chicken broilers	ton	61976	7.10	53,235	6.08	8,741	-2,274
Chicken eggs	eggs	429901600	7.32	257,964,285	4.61	171937315	277,104,261

Source: Own computations based on data from Statistics, SA, Grain SA, MPO, SAMIC, SAFA

5.8 Production costs and returns

Programming models usually progress from a partial budget analysis, which is still the dominant method for microeconomic analysis of resource use and agricultural production (Howitt, 2005a). Table 5.7 shows the marginal revenues, costs and gross margins of the production activities considered. The Table shows the profitability of alternative farming systems for each commodity and the profitability of the alternative enterprises in general.

Table 5.7: Expected revenues, costs and gross margins (R/ton or R/animal)

Large farm type

	Expected Marginal Revenue R/ha		Direct Cost (R/ha)		Expected Gross Margin (R/ha)	
Crops	**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**
White maize	4500.33	9818.90	2902.67	7986.17	1597.66	1832.73
Yellow maize	4562.65	10165.91	2902.67	7986.17	1659.98	2179.75
Wheat	4063.66	9346.43	3086.73	6853.76	976.93	2492.66
Sorghum	3672.93	7345.86	2347.63	5151.52	868.60	1280.95
Soya beans	3216.23	6432.46	2319.98	5767.43	1352.95	1578.44
Sunflower	2873.43	6608.89	2198.59	5621.27	674.84	987.62

Livestock	**Expected Marginal Revenue R/animal**	**Direct Cost (R/animal)**	**Expected Gross Margin (R/animal)**
Beef	3524.71	1120.19	2404.52
Mutton	1169.89	254.09	915.80
Pork	15028.78	12616.28	2412.50
Chickens	35.71	18.70	17.02
Eggs	170.21	121.28	48.94
Dairy milk	15532.90	8343.55	7189.35

Small farm type

	Expected Marginal Revenue R/ha		Direct Cost (R/ha)		Expected Gross Margin (R/ha)	
Crops	**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**	**Rain-fed**	**Irrigated**
White maize	3641.17	9000.65	2902.67	7986.17	738.50	1014.49
Yellow maize	4002.33	9205.36	2902.67	7986.17	1099.65	1219.19
Wheat	3250.93	7720.96	3086.73	6853.76	164.20	867.20

Livestock	**Expected Marginal Revenue R/animal**	**Direct Cost (R/animal)**	**Expected Gross Margin (R/animal)**
Beef	1881.88	1120.19	761.68
Mutton	610.63	254.09	356.54
Pork	13266.21	12616.28	649.92
Chickens	29.90	18.70	11.20
Eggs	144.51	121.28	23.23
Dairy milk	12672.50	8343.55	4328.95

Source: Own computations from the Combud Enterprise budgets

The estimates of yields among the large and small farm types are used to adjust the regional averages to get the estimates in the table. It is expected that the farm types will have difference in costs as a result of economies of size, different level of technology use and technical progress among other things; however, there are not enough data to establish the difference in costs between the farm types.

Production costs, resource use per production activity and the cost of inputs were estimated as averages of 5 years of data. This step was taken to account for the coincidental variation in the annual data. The costs were derived by adding all the expenses removing the diesel rebate and adding the interest payable on operating capital. The results were adjusted for inflation and normalised to the base year using the price index of farm requisites. These are costs that are directly allocatable to the individual production activity. Expected marginal revenues were derived from the historical data on prices and yields for 11 years (1994 to 2004).

The probability distributions of the series were formulated to arrive at the expected marginal revenues and the risk in marginal revenues. In estimating this typical budget, the suggestion by Kletke (1979) was followed. Kletke (1979) suggests that in constructing enterprise budget data, the budget should reflect average typical conditions when working on regional problems. The enterprise budgets for the farming areas within the region were used. Furthermore, to account for difference in revenues between the farm types, the regional budgets were adjusted using the records of costs and returns to production activities obtained from the cooperatives.

The opportunity cost of land was included because according to Kletke (1979), when comparing efficiency with the cost of production for different farm sizes, incorporating land rent is necessary. In this study, land rents were included as an annual rental charge. Also, differences in land quality were reflected in corresponding rental changes. Therefore, the budgets contain typical costs and return estimates for different production activities. The marginal revenue is a product of the yield and output price per ton or unit. It is observed that some of the enterprises have by-products that have a substantial effect on income and production decision-making. By-products were valued on a per hectare or per animal basis, which were added to the corresponding marginal revenues.

A few observations noted from the table are that for both farm types, irrigated crop production is more profitable compared to rain-fed crop production. However, the difference is not very large especially for white maize, soya beans and wheat. This is because prices were generally low in the base year 2004. Opportunity costs of irrigable land (R1000/ha) and dry-land (R130/ha) included in the estimation of the direct costs also increased the direct cost of irrigated crops markedly. These data were used as inputs in the objective function of the model developed to achieve the objectives of this study.

5.9 Some important production cost items

Table 5.8 shows the percentage of the cost items for livestock production. Feed constitutes the highest percentage of production costs. It is as high as 73% for dairy milk production. The lowest is about 23% for mutton sheep production.

Table 5.8: Some variable input costs as a percentage of the total variable costs in livestock production (%)

	Beef cattle	Mutton sheep	Pork pig	Broilers	Layers egg	Dairy milk
Chicks/animal	15.09	8.95	0.37	16.22	23.38	2.03
Feed	43.08	23.46	76.52	57.69	59.43	73.49
Vaccination & vitamins	10.89	20.12	0.21	0.68	0.11	8.87
Electricity	0	0	0	1.55	0.48	0
Transport	13.04	14.60	2.03	3.10	0.18	3.63
Rent on land/structure	6.20	18.22	9.17	7.43	1.91	0.28
Interest rate	13.25	13.25	13.25	13.25	13.25	13.25

Source: Own computations based on data from Combud enterprise budgets

Table 5.9 shows the percentages of some cost items that constitute direct cost in the cropping activities. The cost of fertiliser constitutes the highest percentage. For example, it is about 33% and 52% for white maize on rain-fed and irrigated cropping systems respectively.

Table 5.9: Some variable input costs as percentages of the total variable costs in crop production (%)

Rain-fed	*White maize*	*Yellow maize*	*Wheat*	*Soya beans*	*Sorghum*	*Sunflower*
Seed	8.79	8.79	9.90	14.64	4.82	6.77
Fertiliser	52.59	52.59	16.05	18.42	57.42	46.88
Herbicide	5.28	5.28	13.98	10.99	3.22	7.78
Pesticide	1.87	1.87	13.00	7.84	0.95	2.81
Casual labour	6.09	6.09	3.51	2.31	3.12	9.41
Harvest contract	2.39	2.39	6.56	8.87	4.36	4.03
Spray contract	2.99	2.99	5.62	8.53	0.95	0
Insurance	1.01	1.01	14.48	9.86	4.99	2.85
Fuel	4.77	4.77	0.75	0.98	3.98	2.10
Interest rate	13.25	13.25	13.25	13.25	13.25	13.25
Opportunity cost of land	5.18	5.18	4.87	6.41	6.48	6.84
Irrigated	**White maize**	**Yellow maize**	**Wheat**	**Soya beans**	**Sorghum**	**Sunflower**
Seed	3.19	3.19	6.42	10.67	2.71	3.22
Fertiliser	32.50	32.50	14.45	9.23	40.59	20.17
Herbicide	4.24	4.24	6.29	7.18	1.29	11.60
Pesticide	0.68	0.68	5.86	3.57	0.38	4.19
Irrigation water	11.98	11.98	14.41	14.52	11.67	16.27
Casual labour	5.43	5.43	8.25	3.16	3.76	7.92
Harvest contract	6.52	6.52	5.91	8.09	3.51	1.73
Spray contract	1.09	1.09	2.53	3.89	0.38	0
Insurance	6.78	6.78	6.52	4.49	3.01	1.67
Fuel	3.19	3.19	1.75	2.33	2.08	2.13
Interest rate	13.25	13.25	13.25	13.25	13.25	13.25
Opportunity cost of land	14.49	14.49	16.88	22.46	20.06	20.59

Source: Own computations based on data from Combud enterprise budgets

5.10 The farming systems

Table 5.10 shows the relatively typical distribution of farming systems (rain-fed and irrigated) for each crop production. These data were obtained from the Census of Commercial Agriculture 2002. The data were incorporated into base activity levels to account for the options and the typical practices in crop production activities in the region. Each of the crops can be grown once in a year. On the average, each has planting period of about 8 months. The proportion (20%) of area grown to irrigated soya beans is relatively higher than irrigated areas grown to other crops.

Table 5.10: Typical farming system of dominant grain crops

crop	Rain-fed %	Irrigated %	Planting date
White maize	97	3	Nov - July
Yellow maize	97	3	Nov - July
Wheat	95	5	Apr-Dec
Soya beans	80	20	Nov - July
Sorghum	99	1	Nov - May
Sunflower	98	2	Nov-April

Source: Own computations from Statistics, SA (2005)

5.11 Variance and Co-variance matrix of production revenues

Table 5.11 shows the expected marginal revenues for the production outputs at regional level. These estimates differ from estimates in table 5.7 which are estimates at farm type level. The expected marginal revenues compare well with the base year marginal revenues in the Combud enterprise budgets. For example, the expected marginal revenue for white maize is estimated at R4,132.68/ha while that of a dairy milk production is estimated at about R13,275.16/cow/annum.

It should be noted that these estimates include the revenue from what is herein referred to as by products e.g. culled animals in dairy milk production. The variance and covariance matrix of per ha and per animal marginal revenue for crops and livestock respectively are also presented in the table. The variance shows the deviation of marginal revenue from the expected marginal revenue while the covariance shows the correlation between marginal revenues of two outputs. To arrive at this distribution, it is assumed that a farmer's expectations of marginal revenues follow a linear regression model and that the deviations from these expectations, are the observed risks in marginal revenues for corresponding production activities.

It is assumed that a typical agricultural production plan is consisting of the 18 production activities included in the model. The production activities include the 12 cropping activities and 6 animal production activities. The table shows that white maize has the highest expected marginal revenue of about R4,132/ha but it has second to the highest marginal revenue variance of about R966,818/ha. It is the second riskiest crop production activity after sorghum production. Dairy milk production has the highest expected marginal revenue of about R13,276/cow per annum. It also has marginal revenue variance of R284,249/dairy cow per annum. It is the riskiest among animal production activities.

Table 5.11: Historical marginal revenue, expected marginal revenue and variance-covariance of marginal revenues

	White maize	Yellow maize	Wheat	Soya beans	Sorghum	Sunflower	Beef cattle	Mutton sheep	Pigs	Broilers	Layers-chicken	Dairy cattle
Output				**(R/ha)**					**(R/animal)**			
1994	2,887.76	3,386.42	3,883.80	1564.32	3,664.78	2,370.05	1,300.23	318.20	1,952.37	30.84	159.15	13,505.99
1995	4,878.94	4,306.09	3,370.30	2332.31	3,304.95	3,484.20	1,332.85	355.44	2,200.80	29.57	133.69	13,155.08
1996	5,176.64	4,995.01	4,274.19	2786.09	2,894.40	2,551.97	1,233.17	345.01	2,349.64	30.83	149.89	13,152.38
1997	4,637.73	4,104.50	3,563.05	2340.92	2,371.89	2,554.55	1,263.58	318.14	1,993.31	25.58	138.53	13,365.30
1998	3,825.36	3,855.93	4,842.44	2081.48	1,569.35	3,432.55	1,387.36	352.68	2,018.72	27.19	132.42	13,217.24
1999	5,099.08	4,856.90	4,686.90	2757.55	3,162.74	3,912.37	1,662.99	385.75	2,186.05	32.93	144.64	13,601.85
2000	3,042.91	3,186.75	4,527.23	2281.53	1,735.52	3,039.44	1,490.94	353.81	1,986.71	34.16	150.89	13,631.32
2001	2,651.89	2,984.06	3,966.02	1673.53	1,553.33	2,895.48	1,552.85	364.42	2,001.39	32.73	146.22	11,762.35
2002	4,367.41	3,462.05	4,312.95	1354.13	1,673.77	2,350.10	1,223.13	346.30	2,010.62	30.08	144.69	13,399.13
2003	3,322.67	3,371.80	3,035.99	1643.47	3,189.48	2,753.76	1,239.27	325.42	2,135.16	27.16	145.07	13,978.47
2004	5,569.14	5,635.64	4,029.85	3201.52	4,783.72	3,017.78	1,244.69	322.71	2,211.47	28.97	146.39	13,257.60
Expected marginal revenue	4,132.68	4,013.20	4,044.79	2183.35	2,718.54	2,942.02	1,357.37	344.35	2,095.11	30.00	144.69	13,275.16
						Variance-covariance (R)						
White maize	966818.59											
Yellow maize	734450.85	661555.67										
Wheat	47108.01	59842.77	285713.50									
Soya beans	411818.28	403364.90	67597.03	310807.51								
Sorghum	471554.63	537376.00	-1.95E+05	285219.74	982781.87							
Sunflower	125990.79	125254.00	83511.97	122615.91	32220.84	228071.20						
Beef cattle	-33706.60	-17578.97	36040.98	8029.16	-42147.17	46593.02	20282.76					
Mutton sheep	947.15	-90.54	5969.95	1300.12	-8050.50	6898.58	2372.81	418.24				
Pigs	86729.37	76861.33	-4829.30	45957.40	63486.32	15907.38	-2753.95	411.19	14874.21			
Broilers Chicken	-616.45	-315.75	618.26	56.48	-369.42	256.81	237.64	32.50	2.57	6.49		
Laying hens	-2460.45	-913.23	172.85	-532.32	1832.52	-1759.44	-10.49	-35.80	-86.0	9.99	53.59	
Dairy cattle	105462.74	64290.35	-22654.33	25341.17	171355.41	218.63	-22837.60	-3313.87	6080.52	-340.90	389.45	284249.18

Source: Own computation based on data from Statistics, SA (2006), SAFEX, MPO, SAMIC, SAFA

5.12 Risk attitudes of Free State farmers

Risk terms were incorporated into the PMP model developed in this study. However, the level of improvement in the model calibration is similar to what Heckelei and Britz (1998) observed in a similar model for German agriculture. In the case study of German agriculture by Heckelei and Britz (1998), the duals of the calibration constraints could not be reduced significantly by changing the risk aversion parameter. The study shows very small positive effects with small risk aversion parameter (0.01). The authors then conclude that incorporating the risk term into the PMP framework did not explain better the observed activity level and consequently did not influence the model behaviour. This result does not support the argument by Howitt (2005) that programming models are a more normative approach, and calibrating them to actual behaviour by adding constraints or risk terms could improve the positive attributes and minimize the normative attributes.

In this study, for large farm types, the estimated optimal level of risk aversion parameters (RAP) that reproduces the observed activity levels is 3.0×10^{-7} after which the F statistic decreased by 0.0131 at minimum absolute deviation (MAD). For small farm types on the other hand, the optimal level of RAP that reproduces the observed activity level is 2.0×10^{-5} after which the F statistic decreased by 0.0557. In terms of using the risk term to improve the model calibration within the PMP framework, these results confirm the calibration. In terms of magnitudes of risk aversion parameters, the estimates are comparable to 5.24×10^{-6} and 6.32×10^{-6} reported by De Zen, Peres and De Camargo Barros (2003) for Mato Grasso and Rio Grande do Sul regional typical farms of Brazil respectively. The typical farm size (about 200ha) in the Rio Grande do Sul region is smaller than the typical farm size (about 3,000) in the Mato Grasso Region.

This also implies that the estimates in this study give same indication that, the smaller the farm size, the higher the risk aversion. In other words, the small farm type is more risk averse compared to the large farm type. The estimates in our study are also comparable to the 2.0×10^{-6} risk aversion parameter reported by Agriculture and Agri-Food Canada (1998) for the Canadian farm type.

A lower risk aversion attitude on the part of the large farm type could be explained by availability and the use of contingent claim markets, such as insurance, which allows risk to be transferred to other stakeholders. Farmers using such a risk management instrument may be risk-averse and increase activity levels even when risk is higher (Agriculture and Agri-Food Canada, 1998). Also, farmers may be risk-averse or less risk-averse, depending on which cost they consider in making production decisions. Van Schalkwyk (1995) reported that government supports reduce the normal risk in farming and expectation about future income from land and farming in South Africa.

In a Free State context, some costs are borne by the government, which acquires land for farmers and pays the service providers to supply the initial production stock for the small farm type. Therefore, there are a number of possible reasons, which may explain why the RAP estimates in this study are low. Among such reasons is the argument by Casson (2004), who argues that the perception of risk is subjective. This implies that a confident entrepreneur (say farmer) may perceive no risk when data show that there is considerable risk. Such a farmer may invest when the trend in data suggest high volatility in price or revenue when the farmer is both optimistic and confident in own judgment, relative to that of the data. It should be acknowledged that such a farmer's perception might be right or wrong. However, if the farmer's optimism is warranted, the farmer's investment may be profitable, while if not, the farmer may lose.

Also, a number of factors, among others, that may warrant low risk aversion among the Free State farmers include government intervention in the form of a drought relief, willing-buyer willing-seller government-assisted land markets, and future markets. In an industry, where government intervenes for example with risk-hedging mechanisms, an increase in expected income may cause farmers to increase activity levels (Silberberg, 1990; Gravelle and Rees, 1992; Turvey *et. al.*, 1995). However, such intervention may not encourage farmers to practice optimal resource allocation.

5.13 Estimates of supply elasticities found in the literature

Table 5.12 presents the own-price supply elasticities estimates from econometric models as reported in the literature. The most consistent are the elasticities from BFAP (2006). These are the long-run elasticities for the Free State farm industry. It is acknowledged that the elasticities are for the large farm type. The distribution of resource availability at farm level was used to scale down these elasticities to represent the probable response among the small farm type. The elasticities were adjusted and used to calibrate the marginal cost functions of the model. Besides, since the elasticity of supply is the essential measure of how the calibrated PMP model responds to policy changes (Howitt, 2005a), it is advantageous to make use of the best available information. In this study, PMP marginal cost functions were specified with these elasticities.

Table 5.12: Estimates of own price supply elasticities from econometric models

Product	*Sources*				
	BFAP (2006)	**Meyer (2006)**	**Niebuhr (1991)**	**Van Zyl (1990)**	**Van Schalkwyk and Groenewald (1993)**
Grains					
White maize	0.660			0.026	
Yellow maize	0.570				
Sorghum	0.550				
Soya beans	0.350				
Sunflower	1.150				
Wheat	1.140		0.33	0.2	
Livestock					
Beef cattle	0.074				
Dairy cattle	0.112				
Mutton sheep	0.101				
Pork pig	0.170				
Chicken broilers	0.276	0.328			
Chicken eggs	0.123				
Aggregate agriculture					0.92

5.14 Model validation

One of the ways to calibrate a programming model is to incorporate some positive data-based parameters into the model. This is to build a continuous connection between econometric programming models (Howitt, 2005). However, it is necessary to check the equilibrium elasticity implied by the calibrated model. In the context of this study, the response to an increase in the price of output is to increase the activity level. The response depends on the levels of risks in price, yield and revenue of the activity. It also depends on the relative economics, i.e. the expected marginal revenues of the activities and the resource constraints.

Table 5.13 presents the adjusted elasticities, in columns 2 and 4 for large and small farm types respectively, which were used to specify the model. Columns 3 and 5 show the equilibrium elasticities reproduced by the model when a shock of a 1% increase in expected price was introduced. For each crop production there is generally, a slightly greater response with respect to irrigated cropping compared to rain-fed cropping for the two farm types. The difference may be explained by the relative economics of the farming systems.

Table 5.13: A *priori* elasticities and equilibrium elasticities at farm type level

	Large farm type		**Small farm type**	
	***a priori* elasticities**	**Equilibrium elasticities**	***a priori* elasticities**	**Equilibrium elasticities**
White maize	0.66	**-**	0.19	-
Rain-fed	-	**0.675**	-	**0.211**
Irrigated	-	**0.705**	-	**0.211**
Yellow maize	0.57	**-**	0.16	**-**
Rain-fed	-	**0.582**	-	**0.174**
Irrigated	-	**0.607**	-	**0176**
Wheat	1.14	**-**	0.33	**-**
Rain-fed	-	**1.163**	-	**0.342**
Irrigated	-	**1.219**	-	**0.360**
Soybeans	0.35	**-**	0.10	**-**
Rain-fed	-	**0.360**	-	**-**
Irrigated	-	**0.387**	-	**-**
Sorghum	0.55	**-**	0.16	**-**
Rain-fed	-	**0.564**	-	**-**
Irrigated	-	**0.600**	-	**-**
Sunflower	1.15	**-**	0.33	**-**
Rain-fed	-	**1.184**	-	**-**
Irrigated	-	**1.266**	-	**-**
Beef cattle	0.074	**0.070**	0.037	**0.033**
Mutton sheep	0.101	**0.097**	0.051	**0.048**
Pork pig	0.170	**0.160**	0.085	**0.079**
Broilers chicken	0.276	**0.270**	0.138	**0.134**
Layers eggs	0.123	**0.111**	0.062	**0.005**
Dairy cattle	0.112	**0.099**	0.056	**0.048**

Source: Own computations

The implied elasticities of supply are consistent with the *a prior*i elasticities used to specify the model. Table 5.14 shows the calibration at regional level. Column 2 shows the elasticities used to calibrate the model and column 3 shows the implied elasticities when a shock of a 1% increase in expected price is introduced to the model. Column 4 shows the point elasticities at the base level price and the activity level. This simulation was repeated with a 1% decrease in the expected price and the corresponding equilibrium arc and point elasticities were recorded in columns 5 and 6, respectively. The simulation response appears almost exactly and thereby confirms the model calibration and validation.

In practice, the dependence of supply on price may take any number of functional forms, but an assumption of linear dependency will often provide an adequate approximation to the true relationship (Howitt, 2005a). Therefore, to better validate the model, the linear regression method was used to generate point elasticities at the observed prices and activity levels. The prices were parameterised in ten steps of a 1% price increase after reducing the base price by 50%. Excel regression was then used to calculate the point elasticities for each crop at the base price and activity level. The formula used is as follows:

$$\varepsilon_p = \frac{1}{\mu_p}\frac{P_p^{\ *}}{X_p^{\ *}} \qquad 5.1$$

Where ε is the point elasticity for each production activity presented in columns 4 and 6 of Table 5.13.

μ is the slope of the supply curve for production activity p.
P^* is the base output price and
X^*_p is the base activity level for each production activity p.

Table 5.14: A *priori* and equilibrium elasticities at regional level

	a priori elasticities from the literature	**1% increase in own price**		**1% decrease in own price**	
		Equilibrium elasticities	**Point elasticities of supply**	**Equilibrium elasticities**	**Point elasticities of supply**
White maize	0.660	**0.676**	**0.676**	**0.669**	**0.670**
Yellow maize	0.570	**0.581**	**0.581**	**0.575**	**0.575**
Wheat	1.140	**1.169**	**1.167**	**1.157**	**1.156**
Soybeans	0.350	**0.369**	**0.368**	**0.365**	**0.364**
Sorghum	0.550	**0.565**	**0.565**	**0.559**	**0.560**
Sunflower	1.150	**1.188**	**1.186**	**1.176**	**1.175**
Beef cattle	0.074	**0.070**	**0.070**	**0.069**	**0.069**
Mutton sheep	0.101	**0.097**	**0.097**	**0.096**	**0.096**
Pork pig	0.170	**0.158**	**0.158**	**0.156**	**0.157**
Broilers chicken	0.276	**0.270**	**0.271**	**0.267**	**0.268**
Layers eggs	0.123	**0.111**	**0.111**	**0.110**	**0.111**
Dairy cattle	0.112	**0.099**	**0.099**	**0.098**	**0.098**

Source: Own computation

This process was repeated by parameterising in ten steps of a 1% decrease in price. The elasticities (column 6) obtained when prices were reduced are also consistent with the elasticities (column 4) when prices were increased. This model appears valid because

i. arc elasticities when prices were increased are consistent with arc elasticities when prices were decreased;

ii. point elasticities at base data and when prices were increased are consistent with point elasticities when prices were reduced; and

iii. arc elasticities are consistent with point elasticities when prices were increased and decreased.

It is noticed that the lower *a priori* elasticities assumed for small farm types reproduced equilibrium elasticities, both at farm and regional level that are consistent with the *a priori* elasticities. However, this does not necessarily support the assumption that small farm types have steeper supply curves. Literature shows that conventional supply response analyses may significantly underestimate elasticity because of poor specification of price expectation (Williams and Wright, 1991; Brennan, 2003).

Back to the discussion of the model calibration and validation, in this study, the model was solved to obtain optimal activity levels. The results are reported in Tables 5.15. The observed and optimum activity levels are the observed areas planted to crops and numbers of animal breeding stocks. Observed and optimum activity levels for the large farm type are presented in columns 2 and 3 respectively. These values were split into farm unit's activity levels and are presented in columns 4 and 5 respectively. Base and optimal activity levels for the small farm type are presented in columns 6 and 7. The values are also split into base and optimal values for each small farm unit and are presented in columns 8 and 9 respectively. The optimal values are almost exactly equal to the observed values for each farm type.

Table 5.15: Observed and optimum activity levels

	Large farm				*Small farm*			
	Farm type		**Farm unit**		**Farm type**		**Farm units**	
	Base	**Optimum**	**Base**	**Optimum**	**Base**	**Optimum**	**Base**	**Optimum**
Grains				***(ha)***				
White maize	659958.16	659958.80			1801.80	1801.80		
Rain-fed	640159.42	640194.05	75.04	75.04	1747.75	1747.75	3.53	3.53
Irrigated	19798.74	19798.75	2.32	2.32	54.05	54.05	0.11	0.11
Yellow maize	385004.03	385004.30			3400.65	3400.65		
Rain-fed	373453.91	373454.17	43.78	43.78	3298.63	3298.63	6.66	6.66
Irrigated	11550.12	11550.12	1.35	1.35	102.02	102.02	0.21	0.21
Wheat	190497.23	190497.29			128.70	128.70		
Rain-fed	180972.37	180972.43	21.21	21.21	122.27	122.27	0.25	0.25
Irrigated	9524.86	9524.86	1.12	1.12	6.44	6.44	0.01	0.01
Soya beans	12369.95	12369.95			-	-	-	-
Rain-fed	9895.96	9895.96	1.16	1.16				
Irrigated	2473.99	2473.99	0.29	0.29				
Sorghum	42484.38	42484.40			-	-	-	-
Rain-fed	42059.54	42059.56	4.93	4.93				
Irrigated	424.84	424.84	0.05	0.05				
Sunflower seed	185037.39	185037.51			-	-	-	-
Rain-fed	181336.64	181336.76	21.26	21.26				
Irrigated	3700.75	3700.75	0.43	0.43				
Livestock				***(head)***				
Beef cattle	443612	443612	52	52	495	4950	10	10
Mutton sheep	1117561	1117561	131	131	11385	11385	23	23
Pork pig	17062	17062	2	2	495	495	1	1
Chicken broilers	49010600	49010600	5745	5745	6435	6435	13	13
Chicken eggs	1868289	1,868,289	219	219	2475	2475	5	5
Dairy cattle	51186	51186	6	6	495	495	1	1

Source: Own computations

Table 5.16 shows the corresponding production level aggregated at farm type and regional levels. For the large farm type, columns 2 and 3 show the observed and optimal production levels respectively. The two columns are almost exactly equal in values. Columns 4 and 5 show the same trend for small farm type. Columns 6 and 7 show observed and optimum production levels at regional level. The columns are almost exactly the same, implying that the model reproduces the production level observed at the base year. Therefore, this model is validated in its capability to reproduce observed data. The model reproduces almost exactly the base activity levels. Also, it reproduces exactly the observed base period allocation of land among cropping activities and among farm types at regional level. It also calibrated to supply response to *a priori* supply response at all levels.

Table 5.16: Observed and optimal supply

	Large farm type		*Small farm type*		*Region*	
	Observed	**Optimal**	**Observed**	**Optimal**	**Base**	**Optimum**
Crops			**(ton)**			
White maize	2,718,393	2,718,395	6,055	6055	2,724,448	2724451
Yellow maize	1,617,418	1,617,420	12,558	12558	1,629,976	1629977
Wheat	517,675	517,674	281	281	517,956	517955.78
Soya beans	305,08	30,508	-	-	30,508	30508.35
Sorghum	162,899	162,899	-	-	162,899	162899.10
Sunflower seed	269,343	269,343	-	-	269,343	269343.33
Livestock			**(ton/litre/unit)**			
Beef cattle	60,255	60,255	336	336	60,591	60591.35
Mutton sheep	30,000	30,000	151	151	30,151	30150.88
Pork pig	10,233	10,233	260	260	10,493	10492.79
Chicken broilers	74,361	74,361	8	8	74,369	74369.05
Chicken eggs	515,199,400	515,199,400	568,755	568755	515768100	515768100
Dairy cattle	357,984,700	357,984,700	2,740,696	2740696	360725400	360725400

Source: Own computations

CHAPTER 6

EFFECTS OF MARKET AND LAND REDISTRIBUTION POLICIES ON RESOURCE USE AND OUTPUT SUPPLY

6.1 Introduction

It was established earlier that the South African (Free State included) agricultural sector has been undergoing important changes since late 1980s and early 1990s. For example, the long period of producer price supports through the State marketing boards has been replaced by a more liberal market. The risk in a farm business is not only related to production or yield risk but also to price which is inevitable in a free market. In addition to this, there is agrarian reform which is meant to restructure the farm industry.

Therefore, in this chapter, the model is applied to simulate the possible effects of the changes and implementation of some policies, on resource use and output supply response at farm-level. The responses are aggregated at the regional level, and some policy issues related to the results are mentioned. The research questions are answered based on the model behaviour.

6.2 Effects of changes in and implementation of some policy and development strategies

Since 1994, after the democratic election when the ANC took over government, the government put in place and are still proposing a number of policies and development strategies to restructure the farm industry and encourage competitiveness. Main policies include agrarian reform, agricultural trade liberalisation, deregulation of agricultural marketing; removal of certain tax concessions and direct subsidies. In the recent time agricultural land tax is being proposed and already being implemented in some provinces.

The strategic plans for agriculture include sustained profitable participation in agriculture by all stakeholders. Farmland is being redistributed to create new farm economic activities. The effect of government-assisted land acquisition for emerging farmers is evidenced in the growth in the number of farming units of the small farm type in the Free State. However, decline in the number of active farm units in the large farm type may be attributed to the changes in some macro-economic variables which make farming less profitable and/or more risky. Jooste *et. al.* (2003) states that trade liberalization and market deregulation are measures that could put producers under pressure to become more efficient otherwise farmers that could not be competitive may exit the industry.

The South African government in its efforts to redistribute wealth in the economy, does not only leave the industry to the effects of macro-economic variables but also is implementing and propose to implement some policies to achieve agricultural-led growth, employment and redistribution, among other things. Therefore, the model developed in this study was applied to simulate the potential effects of transferring the targeted 30% of commercial farmland to establish more farm units of the small farm type. The model was also applied to simulate the potential effects of levying the proposed agricultural land tax.

Therefore in this Chapter, it is envisaged that the liberalized market environment may pose some challenges to the farm types, hence the simulation of potential effects that some macro-economic variables may have on the farm and regional supply. Table 6.1 presents the scenarios considered with the underlying assumptions, the endogenous variables and the dimension of the effects examined. Some of the agricultural policies and development strategies were conceptualised into different scenarios. One or more assumptions are made in a scenario to represent a more realistic but simple-to-understand results for the purpose of this study.

Table 6.1: The scenarios considered

Scenarios	*Assumptions*	*Endogenous variables*
I	• Agricultural land transferred from the large farm type to establish more small farm units • Large farm units decrease • Small farm units increase • Both farm types have technical progress • Constant cost of production	• Output supply response at farm-type and regional levels
II	• Agricultural land transfer from the large farm type to establish more small farm units • Large farm units decrease • Small farm units increase • Small farm type do not have technical progress • Constant cost of production	• Output supply response at farm-type and regional levels
III	• No 'forced' land transfer • Large farm units decrease • Large farm size increase • No small farm type • 10, 15 and 20% increase in TP • Constant cost of production	• Output supply response at farm-type and regional levels
IV	• Implementing agricultural land tax at 1% and 2% • It increases opportunity cost of land i.e. revenue from land rented-out increases as much as cost of renting-in land • Constant cost of production	• Changes in technology of production • Output supply response at farm-type and regional levels

6.2.1 The effects of scenario I on output supply

In Scenario I, the effects of the risk in the marginal revenues of the selected production activities and the trends in the number of farm units are combined. The technical progress in the farm industry, as found in the literature, is also assumed to be observed for the farm types. The cost of production is assumed constant. This scenario was simulated and the effects on farm-level supply curves are examined. The farm type supply curves are aggregated into a regional supply response.

The number of farm units in the large farm type has been decreasing from 1994 to 2004. This trend is assumed to continue to decrease from 8,531 in 2004 to 7,112 in 2015 at the arithmetic mean of 129 farm units per year. However, the number of farm units in the small farm type is assumed to continue increasing from 495 in 2004 to 8,635 in 2015 at the arithmetic mean of 740 farm units per year. It is acknowledged that an arithmetic mean of 740 farm units per year is considerably high as such increase has not been recorded in the Free State LRAD programme. However, this assumption is based on the proposal by the Ministry of Agricultural and Land Affairs. The Ministry hopes to transfer land at the rate of 2.2 million ha per year from 2006 to 2015 in order to reach the target of transferring 30% of farmland from commercial agriculture by 2014

It is also acknowledged that despite the decrease in the number of the large farm units, there are increases in the production outputs per hectare because of an increase in factor productivity. It is therefore assumed that there is technical progress in the farm industry. Technological progress was incorporated into this scenario as a means through which farmers respond to the challenges in the industry. It is also assumed that the technical coefficients and costs of production for the two farm types do not change.

The projected marginal revenues and the number of farm units in each farm type for the 11 years (from 2005 to 2015) are presented in Table 6.2. The probability distributions of the marginal revenues suggest increasing trends in the marginal revenues for white maize, yellow maize and wheat while the marginal revenues for other production activities may be on the decrease.

Table 6.2: The projected trends in number of farm units and the marginal revenues

	Projection										
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	Number										
Number of farm units:											
Large farm	8402	8273	8144	8015	7886	7757	7628	7499	7370	7241	7112
Small farm	1235	1975	2715	3455	4195	4935	5675	6415	7155	7895	8635
Crop output	**Expected marginal revenue (R/ha)**										
White maize	4132.68	4267.63	4402.59	4537.54	4672.49	4807.44	4942.39	5077.34	5212.29	5347.24	5482.19
Yellow maize	4013.20	4226.63	4440.07	4653.51	4866.95	5080.39	5293.83	5507.27	5720.71	5934.15	6147.59
Wheat	4044.79	4138.54	4232.28	4326.02	4419.76	4513.50	4607.25	4700.99	4794.73	4888.47	4982.22
Soya beans	2183.35	2173.36	2163.37	2153.39	2143.40	2133.41	2123.42	2113.44	2103.45	2093.46	2083.47
Sorghum	2718.54	2702.58	2686.61	2670.65	2654.69	2638.72	2622.76	2606.80	2590.84	2574.87	2558.91
Sunflower	2942.02	2931.61	2921.20	2910.79	2900.38	2889.97	2879.56	2869.15	2858.74	2848.33	2837.92
Livestock output	**Expected marginal revenue (R/unit)**										
Beef	1357.37	1305.06	1252.76	1200.46	1148.15	1095.85	1043.54	991.24	938.93	886.63	834.33
Mutton	344.35	342.79	341.23	339.67	338.12	336.56	335.00	333.44	331.88	330.32	328.76
Pork	2095.11	1984.67	1874.22	1763.77	1653.33	1542.88	1432.44	1321.99	1211.54	1101.10	990.65
Chicken	30.00	29.71	29.42	29.13	28.84	28.55	28.26	27.97	27.68	27.39	27.10
Egg	144.69	144.58	144.46	144.35	144.24	144.12	144.01	143.90	143.79	143.67	143.56
Dairy milk	13275.16	13233.32	13191.48	13149.64	13107.80	13065.96	13024.13	12982.29	12940.45	12898.61	12856.77

Source: Own computations

This scenario shows the picture of a transformed farm industry by the year 2015. From the base data which is used, it is estimated that only about 2.5% of agricultural land has been transferred so far from 1994 to December, 2003 (DLA, 2004). This amount of land was transferred to establish about 495 farm units of the small farm type. So it is therefore assumed that the remaining 27.5% of land will be transferred from the commercial farm type to establish an additional number of developing farm units. It is also assumed that the average farm size in the base year for the small farm type units is maintained such that transferring the remaining 27.5% of land will amount to about 3,214,758ha of farmland to establish an additional 8,145 units of the small farm type. This amount is added to the existing 495 units in the base year adding up in 8,640 farm units of the small farm type by the year 2015. The scenario formula is as follows:

$$Scinario\_nf_2 = \frac{0.275\, x\; bas\_nf_1\; x\; bas\_land_{f_1}}{bas\_land_{f_2}} + bas\_nf_2 \qquad 6.1$$

where parameter $scenario\_nf_2$ = number of farm units of the small farm type in 2015. Constant 0.275 represents the 27.5% land transfer from the commercial farm type. Parameter bas_nf_1 is the base year number of farm units in the commercial farm type which is 8,531 in the base year. Parameter bas_land_{f1} is the farm size (ha) of a typical farm unit in the large farm type which is 1,370.3ha after transfer of land is accomplished. Parameter bas_nf_2 is the base number of farm units in the small farm type which is 495 in the base year.

The discussion presents a decline in the number of farm units in the large farm type. The current observed decreasing rate of number of farm units from the large farm type indicates a decline of about 129 farm units per year. Therefore, the yearly decrease of about 129 farm units in the large farm type will result in about 7,112 farm units by the year 2015 when 30% of the transfer will have been achieved. One can argue that as the number of large farm type units is decreasing, average farm size of the remaining farm units will be increasing. However, there are not enough data to establish the possible increase in the farm sizes of the remaining large farm units. But since land reform is to redistribute land from existing large farms to the small farm type, then the farm size of the remaining farm units of the large farm type is estimated with the following formula

$$Scenario\_landf_1 = \frac{0.725\, x\, bas\_nf_1\ x\, bas\_land_{f_1}}{scenario\_nf_1} \qquad 6.2$$

Where parameter scenario_land$_{f1}$ is the average farm size of the remaining farm units in the large farm type. Scenario_nf$_1$ is the projected number of farm units in large farm type estimated at 7,112. Other variables and parameters are as defined above.

The land transfer is based on the principle of willing-seller willing-buyer government-assisted land market approach. Therefore, it is further assumed that those commercial farm units who are less competitive would be the ones that would sell their lands. Also, some may sell an excess of their land to have a manageable farm size and become more efficient as van Zyl, Binswanger and Thirtle (1995) report an inverse relationship between farm size and efficiency in the South African agriculture. This is not to assume that only size determines efficiency as there is the possibility of scale efficiency. Therefore technological progress is incorporated into this scenario as a means by which farm types may shift their supply curve to the right. The positive increase in a number of agricultural production outputs despite the decline in the number of farm units as reported in NDA (2006) justifies this assumption. This could be considered as scale efficiency.

Equation 6.2 depicts a decrease in average farm resources in the large farm type to about 993.34ha of agricultural land as a result of land reform. This is expected to consist of about 359.64ha of arable land and 633.83ha of grazing land. The arable land may be composed of about 351.36ha of dry non-irrigable arable land while the remaining arable land is irrigable at an estimate of about 8.27ha per unit. This scenario implies that by 2015, there will be 7,112 farm units of the large farm type and 8,640 farm units of the small farm type. This assumption gives indication of redressing the skewed farm industry which the land reform policy is meant to achieve.

This scenario represents a set of changes and it is not possible to establish a rigid *a priori* direction of response. The traditional analysis based on comparative static equilibrium is no longer valid because more than one parameter changes simultaneously. However, it would seem plausible to expect that changes in each of the parameters in each of the assumptions would have different effects on the level of resource use, switches between farming systems, changes in cropping pattern, substitution effects, and regional supply response. Increase in marginal revenue is expected to cause a movement upward the supply curve and vice versa. However, since the model is specified with risk terms and farmers' risk attitudes, the higher the variance (risk) in the revenue of a production activity, the lower the supply response even when marginal revenue increases. Also, the farm type with relatively higher risk aversion parameter will reduce the activity level for production activities whose marginal revenues are increasing. A decrease in the number of large farm units is expected to shift the supply curve to the left and an increase in the number of the small farm type units is expected to shift the supply curve to the right.

Table 6.3 shows that for the large farm type, despite that the expected marginal revenues of white maize, yellow maize and wheat are higher in 2015, the supplies in 2015 decrease for all the crops and animal products by an average of 15.23%. The general decrease in the supply of the crops and animal products could be explained partly because of the decrease in the number of large farm units. The decline could have been more pronounced if technical progress had not been incorporated into this scenario. More of these effects could be attributed to the decline in the number of the large farm units from 8,531 units in the base year to 7,112 units in the scenario year. This is a decline of about 17%. It could be inferred that a decline in the number of farm units shifts the farm-type supply curves by almost the same proportion. It is also noticed that about a 15% decline in each of the supply curves could have been because the expected revenue, the level of risk in the revenue and technical progress minimise such effects.

Table 6.3: Base level and % changes in supply as a result of scenario I

	Base			27.50% land transfer		
	Large farm type	**Small farm type**	**region**	**Large farm type**	**Small farm type**	**Region**
No of farm units	8531	495		7112	8640	
Crop		**(ton)**			**(%)**	
White maize	2718395	6055.29	2724448.07	-15.03	1657.51	-11.32
Yellow maize	1617420	12557.90	1629976.83	-15.12	1657.14	-2.24
Wheat	517674.00	280.78	517956.78	-14.56	1658.85	-13.65
Soya beans	30508.34	-	30508.34	-15.33	-	-15.33
Sorghum	162899.11	-	162899.11	-15.14	-	-15.14
Sunflower seed	269342.58	-	269342.58	-15.54	-	-14.54
Livestock		**(ton/litre/unit)**			**(%)**	
Beef-cattle	60255.18	336.18	60591.36	-15.41	1657.81	-6.13
Mutton	30000.00	150.92	30150.88	-15.38	1657.98	-7.00
Pork	10233.02	259.77	10492.79	-15.31	1658.36	26.13
Broilers-chicken	74360.98	8.14	74369.12	-15.18	1659.02	-15.00
Layers-chicken	515199600	568755.24	515768700	-15.36	1658.07	-13.52
Dairy milk	357984700	*274069600*	360725400	-15.38	1657.99	-3.66

Source: Own simulation results from the model

For the small farm type, as expected, the supply curves for the crops and animal products are shifted to the right at an average of about 1,658%. This could be mainly explained by a massive increase in the number of farm units from 495 in the base year to 8,640 in the scenario year. This is an increase of about 1,645%. It confirms that percentage change in the number of farm units could lead to more or less a proportional change in the supply curves.

These show the overwhelming effects of the increase in the number of farm units and technological progress. An increase in the number of the small farm units shifts the regional supply curves to the right. This looks promising with respect to establishing more developing farm units as a means of redressing the imbalance in the industry. However, these results must be interpreted with caution. It is obvious that some LRAD farms will be established. However, one burning issue in the agrarian reform remains the productivity and efficiency among the LRAD farms as the government lacks enough resources to provide integrated support services which would enhance productivity among the LRAD farms.

Also, the decreasing effects that the declining number of the large farm units has on the regional supply curves crowd-in the increasing effects that the increasing number of small farm units has on the regional supply curves. This happens for all the crops but it is pronounced in the supply responses for soya beans, wheat, sorghum, sunflower seeds, broilers chicken and layers-egg. These are relatively capital-intensive production activities. The net positive change in the regional supply curve for pork production is as a result of the observation that a relatively high proportion of the small farm type gets engaged in rearing pigs for pork production. It is the only production activity where the small farm units produced about 2.28% of the regional production. This result shows the implication of small farm types not having enough capital and other resources necessary to engage in capital-intensive production activities.

The results could still have been over-estimated by assuming technical progress among the small farm type after the assumed massive land transfer. Of course, some assumptions in this scenario have affected the effects of other assumptions. It is obviously difficult to isolate the effects of each assumption. However, the importance of some assumptions and the implications should not be overlooked. First, as revenue changes, there is a movement along the supply curve. Also as the number of farm units changes, there is a shift in the regional supply curves. Therefore efforts are made in the next section to give more details on the impacts of the proposed and assumed agrarian reform and assumed technical progress.

6.2.2 Output supply response based on scenario II

In this scenario, the assumed technical progress for the small-scale farmers in scenario I was dropped as indication exists that most LRAD farms have not been able to make a substantial contribution to the regional supply. This can among other things be attributed to a lack of capital, experience, etc. which are necessary for large volume production. Therefore scenario II was simulated to minimise the overestimation that may be embedded in scenario I because of the technical progress assumed for the small farm type.

Table 6.4 shows that the assumed technical progress has negligible effects on the simulated production levels of the small farm type. It could therefore be inferred that multiplying the number of small farm units has negative implication on regional resource use and output supply especially when land is been transferred from the large farm type to settle small farm units. The decline in the supply response on average is about 0.25%. These results raise concern about the policy objective to settle a large number of small farm units which are less efficient compared to large farm units.

Table 6.4: Base level and % changes in supply as a result of scenario II

	Base			27.50% land transfer		
	Large farm type	**Small farm type**	**region**	**Large farm type**	**Small farm type**	**Region**
No of farm units	8531	495		7112	8640	
Crop		**(ton)**			**(%)**	
White maize	2718395	6055.29	2724448.07	-15.03	1645.45	-11.34
Yellow maize	1617420	12557.90	1629976.83	-15.12	1645.45	-2.33
Wheat	517674.00	280.78	517956.78	-14.56	1645.45	-13.66
Soya beans	30508.34	-	30508.34	-15.33	-	-15.33
Sorghum	162899.11	-	162899.11	-15.14	-	-15.14
Sunflower seed	269342.58	-	269342.58	-15.54	-	-14.54
Livestock		**(ton/litre/unit)**			**(%)**	
Beef-cattle	60255.18	336.18	60591.36	-15.41	1657.81	-6.13
Mutton	30000.00	150.92	30150.88	-15.38	1657.98	-7.00
Pork	10233.02	259.77	10492.79	-15.31	1658.36	26.13
Broilers-chicken	74360.98	8.14	74369.12	-15.18	1659.02	-15.00
Layers-chicken	515199600	568755.24	515768700	-15.36	1658.07	-13.52
Dairy milk	357984700	*274069600*	360725400	-15.38	1657.99	-2.66

Source: Own simulation results from the model

6.2.3 Output supply response based on scenario III

The previous scenario indicates the direction of regional output supplies if the farmland is transferred from the large farm type to establish more small farm units. The implication may be reduced production as less and less farmland is available for the more efficient large farm units. This is contrary to the trend in the developed world were farms are consolidated to achieve economies of size and higher production levels (Ahearn, Yee and Huffman, 2002). Therefore in this scenario, it is assumed that the observed decrease in the number of the large farm units is an indication that in South Africa as elsewhere farmers are getting bigger to become more efficient. This scenario is to present a picture of a reduced number of large farm units but with larger farm areas with more efficiency. This is not an objection to the land reform in South African context but to present another perspective of a more efficient agrarian reform. Policy that allows the emerging of larger farms as economically viable farm units to gain economies of scale is therefore assumed as an alternative to small farm types that are numerous in numbers but lack output as observed in the less-developed and developing economies. It has been established earlier in this study that a means by which a nation could be more productive and thus become wealthier is to allocate the existing resources efficiently and to increase the rate of use of such resources.

In this scenario, it is assumed that the targeted 30% land transfer is to establish a number of large farm units where the intended beneficiaries have proven commitment and knowledge of agriculture. In this scenario, it is assumed that there is no small farm type. It is also assumed that the average farm size of the larger farm type increases as the decreasing number of the larger farm units is observed with constant regional land supply. The scenario farm size is computed with the following formula:

$$Scenario\_land = \frac{(bas\_nf_1 - scenario\_nf_1)\ x\ bas\_land_{f_1}}{scenario\_nf_1} + bas\_land_{f_1} \qquad 6.3$$

Scenario_land = average farmland of each larger farm unit in the scenario; bas_nf_1 = base year number of farm units in the commercial farm type which is 8,531; $scenario\_nf_1$ = number of larger farm after land transfer; bas_land_{f1} = an average farm size (ha) of a farm unit in the base year which is 1,370.3ha.

From the previous scenario, the yearly decrease of about 129 farm units in the large farm type will results in about 7,112 farm units by the year 2015 when 30% of the transfer will have been achieved.

Equation 6.3 gives an increase in average farm resources in the larger farm type to about 1,643.70ha of agricultural land. This is expected to consist of about 595.02ha of arable land and 1,048.68ha of grazing land. The arable land may be composed of about 581.34ha of dry non-irrigable arable land while the remaining arable land is irrigable at an estimate of about 13.69ha per unit. This scenario implies that by 2015, there will be 7,112 farm units of the larger farm type. This assumption gives indication of farm consolidation which may enhance productivity both at farm-level and regional level.

This scenario represents a set of changes and it is not possible to establish a rigid *a priori* direction of response. The traditional analysis based on comparative static equilibrium is no longer valid because more than one parameter changes simultaneously. However, it would seem plausible to expect that changes in each of the parameters in each of the assumptions would have different effects on the level of supply response.

The projected marginal revenues in the 2015 are expected. Each of the activity levels has different level of revenue risk. Technical progress is also assumed. The farm size has increased. However, it is difficult to precisely conceptualise an increase in efficiency or technical progress that may result from farm consolidation or increase in farm size. But it seams plausible to assume that efficiency or technical progress will occur after farm consolidation or transforming of large-scale farms to larger farm type.

An increase in technical progress at 10%, 15% and 20% were simulated in this scenario. Among and in addition to other changes, the increase in technical progress is expected to shift the supply curves to the right for each crop and animal product. Also, the economics, the risk in the marginal revenues of each crop and animal products coupled with the risk attitude of the farmer are expected to have effects on the supply curves.

Table 6.5 shows the base level and the impacts of the assumed technical progress of the larger farm type. It is observed that at a 10% additional technical progress, only supplies of white maize, yellow maize, wheat and sunflower seeds would increase while the others decrease. This can be explained by the relative level of risk in the marginal revenues and the magnitudes of the gross margins which resulted into substitution between the enterprises. At the 15% increase in technical progress, more of the enterprises have positive response. The response remains highest in wheat followed by sunflower seed. Uncertainty of profits would lead risk-averse and risk-neutral economic agents to redirect their investment from a relatively higher-risk enterprise to a relatively lower-risk enterprise. Why there is a decrease in livestock production in favour of crop production could also be attributed to the relatively lower technical progress in livestock production as compared to crop production. Therefore these results show that having more farmland and lack of capital constraints as assumed in this model would not necessarily imply increase in all the production activities. However at the 20% increase in technical progress, all the enterprises have positive response. These results are similar to what Monke, Avillez and Ferro (1991) estimated for the restructuring of agriculture in the Northwest Portugal.

Table 6.5: Base level and % changes in supply as a result of scenario III

	Base	*Changes in technical progress*		
		10%	**15%**	**20%**
No of farm units	8531	7112	7112	7112
Crop	**(ton)**			
White maize	2718395	2.10	9.95	18.08
Yellow maize	1617420	0.98	8.33	15.92
Wheat	517674.00	7.99	18.51	29.53
Soya beans	30508.34	-1.58	4.60	10.94
Sorghum	162899.11	0.73	7.96	15.42
Sunflower seed	269342.58	8.16	19.50	29.86
Livestock	**(ton/litre/unit)**			
Beef-cattle	60255.18	-5.93	-1.39	3.19
Mutton	30000.00	-5.62	-0.93	3.80
Pork	10233.02	-4.92	0.11	5.21
Broilers-chicken	74360.98	-3.71	1.91	7.64
Layers-chicken	515199600	-5.47	-0.70	4.11
Dairy milk	357984700	-5.60	-0.90	3.84

Source: Own simulation results from the model

6.2.4 The effects of scenario IV on resource use and output supply

The proposed agricultural land tax is, according to the policy document, to discourage idle land or speculation in the land market. Van Schalkwyk, Louw and Dannhauser (1998) in a study on introduction of land tax in South Africa used a linear programming model to simulate possible impacts of levying land tax on shadow prices of land and on market values of land in different scenarios. The study shows that if a land tax is implemented, the cost of the land tax to the land owner is difficult to measure.

Therefore, this study aims to contribute to a discussion of agricultural land tax from another perspective. In this scenario, it is assumed that land tax will affect the opportunity costs of land such that the proportional effect of land value tax is reflected in the cost of renting-in land by a tenant and in the revenue accruable from renting-out land by a farmer. This assumption is found on the insight that the intention with the policy may be to bring under-utilized farm land into the market.

Therefore, in this scenario an attempt was made to represent the policy thrust by assuming[4] that land tax is an additional cost on land. Rent value of land is used as an indication of the increase in the opportunity cost of land. It is assumed that land are rented-in at the prevailing land rent of about R130 per ha per annum for non-irrigable arable land; R1,000 per ha per annum for irrigable land and R80 per ha per annum for grazing land. Rental values were also imputed for the housing of livestock to balance the economics of each production activities. The rental values of housing or structures for livestock production imputed in the model are R1,000/sow per year, R1.20/broilers chicken per year and R2/layer-chicken per year.

Therefore the levying of a land tax was incorporated into the scenario to reflect an increase in the cost of land rented-in or the opportunity cost of land and revenue from land rented-out. Also, it is assumed that the tendency to rent-out land might increase if levying land tax raises cost of renting-in land to tenants or erodes the profitability of agricultural production to land owners or the land value increases more than the marginal revenue from production activities. It is therefore assumed that farmers have choice of renting-out land when production is not profitable. It is also assumed that the rate of land tax is an indication of the increase in land value when renting-out such land. Such that the land owners transfer a proportional land tax to the tenant. These assumptions were incorporated into the scenario formula as

$$Scenario\_\cos t \;=\; bas\_\cos t \cdot (1 + scinario\_tax) \qquad 6.4$$

$$Scinario\_rent \;=\; bas\_rent \cdot (1 + scinario\_tax) \qquad 6.5$$

Where parameter Scenario_cost is the assumed opportunity cost of land or cost of land rent when land tax is introduced. Parameter bas_cost is the opportunity cost of land or cost of land rent-in at the base level (when tax has not been introduced).

[4] This insight or assumption benefited from the discussion with Prof. Terry Roe of the Department of Applied economics, University of Minnesota, US. The author therefore gratefully acknowledges such inputs in this study.

Parameter scenario_tax is the proposed land tax rate. Parameter Scenario_rent is the revenue from land rented out when land tax is introduced. Parameter bas_rent is the revenue from land rented-out at base level (when tax has not been introduced). Revenue from land-rented out was incorporated into the objective function of the model as alternative revenue if production is not profitable. It is assumed that each farm type will rent out the proportion of farm land that is not used in agricultural production. However, to account for rental transaction costs in renting-out farmland a factor was used to reduce revenue from renting out land.

This approach was to adjust for macro-economic variables that affect the costs of or returns to land and to prevent land owners from transferring more than a proportional tax increase to tenant. Empirical justification for this assumption was found in the Van Schalkwyk's (1995) findings that returns to farming are affected by land price movements in South Africa between 1960s and 1980s. Also, the theoretical justification was found on the argument by Trivelli (1997) that land transaction costs should be considered in land rental market because

i. Increase in transaction costs decreases the real net rent received by land owners;
ii. Increase in land owner's fixed costs such as maintenance or depreciation reduces the net rent that could be obtained from land;
iii. Increase in searching, bargaining and transfer costs in the land market also reduce the net rents that could be obtained from renting-out land; and
iv. Increase in real interest rate changes the opportunity cost of investments and makes other production more attractive. This can also reduce the rental value.

Although there are other factors that drive up the rental value of land, the empirical analysis by Van Schalkwyk (1995) shows the peculiarity of the South African land rental market. The rental market is thin and agricultural use value of land may not give an indication of rental values of land. A number of socio-economic variables exist that will not allow expansion of the rental market. Therefore the rental value of land could be low even when tax is levied on such land because his structural model gives an indication of a negative impact of land tax on land values. Therefore, rental value of land rented-out are penalised based on those assumptions such that revenue from renting-out land is imputed to compete with the least gross margin production activities in the model. For this scenario, 1% and 2% tax rates were applied and the effects are discussed in the sub-section that follows. This scenario represents increase in the cost of production yet it is not straight forward to expect a rigid relationship between land tax and resource use and supply response. In strong economic terms, increase in cost of production may result in decrease in activity levels or switching to more productive use of a resource. However, the assumptions and the way land tax is modelled will influence the response.

6.2.4.1 Effect of scenario IV on activity level

In contrast to a tax on buildings, a land value tax is levied only on the unimproved value of land. An economic argument that justifies land tax states that land tax is the only tax which does not distort market mechanisms nor deter production (George, 1897; Hyman, 1973). However this argument holds only if it is implemented properly. It is a tax that is levied on a land-owner as a portion of the value of a site or parcel of land that would exist even if that land had no improvements. In quantifying the probable land tax, expert's idea was that the prevailing thought is to levy a highest rate of about 2%. The general inclination informed the choice of a 1% and 2% simulation.

Due to lack of data on land market values by quality, the land tax payment is based on the general market value of land. Given the average of R1,119/ha market value of agricultural land in the region, about R11/ha/annum and R23/ha/annum will be the rent on land to be paid by each farm unit if 1% and 2% tax rates respectively were levied. Given about 12 million ha of farmland in the region, the revenue accruable to the government will be about R133 million and 266 million per annum at 1% and 2% respectively. Of this amount, an average large farm will be paying about R15,334 per annum or R30,667 per annum at 1% and 2% tax respectively. On average a typical small farm will be paying about R4,416 or R8,831 per annum at 1% or 2% tax rate respectively. It must be remembered that these estimates are based on land areas rather than land quality due to lack of data on the market values of different land qualities.

6.2.4.2 The effects of scenario IV output supply

Table 6.6 shows no substantial changes in the activity level. It is interesting to note that if the tax is levied at either 1% or 2%, it will not induce both farm types to decrease production activities in favour of renting-out farmland substantially. However, it is also interesting to note that the decrease in production activity levels is marginal (for large farm type, the highest is about 0.23% and 0.17% for irrigated sunflower seed and wheat productions respectively if 2% tax rate is levied). The response by the small farm type is less.

These results support the arguments by George (1897) that land supply is inelastic. The decrease is pronounced on irrigated cropping. This can be explained by the high cost of irrigable land. It implies that the cost of renting-in irrigable land or acquiring irrigation facilities will be appreciably high or that opportunity cost of irrigable land or irrigation facilities will be relatively higher when tax is levied per land value.

Another interpretation is that levying land tax may discourage intensive production such as irrigated farming because the rental cost of irrigable land would be higher when land tax is levied. These results support the arguments by Nieuwoudt (1995) that land tax may discourage investment (e.g. irrigation infrastructure) on land in the long-run and that such a tax also has a minimum impact on production level.

Table 6.6: Base level and % changes in activity levels as a result of scenario IV

	Base			*1% tax rate*			*2% tax rate*		
	Large farm type	**Small farm type**	**region**	**Large farm type**	**Small farm type**	**region**	**Large farm type**	**Small farm type**	**Region**
Crop		**(ha)**				**(%)**			
White maize:	659958.84	1801.80	661760.44	-0.01	0[5]	-0.01	-0.03	-0.01	-0.03
Dry-land	640194.05	1747.75	641907.63	-0.01	0	-0.01	-0.02	-0.01	-0.02
Irrigated	19798.75	54.05	19852.81	-0.04	-0.01	-0.04	-0.09	-0.03	-0.09
Yellow maize:	385004.30	3400.65	388404.80	-0.01	0	-0.01	-0.02	-0.01	-0.02
Dry-land	373454.17	3298.63	376752.65	-0.01	0	-0.01	-0.02	-0.01	-0.02
Irrigated	11550.12	102.02	11652.14	-0.04	-0.01	-0.04	-0.07	-0.02	-0.07
Wheat:	190497.29	128.70	190625.61	-0.03	-0.01	-0.03	-0.05	-0.02	-0.05
Dry-land	180972.43	122.27	181094.32	-0.02	0	-0.02	-0.04	-0.02	-0.04
Irrigated	9524.86	6.44	9531.29	-0.08	-0.03	-0.08	-0.17	-0.07	-0.16
Soya:	12369.95	-	12369.95	-0.01		-0.01	-0.03		-0.03
Dry-land	9895.96	-	9895.96	-0.01	-	-0.01	-0.02	-	-0.02
Irrigated	2473.99	-	2473.99	-0.04		-0.04	-0.07	-	-0.07
Sorghum:	42484.40	-	42484.40	-0.01		-0.01	-0.02		-0.02
Dry-land	42059.56	-	42059.56	-0.01	-	-0.01	-0.02	-	-0.02
irrigated	424.84	-	424.84	-0.05		-0.05	-0.10	-	-0.10
Sunflower	185037.51	-	185037.06	-0.03		-0.03	-0.07		-0.07
Dry-land	181336.76	-	181336.32	-0.03	-	-0.03	-0.06	-	-0.06
irrigated	3700.75	-	3700.74	-0.12		-0.12	-0.23	-	-0.23
Livestock		**(herd)**				**(%)**			
Beef-cattle	443612	495	448562	0	0	0	-0.01	0	-0.01
Mutton-sheep	1117561	11385	1128946	-0.01	0	0	-0.02	-0.01	-0.02
Pork-pig	17062	495	17557	0	0	0	0	0	0
Broilers	49,010,640	6435	49017075	0	0	0	0	0	0
Layers	1,868,590	2475	1870765	0	0	0	0	0	0
Dairy milk	51186	495	51681	0	0	0	0	0	0

Source: Own simulation results from the model

From Table 6.7, the decline in irrigation area does not cause substantial decline in total area grown to crops with 1% and 2% land value tax rates. It is noticed that there are negative but marginal responses to relatively land intensive (crop production) activities especially high value crop production activities. The results support the economic justification of a land tax. The argument that land tax if properly implemented will not deter production nor distort market mechanism is, though weakly, supported by these results.

[5] Absolute value less than 0.005%

Table 6.7: Base and % changes in supply as a result of scenario IV

	Base			***1% increase***			2% decrease		
	Large farm type	**Supply Small farm type**	**Region**	**Large farm type**	**Supply Small farm type**	**Region**	**Large farm type**	**supply Small farm type**	**region**
Crop		**(ton)**				**(%)**			
White maize	2718395	6055.29	2724448.07	-0.01	0	-0.01	-0.03	-0.01	-0.03
Yellow maize	1617420	12557.90	1629976.83	-0.01	0	-0.01	-0.02	-0.01	-0.02
Wheat	517674.00	280.78	517956.78	-0.03	-0.01	-0.03	-0.06	-0.02	-0.06
Soya	30508.34	-	30508.34	-0.02	-	-0.02	-0.04	-	-0.04
Sorghum	162899.11	-	162899.11	-0.01	-	-0.01	-0.03	-	-0.03
Sunflower	269342.58	-	269342.58	-0.04	-	-0.04	-0.07	-	-0.07
Livestock		**(ton/litre/unit)**				**(%)**			
Beef-cattle	60255.18	336.18	60591.36	0	0	0	-0.01	0	-0.01
Mutton	30000.00	150.92	30150.88	-0.01	0	-0.01	-0.02	-0.01	-0.02
Pork	10233.02	259.77	10492.79	0	0	0	0	0	0
Broilers	74360.98	8.14	74369.12	0	0	0	0	0	0
Layers	515199600	568755.24	515768700	0	0	0	0	0	0
Dairy	357984700	*274069600*	360725400	0	0	0	0	0	0

Source: Own simulation results from the model

However, the results do not support an argument behind land tax that it discourages speculation bubbles in land market and encourages the efficient and productive use of land with respect to crop production because of a decline in activity level and supply were noticed in the production of relatively land-intensive high value production activities. The declines in supply are 0.07% for sunflower seeds; 0.06% for wheat; 0.04% for soya bean; 0.03 for each of white maize and sorghum; 0.02% for yellow maize productions at 2% land value tax. These though marginal decrease in regional supply resulted from decreases in irrigation cultivations of these crops. The supply response is only marginal because few areas are irrigated generally. It therefore follows that in regions where there are high levels of irrigation facilities, decline in irrigated area would have substantial effects on output supply. These results suggest that levying land tax may discourage investment in irrigation facilities.

By implication, these relatively low effects of land tax are in line with the claim by Van Schalkwyk *et. al.* (1998) that if farmers can down-shift land tax to the tenant, the effect of levying land tax may not be substantial even on land prices or shadow prices of land. Therefore the assumptions behind these simulations give results that are close to *a priori* expectations and therefore could serve as information for general land tax policy formulation. However, there is need for continuous and high frequent studies on land valuations because an effective tax rate will depend on proper and efficient valuation of land. This implies that land tax need not be static but dynamic with respect to the market value of land in each community. Neither should land tax be general but should be related to positional advantages, fertility or natural resources, etc. that affect land value.

CHAPTER 7

SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Introduction

From the early 1990s, the South African government has put in place some policy measures meant to restructure the economy and enhance competitiveness in the farm industry. In addition, trade was liberalised, the market was deregulated and subsidies and price supports were removed to make the industry competitive in both domestic and international markets. These policies may affect resource use and output supply at farm and consequently regional level, in the short term and in the near future.

Thus, in this study, a model that describes the present level of resource use and output supply and the farm industry structure in the Free State was developed. The model was used to simulate the potential effects of government intervention and the macro-economic effects on farm-level resource use and output supply response. These variables are aggregated at farm type and regional levels. The model considers the changes in market prices, the risks in production activity revenue and the resource constraints at farm level to determine the profit maximisation behaviour of farmers. The farm typology represents the large-scale commercial (mainly white) and developing small-scale (mainly black) farms, to which policy, is directed in the South African (Free State) economic reform efforts. The risks in the production activities' revenue were estimated and incorporated into the model to allow for possible substitution between the production activities. Rain-fed and irrigated farming were specified as separate enterprises to allow for switching between farming systems. The resource constraints at farm-level and regional level are specified to constraint the model's behaviour.

Summary, conclusions and policy recommendations follow in the next three sections. The last section of the chapter provides an outline of possible areas in which the model needs improvement and further research areas.

7.2 Summary

In Chapter 1, among other things, an argument on how climate determines resource availability, which in turn determines spatial distribution of resource use and output supply potentials in South Africa, was presented. The new agricultural policies and development strategies, specifically land redistribution, trade liberalisation and market deregulation, along with the current problems in the South African farm industry which may be attributed to these polices were presented. The objectives of the study were stated with methodology on how to answer the research questions namely how would farmers respond to risk, changes in agricultural policies; whether such responses differ between the large-scale and small-scale farmers and from enterprise to enterprise in a Free State case study.

In Chapter 2, details on the Free State agriculture with emphasis on resource availability and previous policies that have influenced the resource use and supply potentials and farm industry structure across the districts and population groups of the province are presented. The two farm types, the established commercial large-scale (mainly white) farmers and the developing small-scale (mainly black) farmers were characterised.

In chapter 3, it was established through a comprehensive literature review that factors that affect supply response among other things include risk, farmers' risk attitude, technology, farm industry structure, cost of production, etc. The choice of methodology for analysing such response behaviours of farmers was established to depend on the need to bridge the gap in knowledge from an empirical application of the mathematical or programming modelling approach, the potentials of mathematical modelling coupled with the dearth of data, necessitated the PMP modelling approach in this study. Reviews of empirical applications of such modelling approach were presented to establish that countries in Europe, America, etc. do such policy analyses to fine-tune their trade agreements, and common policy measures in order to achieve their respective national or regional objectives.

In Chapter 4, the choice of PMP modelling approach was further justified. The model was specified with risk and farmers' risks attitude estimated. In farm typology, the commercial large-scale farmers were broadly aggregated to the large farm type. So also the LRAD farms were broadly aggregated to small farm type. The *a priori* elasticities, which were estimated by other researchers who used econometric models, were used to specify the supply response behaviours of the model. The model was specified such that it maximises profit given prices, describes and predicts the market behaviour of representative farm types with respect to changes in some macro-economic and policy variables.

In Chapter 5, the data used, data sources and validation procedures were presented. The model parameters and variables were also presented. The structural characteristics of the farm types with respect to the model's parameters and farm-level resource limits were presented. The data and model validation results were presented. The model was validated based on its capability to reproduce the observed data and the *a priori* elasticities used to specify its marginal cost functions.

In Chapter 6, some agricultural policies and development strategies were conceptualised into scenarios. The model was applied to simulate the possible impacts of each scenario on resource use, switching between production technologies and output supply response. The main findings and conclusions are presented in the following section.

7.3 Conclusions of the findings of this study

South Africa is implementing and still hopes to implement a number of policies and development strategies namely agrarian reform, agricultural trade liberalisation, deregulation of agricultural marketing and agricultural land tax among others. However, the policy thrust is to have sustained profitable participation in agriculture by all stakeholders. Some of the agricultural policies and development strategies were conceptualised into different scenarios. One or more assumptions are made in a scenario to represent a more realistic but simple-to-understand results for the purposes of this study. The model developed in this study was then applied to simulate the potential effects of these polices and development strategies on resource use and output supply response at farm-level and regional level. The important findings of the study are summarised under the four scenarios simulated in this study.

7.2.1 Scenario I – Changes in supply response as a result of changes in the number of farm units and output revenues combined with technological progress and constant cost of production

In this scenario, the effects of the risk in the marginal revenues of the selected production activities and the trends in the number of farm units are combined. The scenario tries to represent land reform objective of transferring 30% of farmland from the large-scale commercial farmers to settle a number of small-scale farmers. The technical progress in the farm industry is also assumed to be observed for both the land and the small farm types. The cost of production is assumed constant. This scenario was simulated and the effects on farm-level and regional supply curves could be summarised as follow:

a) Given the projected marginal revenues in the scenario year and with technical progress, the number of the large farm units decreased at a about 17% from the 8,531 in the base year to about 7,112 in the scenario year, the supplies in 2015 decrease for all the crops and animal products by an average of 15.23%. It could be inferred that a decline in the number of farm units shifts the farm-type supply curves by almost the same proportion. It is also noticed that about a 15% decline in each of the supply curves could have been because the expected revenues, the level of risks in the revenues and technical progress minimise such effects.

b) For the small farm type, as expected, the supply curves for the crops and animal products are shifted to the right at an average of about 1,658%. This could be mainly explained by a massive (1,645%) increase in the number of farm units from 495 in the base year to 8,640 in the scenario year. These show the overwhelming effects of the increase in the number of farm units and technological progress. This looks promising with respect to establishing more developing farm units as a means of redressing the imbalance in the industry.

c) However, these results must be interpreted with caution. It is obvious that some LRAD farms will be established. However, one burning issue in the agrarian reform remains the productivity and efficiency among the LRAD farms as the government lacks enough resources to provide integrated support services which could enhance productivity among the LRAD farms.

d) It is important to note that, the decreasing effects that the declining number of the large farm units have on the regional supply curves crowd-in the increasing effects that the increasing number of small farm units have on the regional supply curves. This happens for all the crops but it is pronounced in the supply responses for soya beans, wheat, sorghum, sunflower seeds, broilers chicken and layers-egg. These are relatively capital-intensive production activities. These results show the implication of small farm types not having enough capital and other resources necessary to engage in capital-intensive production activities.

7.2.2 Scenario II – Changes in supply response as a result of changes in the number of farm units and output revenues combined with lack of technological progress among the small farm type

This scenario also tries to represent possible impact of land reform. The previous scenario assumes that the small farm type will also have technical progress however; there are indications that LRAD farms on most cases lack capital, knowledge and experience to adopt new technology. Therefore in this scenario, the assumed technical progress in scenario I was dropped to avoid overestimating the contribution of the small farm type to the regional output supply. Summary and conclusion drawn from this scenario are as follow:

a) The assumed technical progress has negligible effects on the simulated production levels of the small farm type. It could therefore be inferred that multiplying the number of small farm units has negative implication on the regional resource use and output supply especially when land is been transferred from a more efficient large farm type.

b) However, the scenario shows that the productivity and production level among the small farm type is so small that the lack of technical progress did not have any substantial effects on the supply response at the regional level. The supply response at regional level looks almost same compared to the response in scenario I expect that supply response by the small farm type drops by about 0.25% as a result of lack of technical progress.

7.2.3 Scenario III – Changes in supply response as a result of decrease in the number of the large farm units but with increasing farm size and technical progress:

This scenario tries to represent implementing land redistribution in a more conservative and economic way. The previous scenario indicates the direction of regional output supplies if the farmland is transferred from the large farm type to establish smaller farm units. The implication may reduce production if land reform is implemented in such a way that less and less farmland is available for the more efficient large farm units. Therefore in this scenario, it is assumed that the observed decrease in the number of the large farm units is an indication of larger farm units with higher efficiency. This is a possible picture of an agrarian reform that allows the emerging of a larger farm unit and assisting a previously disadvantaged portion of the population, who has proven commitment to farming as a business. This will ultimately result to consolidation of the large farm units to a more efficient and viable economic farming unit.

In this scenario, it is assumed that the targeted 30% land transfer is to establish a number of large farm units where the intended beneficiaries have proven commitment and knowledge of agriculture. The projected marginal revenues in 2015 are expected. Each of the activity levels has different level of revenue risk. Technical progress is also assumed. The farm size has increased. However, it is difficult to precisely conceptualise an increase in efficiency or technical progress that may result from farm consolidation or increase in farm size. Therefore increases in technical progress at 10%, 15% and 20% were simulated in this scenario. Summary and conclusion drawn from this scenario are as follow:

a) At a 10% technical progress, only supplies of white maize, yellow maize, wheat and sunflower seeds would increase while the others decrease. This can be explained by the relative level of risks in the marginal revenues and the magnitudes of the gross margins of individual production activities which resulted into substitution between the enterprises to have maximum net farm profit.

b) At the 15% increase in technical progress, more of the enterprises have positive response. The response remains highest in wheat followed by sunflower seed. However at the 20% increase in technical progress, all the enterprises have positive response.

7.2.4 Scenario IV – Changes in activity levels and supply response as a result of levying a land tax

The proposed agricultural land tax is, according to the policy document, to discourage idle land or speculation in the land market. Therefore, this study aims to contribute to a discussion of agricultural land tax from a perspective. It is assumed that land value tax will affect the opportunity costs of land such that proportional effect of land value tax is reflected in the cost of renting-in land by a tenant and in the revenue accruable from renting-out land by a farmer.

Also, it is assumed that the tendency to rent-out land might increase if levying land tax raises cost of renting-in land to tenants or erodes the profitability of agricultural production to land owners. Revenue from land rented out was incorporated into the objective function of the model as alternative revenue if production is not profitable. It is assumed that each farm type will rent out the proportion of farm land that is not used in agricultural production. However, to account for rental transaction costs in renting-out farmland a factor was used to reduce revenue from renting out land. Summary and conclusion drawn from this scenario are as follow:

a) Levying land tax at 2% of land value and given the assumption in this scenario will induce the large farm type to decrease marginally the level of production activities in favour of renting-out farmland. The highest impact is that large farm type would reduce irrigated areas of sunflower by 0.23% and wheat by 0.17%. The declines in supply are 0.07% for sunflower seeds; 0.06% for wheat; 0.04% for soya bean; 0.03 for each of white maize and sorghum; 0.02% for yellow maize productions.

b) Since the decrease is pronounced on irrigated cropping, it can be concluded that the high cost of irrigable land will increase the cost of renting-in irrigable land or acquiring irrigation facilities or that opportunity cost of irrigable land or irrigation facilities will be appreciably higher when tax is levied per land value.

c) Therefore levying land tax may discourage intensive production such as irrigated farming. It may also discourage investment (e.g. irrigation infrastructure) on land in the long-run.

d) In regions where there are much irrigation resources and facilities, decline in irrigated area as a result of levying a land tax would have substantial effects on output supply in such a region.

e) The decrease in activity levels and output supply by the small farm is insignificant.

f) Therefore the assumptions behind these simulations give results that are close to *a priori* expectations and therefore could serve as information for policy formulation on agricultural land tax.

7.3 Policy recommendations

The South African government, as much as it has a responsibility to redress the imbalance created by the legacy of apartheid, also has the challenge to balance equity with efficiency in a free market economy. An agrarian reform if it lacks sound economic imperatives could tend towards smallholder agriculture that cannot produce to meet neither domestic demand nor a tradable volume. Settling small farmers is contrary to the trend of farm consolidation which has proven to be more productive in the developed world. To this end, a number of policy recommendations are made based on the results.

a) Relatively rapid and massive transfer of farmland from the large farm type to settle more of the small farm units represents the political imperatives of the land reform. However, the results show that implementing this land reform objective will not only result to an insignificant contribution by the small-scale farm sub-sector to the regional production but also to a poverty trap for them. Policy needs to discourage settling groups of people and small so called communal farmers. Land reform could limit the production of the large-scale farm sub-sector especially if the farmland is transferred from a more productive large-scale farmer. Such a trend could also lead to land fragmentation which has consequence on large production that are necessary for export surplus.

b) It is necessary to state that land reform should target less-successful large-scale farmers in land transfer. Government can partner with banks to identify unsuccessful large-scale farmers whose farmland and capital need to be liquidated.

c) It is in the interest of all the stakeholders in the farm industry to implement land transfer and capacity development of the intended beneficiaries simultaneously and quickly too. In this model, the output and supply response of the small farm type is lower, the seemingly significant production level could have resulted from an assumed increase of about 740 farm units per year. The production though it looks massive is negligible at regional level. Such production levels cannot meet the regional need let alone exporting surplus. Therefore as much as it is an imperative to restructure the farm industry, establishing small-scale farm units may not be able to meet the regional food self-sufficiency. The repercussion could be worse as the land redistribution projects and programmes are characterised with the following problems:

i. There is delay as a result of the bureaucracy in land transfers. This makes some land lie idle during the land transfer process;
ii. evidence exists that often land are transferred to beneficiaries that lack proven knowledge of, experience in and commitment to farming. This often results to absentee land owners;
iii. there is a lack of post-settlement support services; and
iv. there is lack of project monitoring and evaluation.

d) It should be acknowledged that the trend in the rest of the world is for bigger and bigger farms because of declining trends in the net farm income. However, in the context of the South African agricultural development strategies, the aim is for more for small- and medium-scale farms. Scenario III provides general information on settling a black farmer that has a proven commitment to farming on a viable economic farm unit with large-enough land to secure capital. This should also be considered instead of only proliferating small-scale but inefficient land redistribution beneficiaries. The policy question may be how to identify such a prospective beneficiary? It may be necessary to increase the economic imperative of the land reform such that very effective and highly competitive farmers are identified through the market mechanism.

e) There is need to settle black successful large-scale farmers who compete on the same basis with their white counterparts. There is no justification for settling small-scale black farmers thereby ascribing small to black and large to white.

f) Small-scale farmers can be settled but only on very intensive projects with high valued crops such as vegetables on irrigation projects, etc. Such farm units may be small in size but big in turnover. More research is necessary on this approach.

g) Furthermore, it was mentioned earlier that the imbalance and inefficiency fostered by the previous government policies necessitated changes in policies to redress the imbalance and enhance competitiveness in the industry. Therefore, it can be concluded that the policy of land reform is justified. However, implementing such policy needs not be radical and should not overlook the basic and enabling environment within which the farmers operate. The implementation should, in a very balanced way, encourage establishing small-scale farm units on high-capital intensive projects. It is also necessary to prevent the decline in the large-scale commercial farms.

h) Policy should specifically address the risk in production revenues as this affects both farm types. It is not enough to liberalise markets only it will be more helpful to train the farmers in the use of risk-hedging mechanisms.

i) The results also indicate the implication of concentration on production activities by a farm type and suggest a policy that will encourage a wide range of production activities among both farm types.

j) It is noted that rural land can act as a safety-net. In this case the above efficiency arguments do not hold. However, if this is the case then these projects should be identified as such.

k) On levying land tax, there is a need for continuous and high frequent studies on land valuations because the effective tax rate will depend on proper and efficient valuation of land. This implies that land tax need not be static but dynamic with respect to the market value of land in each community. Neither should land tax be general but it should be related to positional advantages, fertility or natural resources, etc. that affect land value.

7.4 Recommendations for further studies and model development

The expected calibration and validation of the model was observed before it was applied to analyse various scenarios in achieving the objectives of the study. SAROS was based on economic theory, which makes the interpretation of results easier. Incorporating farm level resource limits, technical requirements and farm type differences enable SAROS to be consistent in describing changes in resource use, activity levels and shifts in the supply curves at farm type level and how these result to an aggregate regional supply response. However, SAROS in its present form being a 'typical farm', 'typical activities' analyses model needs a number of improvements as itemised below:

a) The farm typology and aggregation assumed in this study satisfy the three sufficient conditions of avoiding aggregation bias and were adequate for the purpose of this study but there are a few things that could be improved. First, Free State farm units were categorised into established large-scale and new entrant small-scale LRAD farms. This caused a bias in the farm typology because, all the established commercial farms were considered as only large-scale farm type while all the new entrant LRAD farms were considered as only small-scale farm type. It should be acknowledged that there are different scales of operation among each of these farm types, and possibly a few overlapping. Secondly, weighted average analysis was used to estimate the average farm size, level of production activities, etc for each farm type. In addition, farm units in each of the farm types were aggregated at regional level. It should also be acknowledged that production activities and size of production activities are concentrated in some areas of the region because of climate. This may have caused misrepresentation of production plans in the model. To solve these problems, there is a need for

- a comprehensive farm level survey on farm characteristics; and
- using statistical techniques such as principal component and factor analyses to categorise the farm units into a number of more homogenous farm units in homogenous production areas in the province.

b) Also, SAROS need improved data handling and updating, especially the enterprise budgets since these are the bases for microeconomic interpretation of the model's results.

c) Common sense says that supply, demand, price and quantity produced are interdependent. Modern economics states that the demand and supply model may well capture the interdependence. In this study, while price is considered in supply response analysis, demand is assumed constant. There are welfare impacts that would be shown if the model captures the market equilibrium effects of the consumer's demand.

d) There is need to quantify the risk in the factors market and incorporate such into the model to improve the realism of the assumptions underlining the model.

e) Additionally, it should be noted that as a partial equilibrium model, the results show only the impact, on the producer's profit, of selected macro-economic and policy variables. These variable were deemed to represent a number of variables that interact in an economy where farmers operate; whereas, controversies over the explanation of farmers' market behaviour are, in many cases, the results of the omission of variables which affect farmers' behaviour. Therefore, recent efforts in the field of policy analysis (linking partial equilibrium models with general equilibrium models) should be pursued for the South African agriculture and the economy as a whole.

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