South African Agricultural Production, Productivity and Research Performance in the 20th Century

by

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submitted in partial fulfilment of the
requirements for the degree

Philosophiae Doctor

in the

Department of Agricultural Economics, Extension and Rural Development
Faculty of Natural and Agricultural Sciences
University of Pretoria
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February 2013

DECLARATION

I, Frikkie Liebenberg, hereby declare that thesis, which I submit for the degree PhD in Agricultural Economics at the University of Pretoria is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature: ______________________

Date: 13 February 2013

FOREWORD

This study was made possible through the help, co-operation and patience of many individuals to whom the author is truly grateful. In addition to those mentioned in the introduction to each section of this thesis, I hereby express my special appreciation for the assistance and patience of the following persons and institutions:

Prof Johann Kirsten, Head of the Department of Agricultural Economics, Extension and Rural Development, for his enthusiasm and continued encouragement in seeing this study through to completion, even at times when the data problems seemed insurmountable.

Prof Phil Pardey, Professor of Science and Technology Policy in the Department of Applied Economics at the University of Minnesota and Director of the University's International Science and Technology Practice and Policy (InSTePP) centre, for his assistance and guidance in the technical analysis of this study and for financial and other research support from InSTePP, especially in the early phases of this research.

Dr Matt Anderson, Assistant Professor, University of Wyoming, who helped me grasp the technicalities of the capital service flow estimates.

Nienke Beintema, and through her, the International for Food Policy Research Institute, for the financial support through the Director-General's Grant that funded components of this study.

Dr Joseph Sebola, Director of Directorate: Scientific Research and Development of the Department of Agriculture, Forestry and Fisheries, for his interest in and funding of the initial phase of investment data collection.

The staff at the Agricultural Research Council who enthusiastically contributed many hours to describe and explain 'how the system actually operated'. Information and insights that were indispensible in tracing and tying up loose ends in developing the investment data series.

The Bill and Melinda Gates Foundation for the financial support provided to make many of the study visits and components of the data capture possible.

The librarians at the National Library, Lidia Coetser at the Agricultural Research Council (ARC), Erika van den Heever at the ARC-Agricultural Engineering Institute and Daleen Khun at the Agricultural Library of the Department of Agriculture who assisted in tracking down many old documents and Census Reports.

Finally, but by no means least, a special word of gratitude to my wife Annelien, my daughter Nienke and my son Nieko who for many years had to be content with what little spare time I could avail to the very people whose support and encouragement inspired me to take just another go at tackling a sometimes seemingly intractable series of data and measurement problems — the occasions when that happened seemed endless at times.

ABSTRACT

SOUTH AFRICAN AGRICULTURAL PRODUCTION, PRODUCTIVITY AND RESEARCH PERFORMANCE IN THE 20TH CENTURY

by

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The objective of this study was to provide a more complete understanding of the changing pace and nature of production and productivity growth in South African agriculture during the 20th century and the associated changes in research and development (R&D) investments and institutions that affect agricultural input, output and productivity performance. A completely new panel of data was constructed to track investments in agricultural R&D and scientific capacity that took account of the numerous structural and organizational changes that shaped public R&D since 1910. The national agricultural production accounts were also revised to address the legacy of South Africa's history of racial segregation and a multitude of problems that arose in the official time series data due to changes in the underlying statistical methods and procedures. With these new output and input data in hand the evolution of production agriculture over the past century was quantified and described. The modern indexing methodologies deployed in this study, in conjunction with new primary price and quantity data yielded new insights into the economic evolution of South African agriculture over the past century.

This study analyses the changing historic patterns of public sector investment in the agricultural sector and identifies the phases in policy evolution against the trends in aggregate spending on agriculture, farmer support and R&D. Following an initial phase of scientific capacity building, the R&D system

developed a measure of synergy in its activities as evident in the spending patterns of the national and regional institutes from 1926 to 1971. The concordance of policy and institutional changes with R&D investment, output and productivity trends in the funding of the various research entities came to an end in 1980, and overall public investment in agricultural R&D has stalled since 1978.

Growth patterns in multi-factor productivity estimated in this study substantially differ from earlier studies, especially in terms of magnitude, and present different results on the estimates of the growth in agricultural output that is attributable to productivity growth. It was found that not only did the earlier methods yield indexes that overstate growth patterns — thus suffering from aggregation bias in their index numbers — but trended more erratically and in poor concordance to the timing of policy changes.

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CHAPTER 1

INTRODUCTION

1.1 Historical Context

With the democratization of South Africa in 1994 and the introduction of land reform and farmer settlement programs to redress past injustices, the issue of finding appropriate support structures and service delivery mechanisms for South African agriculture has resurfaced in public policy debates. In the hundred years since the establishment of the Union of South Africa in 1910, the country's agricultural sector and the structures governing and supporting it have changed significantly. A hundred years ago agriculture played a pivotal role in addressing the country's rural poverty problems while also contributing substantially to the country's overall economic growth. This was achieved through substantive and sustained public support by way of investments in rural infrastructure development, comprehensive farmer support programs, education and training programmes and a dedicated drive toward the industrialization of production agriculture. Since 1994 the agricultural sector has again been expected to serve as a source of employment with an added emphasis on income redistribution (along with other sectors in the economy). While the pressures for that are clear and compelling, the approaches followed appear to be undermining the overall growth and productivity performance of the sector. If history is any guide to the future, it is the nature and pace of productivity growth that will largely ultimately determine the employment and income generating capacity of South African agriculture in a rapidly changing global agricultural environment.

In broad terms, the agricultural sector has gone through four policy phases during the past century of development, and the sector's institutional structures have evolved in line with this (Vink 1993). Initially, the main focus of government was to consolidate all government functions related to agriculture and agricultural education within a single Ministry of Agriculture, a process that took almost 30 years to complete. This included scholarship programs to develop staff capacity in agricultural extension and scientific research. This phase contrasts with the following phases in that policy administration, regulatory services and research and extension were all part of the same department. Throughout this phase high levels of poverty, frequent droughts and recurring recessions (even a depression) were salient features of the agricultural economy.

Beginning a few years prior to World War II, a second phase took hold characterised by a stronger government focus on providing technical and financial support services to new and existing farmers, whilst consolidating its policy measures on regulatory services. The research and development services of the Department of Agriculture were moved to a separate Department of Agricultural Technical Services with education at agricultural colleges and universities forming part of this structure, where it initially was strongly integrated and focussed around regionally focussed centres, but toward the closing stages of this phase university education was transferred back to the responsibility of the Department of Education and commodity focussed research institutes were separated out from the regional development centres. During this phase the responsibility for farmer settlement and the administration of financial support programs related to providing credit to farmers were shifted to the Department of Agricultural Credit and Land Tenure inclusive of the extension services tasked with farmer settlement. The administration of 'general' policy matters became the mandate of a new Department of Agricultural Economics and Marketing responsible for the administration of trade and marketing policy and the inspection services guarding product safety and quality.

The expansion of farmer and industry assistance support measures lasted almost four decades. Beginning around 1981 government began to revise the nature of support to the sector. Policy changes took the form of the deregulation of financial support measures, the revision of tax incentives and forcing control boards to apply more market related principles in the pursuance of 'orderly marketing' (Kirsten and Van Zyl, 1996). About a decade later there was an almost complete abolition of financial support programs to agriculture. This recent phase is further characterised by the redress of past land ownership interventions of government, the liberalization of trade and the abolishment of state controlled marketing measures. At the same time the regional research and development services of the Department of Agriculture were re-assigned to serve under a new provincial dispensation that bare little relation to the former agroecological zonal focus of agricultural research and development. The national research institutes were all transferred to a newly established Agricultural Research Council and funded through a competitive grant program that had them competing for a substantial share of their funding with other service providers.

The four phases described here point to a host of institutional and policy changes that were influenced by and subsequently affected the changing nature of the agricultural sector itself. Over the past century the size and structure of the South African agricultural economy changed markedly. In 1910/11, agricultural output (as measured by agricultural gross domestic product, AgGDP) accounted for 21 percent of total economic output (GDP) and employed 781,359 people (54 percent of whom were permanently employed in agriculture). In 1918 there were 76,149 commercial farming units and farm size averaged 1,189 hectares with 55 percent of the gross value of agricultural production coming from livestock, 33 from field crops, and just 12 percent from horticulture.

By 2010 the agricultural share of the total economy had shrunk to just 2.5 percent even though the agricultural economy had grown in absolute terms from R10.9 billion (US$1.7 billion) in 1910 to R40.9 billion (US$ 6.4 billion) in 2010 (both measured in 2005 prices). Primary agriculture employed 811,441 workers, or about 10 percent of the total economically active population, having peaked in 1971 at 2.48 million. The number of commercial farmers had declined to an estimated 39,982 in 2007, averaging 2,113 hectares per farm. By 2010 the horticultural share of the gross value of agricultural production had more than doubled to 26.1 percent, the livestock share had decreased a little to 50.1 percent, and the field crops share had dropped markedly to 23.5 percent.[1]

Studies on productivity growth in South Africa could serve as a guide to determine which of these policy phases and the institutional structures that evolved under them were more effective in promoting agricultural productivity growth in the country. Prior to the initiation of this study Thirtle, Sartorius von Bach, and van Zyl (1993) was the only source of long-run productivity estimates for South African agriculture. They identified three distinct phases of productivity growth: negligible growth during the period 1947 to 1965, comparatively strong growth during the period 1965 to 1981 (2.15 percent per year), and slightly higher growth during the period 1981 to 1991 (2.88 percent per year). The period of analysis covered by their study largely focus on the second and third phases described earlier. The second began with the change in the organization of the modality of the research and extension services provision to a more regionally structured and focused service and ended with the dismantling of the integration of the universities with the R&D services of the Department of Agricultural Technical Services from 1971.

However, several factors raise concern over the usefulness of past productivity studies and the subsequent estimates of the return to public sector investment in research and extension that build on the productivity analysis. The first emanates from the fact that the country's history of racial segregation affected its statistical records. The *Abstract of Agricultural Statistics* essentially provides a summary of the more important variables included in estimating the sector's contribution to national income. As mentioned by Thirtle et al. (1993) the accounting conventions in this are not always readily apparent. During the era of racial segregation, especially since 1975 when the homelands were established, this resulted in the contribution of the black farmers and later the economies of the homeland areas being excluded from the commodity specific data tables — but not from the national income accounts.[2] With the reintegration of the homeland territories after 1994 their contribution has been reintroduced into the national income estimates and backdated to 1975; the earliest year reported

[1] The long–run trends reported here draw on data collected from various reports and unpublished ledger files of the Directorate of Agricultural Statistics, and Census reports of Stats SA and its predecessor agencies. Much data from these sources was adjusted to deal with changes in measurement practices, variable definitions and aggregation procedures over time as described in more detail in Part I of this thesis.

[2] This fact is not spelled out in the explanatory notes to the data tables in the various issues of the *Abstract of Agricultural Statistics* since it first appeared in 1958.

in the 1995 edition of the *Abstract*. Related to this is the inconsistency that results from changing methods of measurement and statistical procedures which in itself evolved over the hundred year history of measured agricultural performance (UNSD 2011).

Further analysis would reveal that the public sector research and extension system have also experienced numerous structural and organizational changes since unionization in 1910 (Roseboom et al. 1995). Tracking investments made in agricultural R&D by the various organs of the departments of agriculture, and later the institutes under the ARC, is a complex venture carrying with it a huge risk of potential measurement error. Research conducted by specialist institutes, in particular the Plant Protection and Agricultural Mechanization Institutes were often not reported under the same programs as the national commodity and the regional development institutes — the situation is worse for research conducted by the discipline specific units such as agricultural economics services. Collectively, investments made by these components of agricultural R&D represents, in some years, close to 20 percent of public sector agricultural R&D investment (Roseboom et al. 1995).

This process is further complicated by the fact that the structure of government budget reports in itself has also changed over time. This has further implications for the tracking of financial support payments to industry, farmers and regulatory services. Though earlier productivity studies accounted for commodity specific subsidies as reported in the *Abstract of Agricultural Statistics*, this only represent a subset of farmer support measures in use at the time. Support programs implemented by non-agricultural departments were poorly tracked and reported on in the *Abstract*, serving as another source of inaccuracy in existing productivity studies.

Finally, the methodology used to construct productivity indexes has changed with the evolution of this field of science over the past two decades since the study by Thirtle et al. (1993). Their study reported a type of Tornqvist-Theil aggregate index formed from pre-aggregated Laspeyers indexes of production quantities and input prices as reported by the Department of Agriculture. This approach distorts relative price ratios and introduces a host of index number (i.e. aggregation) problems in the analysis (Alston et al. 1998). It also precludes the ability to adjust for changing composition (or quality) of inputs and outputs, a source of potential measurement error that can be exacerbated in productivity analysis in agriculture that run for longer periods.

Taken collectively, the changing nature of the underlying data that earlier studies had built on may have influenced the productivity index estimated as well as the causal relationship between investments made in agricultural R&D and the observed effect on productivity growth and calls for a revisit of South African agricultural productivity growth.

1.2 RESEARCH QUESTIONS

Investments in organized agricultural R&D are deemed the principle source of innovations and technical changes that spur productivity and output growth in agriculture over the long-run (Pardey, Alston and Ruttan 2010). However, the production and productivity consequences of R&D take considerable time — typically decades, not merely years — to be realized, making it imperative that a study of these processes encompass a long-run span of data. In addition, a host of factors, including changes in scale and scope of farm operations and the amount and composition of inputs and outputs can confound efforts to disentangle the effects of R&D from other sources of change in aggregate agricultural output (Alston et al. 2010). It is exactly this long-run scope of the data that presents a challenge in the South African context, as much of the primary data are subject to changes over time in methods of measurement and composition of what was reported. Equally so, the process of institutional and policy evolution has affected our measured understanding of the R&D services in terms of its investment/expenditure trends.

The question here is thus, that by extending the period of focus to more fully capture the pre-world war II period, by forming the input and output quantity indexes from the detailed underlying price and quantity data on production and input use, updating the productivity analysis to include the years since democratization in 1994 and with a more detailed accounting of the public investment in agricultural development (and specifically the research and extension services) would it improve our qualitative and quantitative perspectives on South African agricultural productivity growth?

1.3 OBJECTIVES

The overarching objective of this thesis is to provide a more complete understanding of the changing pace and nature of production and productivity growth in South African agriculture during the 20th century and the associated changes in R&D investments and institutions that affect agricultural input and output. To achieve this overriding objective the research for this thesis seeks the following outcomes:

- Using modern index number methods, develop an entirely new and economically meaningful set of aggregate output and input measures (and their components) for South African agriculture for the period 1910/11 to 2010/11.
- Use the newly constructed aggregate output and input indexes to form a range of partial- and multi-factor productivity measures beginning in 1910/11 and 1945/46 respectively.

- Compile a new series on South African public research and extension spending for the period 1910/11 to 2010/11 and place that evidence in the changing policy and institutional environment that shaped the South African agricultural innovation sector.

In pursuing these objectives and outcomes a myriad of data measures and measurement challenges were confronted and addressed in the reported official South African agricultural production statistics. Frequent changes in the construction and scope of variables representing *individual* agricultural input and output prices and quantities were discovered, with consequences, in numerous instances quite profound consequences, for the *aggregate* input, output and productivity measures developed as part of this research. A core contribution of this thesis is to lay bare these measure and measurement problems, and to devise ways to resolve these problems given the available published (and unpublished) statistics.

1.4 HYPOTHESES

The central hypotheses of this dissertation are that:

1) By adjusting for inconsistencies in the underlying data in terms of the inclusion of homeland agriculture, and constructing aggregate output indexes based on the primary price and quantity data instead of using pre-aggregated variables it is expected that the resulting output estimates would differ significantly from past estimates.
2) By using more consistently constructed data and modern statistical methods the resulting input indexes would concord more closely with the structural changes (policy changes) in the identified policy phases.
3) Taken together the resulting productivity estimates would differ significantly from past estimates and lead to different qualitative and quantitative perspectives on the performance of the South African agricultural sector and its ability to contribute to income redistribution.
4) Significant differences exist in the degree of public sector investment in agricultural development during various policy phases and this has strongly influenced the nature and focus of agricultural R&D investment.

To investigate these hypotheses this study will:

a) Correct the underlying production accounts, including new estimates of capital and intermediate input use, as well as revise the data on farm employment to correct for inconsistencies in prior estimates and the inclusivity of homeland agriculture;

b) Construct indexes based on the primary price and quantity data that span a longer period than previous studies and investigate the influence of using different techniques and methods in constructing productivity indexes, comparing the new indexes with those previously available;

c) Develop a comprehensive set of accounts on public spending in agriculture since 1910, including spending on information provision, regulatory and especially research and development services., and;

d) Place the new production accounts and public spending estimates in a changing sectoral and public policy context.

1.5 OUTLINE OF THE STUDY

The opening chapter in Part I of this thesis provides an overview of the broad trends in the structure and performance of South African agriculture throughout the 20th century. Changes over time in the economic size of the agricultural sector vis-à-vis the size of the overall economy are identified, along with changes in the number, size and distribution of farms. Chapter 3 describes the primary data sources and the various methods I deployed to generate an original set of annual, national price and quantity variables for agricultural output and its components, for the period 1910/11 to 2010/11. I compare my estimates against the official statistics and the analogous measures found elsewhere in the economic literature. The implications of alternative aggregation procedures are presented and evaluated. These new estimates are used to quantify and describe the evolution of agricultural output over the past century, offering new insights in the economic evolution of South African agriculture.

Chapter 4 is an empirical and analytical counterpart to chapter 3, but here the focus is on the evolution of aggregate input use and its components. Newly constructed aggregate land and labour input measures are presented, and special attention is given to the construction of two capital flow series. One series is an estimate of the flow of services from physical capital such as fixed improvements, tractors, combines, ploughs, etc. The second series is a measure of the annualized services flowing from the stock of biological capital, which includes cows, sows, sheep and goat ewes, etc. The procedures used to convert reported capital stocks to flow estimates are spelled out in some detail. Aggregate measures of intermediate input use (including farming services, fuel, fertilizer, etc.) are developed, presented and briefly discussed. Finally, an assessment of changes in input cost shares, input factor ratios, and corresponding movements in relative factor prices is presented.

Part II of the thesis presents newly constructed estimates of the public investments in agriculture since 1910/11. Chapter 5 sketches the overall trends in public spending on agricultural services and farmer support. A brief account of associated farmer settlement schemes and land conservation programs is provided by way of context for some of this public spending.

Chapter 6 reports a detailed quantification and thorough assessment of spending on publicly performed agricultural R&D and extension in South Africa. The policy and institutional history of this sector is also described, along with details of the shifting sources of support for public R&D. Agricultural research is also placed in the broader framework of overall public science policy and spending within South Africa. This analysis of public agricultural R&D spans the period 1910/11 to 2010/11.

Part III draws on data developed in prior chapters to measure and analyze long-run trends in agricultural productivity and associated trends in R&D spending. Chapter 7 includes various partial- and multi-factor productivity measures, and compares these new estimates with those previously published. The sensitivity of these productivity estimates to different data and aggregation choices is examined and discussed. South African productivity developments are contrasted with trends in comparable productivity measures for other parts of Sub-Saharan Africa. The chapter draws together the aggregate input, output and productivity indexes and statistically assesses changes in their patterns of growth over time.

The final chapter summarizes the key findings of the thesis and draws out the main conclusions. It ends with a brief assessment of potential areas of additional improvements in the data to further our understanding of the past and prospective long-run sources of production and productivity growth in South African agriculture.

INTRODUCTION TO PART I

An initial phase of this study began with the initial data entry on agricultural production and input accounts in October 2006. The initial data entry from published records was sponsored by the International Science and Technology, Policy and Practice (InSTePP) Centre of the University of Minnesota, who kindly provided the services of a research assistant to enter all the agricultural output and input use data published in editions of the Abstract of Agricultural Statistics for the period 1936 to 2007. The input expenditure accounts included data records that mostly start in 1946/47.

The first efforts to construct the Fisher Ideal Indexes of agricultural outputs revealed major inconsistencies in the available published data. The records on agricultural input use available from the Department of Agriculture were, and continue to be, limited to aggregate estimates of the value of expenditures on farming requisites and a corresponding set of aggregate price indexes of these inputs.

To address the problems identified with the published data, past agricultural census and survey reports and data from producer and commodity organizations had to be collected and the production accounts re-constructed. All the national aggregate data on agricultural production and input use were re-constructed from the available agricultural census and survey reports since 1918 — augmented by statistics obtained from the *Handbook of Agricultural Statistics: 1904 — 1950* and *Union Statistics for Fifty Years: Jubilee Issue, 1910 — 1960*. Detailed price data on agricultural inputs were obtained from the archives of the Directorate of Agricultural Statistics whose staff kindly assisted in tracking down the available records.

Beginning in 1980, data were available in electronic format, prior to that it was compiled from old (hand written) ledger files. Data on the input prices reported in these files contain references to the surveyed source and, as a result, are not generally available to the public. In total, the panel of data covers practically all national level data used in the estimation of the national farm income accounts and the Farming Requisites Price Index series. I owe a debt of gratitude to Dirk Blignaut, Mariëtte Strydom, Marda Scheepers, Tshepo Nkoana, Rona Beukus, Japie Kruger, and others who directly, or indirectly assisted in the numerous queries I had in the subsequent analysis of the data, and to Ruan Stander who typed up a sizeable share of the data on tractor and fertilizer prices. The remainder of the data were captured by myself as the analysis progressed and other areas of inconsistency revealed themselves.

A major caveat of census reports since the 1980s is the declining amount of detail in the report on virtually all the variables of interest. The declining number of analytical cross-tabulations from source data describing the changing nature of farm structure in census reports also posed a problem. In addition, less information is collected with each successive census, e.g. data concerning the on-farm stocks of machinery and implements were last comprehensively enumerated in the 1981 census and ceased altogether in 1983.

As more detailed data by class and type of capital inputs were needed than were available in the census reports, data from the Agricultural Mechanization Survey – conducted from 1968 to 1994 – were compiled. From 1994 to 2010 the data on agricultural machinery sales were obtained from AGFACTS (the information agency of the South African Agricultural Machinery Association). While the census data on agricultural production included the contribution of farmers in the homelands, little information exists in agricultural census reports with respect to their share of input consumption. This shortcoming is addressed to an uncertain extent by the Directorate of Agricultural Statistics with respect to capital inputs, and, contrary to popular belief, only marginally so for intermediate inputs. The inadequacies in the data are discussed in more depth in chapters three and four.

Any observed errors, or concerns over the validity of the official estimates that became apparent in the course of this research were communicated to the staff at the Directorate of Agricultural Statistics. Since 2006 a number of changes to the official estimates on capital formation, such as the rent payments, livestock inventory change and the price trends of certain input types were made in response to the feedback provided by the author.

CHAPTER 2

STRUCTURE OF PRODUCTION AGRICULTURE

2.1 EARLY EVENTS IMPACTING ON AGRICULTURAL DEVELOPMENT IN SOUTH AFRICA

The Union of South Africa, which was to become the Republic of South Africa on 31 May 1961, was established in 1910 through the merger of the four colonies of Britain at the southern tip of Africa. These were the Cape and Natal colonies and the two former Boer republics of the Free State and Zuid-Afrikaansche Republic (Transvaal). The Cape colony was established by the Dutch East India Company in 1652 as a halfway station to the spice trade in the East to provide the company's ships with fresh meat, vegetables, and other supplies. Under Company rule there was practically no functioning local market for agricultural produce (all produce was sold to the company at fixed prices) while overseas trade was discouraged. The restrictive regulations and trade restrictions led to increased discontent amongst farmers and long before 1700 farmers started to trek inland to escape from company rule (Giliomee 2009). As there was practically no opportunity to dispose of their produce profitably these farmers were compelled to fend for themselves through stock farming and hunting (Burger 1952). This pattern repeated itself with the establishment of Natal, the Orange Free State and the Transvaal.

Britain annexed the Cape in 1795 during the Napoleonic wars due to its strategic significance in protecting the trade route via the Cape and especially the important naval base and coaling station at Simon's Town (Pakenham 1981). This necessitated the establishment of a strong garrison and created a relatively stable local market for agricultural produce whilst most trade restrictions were also removed. The border regions, however, still faced a lack of transport and speculators and hawkers made their first appearance around this time.

Natal Colony was annexed in 1845 to pre-empt the establishment of a Boer republic with harbour facilities on the northern border of the Cape colony. In 1873 the Transvaal Republic (founded in1852) was briefly annexed up to 1881 in a move to protect the neighbouring British colonies from the political and financial crises in the Transvaal. In a sense these colonies had little significance to Britain prior to 1860 and placed an enormous burden on its treasury as a result of the regular conflicts it had to deal with on the northern border of the Cape Colony and during its annexation of the Transvaal. The founding of the Orange Free State republic in 1854 (annexed in 1900) also presented problems as it added the burden of the protectorates of Lesotho and Swaziland, which were established to protect these kingdoms against the threat of encroachment of Boers on their land. The burden of the Protectorate of Northern Bechuanaland (Botswana) and the Southern Bechuanaland Crown Colony (later annexed into the Cape Colony) were added in 1885 to protect the railway link with Rhodesia (Meredith 2007).

According to Burger (1952) agricultural exports first exceeded imports in 1865 — mainly wool, hides and skins (and later ostrich feathers). By 1870 agricultural development reached a point — also north of the Orange River — where the following produce and activities began to assume prominence in the different colonies and republics:

Cape Colony: Wheat, oats, barley, rye, maize, fruit, viticulture, wool, stock-farming and horse breeding, while a beginning had already been made with ostrich farming and angora goats.

Orange Free State: Mainly cereals and sheep farming.

Natal: Cereals, fruit, sugar, tea, with livestock as a minor item.

Transvaal: At the time practically exclusively cattle ranching, with sheep and crops of minor importance.

The two main stumbling blocks in the 19th century to the development of agriculture in the interior were, firstly the nonexistence of urban consumption centres or local markets and, secondly, the complete absence of railways or other effective transport facilities, except for the slow moving ox-wagon. The discovery of diamonds in the area of the present Kimberley in 1869 soon saw the partial removal of these stumbling blocks, even if only for a part of the interior (Burger 1952). The concentration of diamond miners and others in the vicinity of Kimberley had immediate and far reaching economic effects. Agricultural products of practically all kinds and varieties were required in large quantities and soon a relatively well-organised market was in operation. The completion of the railway link in 1885 between the coastal towns of Cape Town, Port Elizabeth and East London and Kimberley impacted agriculture in the Orange Free State republic through the establishment of local traders.

Agriculturally, Natal and the Transvaal did not profit much from the first diamond mines. As a result off the Drakensberg mountains to along the eastern side of the country and the arid Karoo on the west, Transvaal, Free State and a large part of Natal were largely isolated from the export harbours and markets of the Cape and Natal colony. In the north eastern region of the Transvaal (known as the lowveld) the endemic cattle diseases precluded farming in this area. However, in 1886 the rich gold reefs of the Witwatersrand were discovered and the first group to profit from this was the Transvaal farmers. Within an amazingly short period of time they also produced agricultural products in large quantities and varieties. This was greatly aided by the railway link with the Cape completed in 1892 and in 1894 the link with Delagoa Bay and then in 1896 with Durban. These railway lines unlocked areas such as the Eastern Transvaal, Northern Free State and a large part of Natal. Farmers in extensive areas were assisted to participate in this trade through the introduction of preferential and long distance tariffs. Around this time farmers began to deliver to 'market agents' at the main fresh produce markets, thus eroding the control of speculators and established traders. Even before 1900 provision has been made for joint abattoirs where butchers provided their own labour (Burger 1952).

The outbreak of the Anglo-Boer War in 1899 commenced with a process of systematic destruction of farm infrastructure, grazing and livestock in especially the Boer republics (Pakenham 1981; Meredith 2007). Farmers in the Cape and Natal, however, benefitted from the increased demand for food and feed by the British forces. At the end of hostilities in 1902 it was clear that the country as a whole could not feed itself in terms of certain primary products. Although food was available, or could have been produced, marketing and distribution were not well organized, with a lack of adequate transport facilities being at the root of the problem (Burger 1952). A start was made to construct branch rail lines that reached into the more fertile agricultural production areas and the introduction of auction sales in the interior for livestock and non-perishable products. In addition, producer's co-operative societies began to appear, first in Natal in 1904, from where they rapidly spread to the other colonies: Cape in 1905, Transvaal in 1908 and the Orange Free State in 1910.

By now the manufacturing capacity of the country had reached a stage where the processing of primary products such as milk and the canning of fruit and vegetables began to take shape; one of the first directions followed by the co-operative movement. Co-operative marketing was soon to follow and in 1908 the Transvaal government introduced a central agency for maize marketing in Johannesburg for the purpose of selling the maize of co-operative societies, the elimination of competition between farmers, assistance to small farmers, obtaining and distribution of market reports and instruction in the grading and determination of the quality of products (Burger 1952).

In the meanwhile a tariff agreement was reached in 1903 by all interested territories, including Southern Rhodesia and the native areas (Burger 1952). This afforded simultaneous protection to all producers in a common market for the first time in the history of the country. Complete understanding and co-operation were, however, to be reached in 1910 with the establishment of the Union.

It can rightly be asserted that the development of the mining industry gave a tremendous impetus to agriculture, especially to that of the interior, but it was the binding power of unification that was responsible for the full development to strong economic units. All branches of agriculture then began to develop rapidly. Moreover, the manufacturing industry also made some progress and this in its turn benefited agriculture still more, not only by creating a bigger demand but also by the processing of agricultural products.

Government supported industrial development in South Africa started with limited success in the Transvaal Republic in 1881 with the concessions policy of President Kruger in his striving for economic independence: high duties were imposed on a long list of commodities which concessionaries had undertaken to manufacture in the Republic. Agriculturally derived products included in this list were leather, sugar, wool, vegetable oil, candles and paper. About half of the 1911 output of R34million (US$131 million) comprised the processing of farm products for the food, drink and tobacco industries (Lumby 1990).

The outbreak of the First World War in 1914 saw a period of extraordinary industrial growth spurred by the disruption of supplies to the local economy, and sharp increases in prices locally of manufactured produce. At the same time the Privy Council for Scientific and Industrial Research initiated a process for British colonies and dominions to develop their own science and industrial capacity as a result of the disruption in the supply of imported goods (Smit 1984). However, it is argued that the decision to abandon the gold standard and the devaluation of the currency in December 1932 provided the greatest stimulus to industrial growth in the Union before 1939 (Lumby 1990). Coupled to the increase in the price of gold from 85s to 120s per fine ounce, unprofitable gold mines were given a new lease on life. The increased investment in and income from the gold mines provided the treasury with the means to finance rural infrastructure development and a host of other social upliftment programs. The outbreak of the Second World War in 1939 provided further stimulus for the transformation of South Africa into an industrial economy — significantly broadening its scope of production from primary processing to the manufacture of a wide range of intermediate and capital goods (Lumby 1990).

Given the largely nomadic existence of Afrikaner farmers up to the late 1800, their levels of education were very low and they were poorly equipped to benefit from the growing mining industry and manufacturing sector. The displacement of the rural population and the destruction of the capital base on farms in the Boer republics resulted in high levels of poverty in rural areas. This situation came to a head following the Great Depression and the subsequent drought that lasted for several years. Many farmers were forced off their land. Several efforts to address rising levels of poverty as a result of decades of economic setbacks to the farming community were undertaken from as early as 1897 by the Dutch Reformed Church, which started with labour colonies (Van Heerden 1947). Since the formation of the Union of South Africa other initiatives followed such as the establishment of the Land Bank in 1912 and after the recession that followed the First World War, the establishment of the Farmers Assistance Board in 1925, investigations into the Poor White problem funded by the Carnegie Foundation in 1928, and the introduction of co-sponsored training programs for labour in 1929 coupled with state assistance in creating employment. This was followed by the establishment of irrigation schemes, tenant farmer support programs and the development of the local agricultural market infrastructure and organised agricultural marketing arrangements. Many of these programs were in place in various forms up to the 1990s, such as the Farmer Settlement program, subsidised loan programs to farmers, and controlled marketing schemes.

2.2 CHANGES IN THE SOUTH AFRICAN ECONOMY

In 1910 South Africa had a total population of 5.9 million of whom only a quarter were urbanised (Table 2.1). With the exception of the decades in which major wars were experienced its population has steadily grown at rates exceeding 2 percent per annum until 2000, whereafter the rate of population growth declined to 1.1 percent per annum for the first decade of the 21st century. The degree of urbanisation grew steadily throughout the 20th century to reach 61.7 percent in 2010; except for 1990 which reported a reduction in the share of the population living in urban areas by 4 percent.

The gross domestic product (GDP) of the South African Economy was R66.1 billion (US$10.4 billion) in 1910, growing by only 0.3 percent per annum until 1920. Thereafter, and in response to government interventions to support economic development, the annual growth rates measured for each decade fluctuated between 3.7 and 6.6 percent annually until 1970 when the output of the economy reached R671.7 billion (US$105.6 billion). Driven by the recession of the 1970s the annual growth rate in GDP declined to 3.7, whereafter the introduction of sanctions against South Africa, and domestic unrest, amongst other factors, has seen its GDP growth slow down to between 1.7 and 2

Table 2.1: Structural Changes in The South African Economy, 1910-2010

Indicator	Unit	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Population (mid-year estimates)	1000	5,973	6,927	9,588	10,353	12,671	17,122	22,465	27,576	36,199	44,820	49,991
Population growth	%	2.4	1.5	3.3	0.8	2.0	3.0	2.7	2.0	2.7	2.1	1.1
Urban	%	24.7	27.9	32.4	38.4	42.6	42.7	47.8	52.6	48.6	56.9	61.7
Gross Domestic Product												
-Rand (current)	million	284	554	551	993	2,626	5,258	12,791	62,730	289,816	922,148	2,662,757
-Rand (2005)	million	66,047	67,779	94,406	171,183	248,107	385,385	671,652	935,617	1,086,901	1,301,773	1,834,292
-US$ (2005)	million	10,382	10,654	14,839	26,908	39,000	60,578	105,576	147,068	170,848	204,623	288,329
-2005 International Dollar	million	17,058	17,505	24,382	44,211	64,078	99,532	173,465	241,638	280,709	336,203	473,735
Share of GDP												
Agriculture	%	21.0	22.2	14.2	12.7	17.7	12.4	7.1	6.1	4.6	3.3	2.5
Mining	%	27.7	18.3	15.6	18.7	13.5	13.7	8.7	20.4	9.0	7.6	9.6
Manufacturing	%	4.0	7.3	9.4	12.4	16.4	20.5	22.7	21.4	23.3	19.0	14.6
Wholesale	%	12.7	15.6	15.1	13.9	14.0	14.2	14.7	11.8	14.1	14.6	13.9
Other	%	34.6	36.6	45.7	42.3	38.4	39.2	46.9	40.3	49.0	55.5	59.4
Employment		-	815	1,089	4,587	4,593	5,721	8,114	8,690	12,178	15,919	18,357
Agriculture		-	270	296	1,913	1,479	1,689	2,483	1,306	1,614	1,482	1,188
Manufacturing		-	68	125	360	502	644	1,026	1,464	1,417	1,307	1,220
Per capita income (Rand 2005)	Rand	11,058	9,784	9,846	16,535	19,580	22,508	29,898	33,929	30,026	29,045	36,692
Per capita income (US$ 2005)	US$	1,738	1,538	1,548	2,599	3,078	3,538	4,700	5,333	4,720	4,565	5,768
Per capita income (Int $ 2005)	International $			2,543	4,270	5,057	5,813	7,722	8,763	7,755	7,501	9,476
Exports as percentage of GDP	%	14	15	11	7	17	15	11	32	21	23	22
Imports as percentage of GDP	%	24	34	23	19	23	21	20	23	15	20	22

Sources: Stats SA (2011); SARB (2011)

Notes: Where relevant, data were deflated using the GDP deflator (long-run GDP and agricultural contribution to GDP statistics 2011 – data provided by the South African Reserve Bank on request by the authors). Farm employees consistently include family, regular, casual and proprietor labour. All data (except for the far right column) represent decade averages.

percent for the subsequent two decades. Since 2000 the growth rate has rebounded to 3.8 percent per year for the first decade of this century to reach R1,834.3 billion (US$288.3 billion) in 2010.

Per capita income in 1910 stood at R11,058 (US$1,738) declining to about R9,800 (US$1,500) for the subsequent two decades. It increased by 5.8 percent annually to R16,535 (US$2,599) in 1940 and subsequently grew by 1.8 percent over the next four decades to R33,929 (US$5,333) in 1980. Thereafter it declined over the next two decades, but rebounded to reach R36,692 (US$5,768) in 2010. Jones (1990) found that the turning point in this metric came in the 1970s, when the relatively high per capita growth gave way to low per capita growth largely as a result of the changing relative growth rates in population and GDP and that this did not compare well with other western economies over the same period.

Its comparative international position in 2009 placed the gross domestic product of South Africa at the 31th largest economy at US$283 billion, next in line after Argentina, which produced US$307 billion in total output that year and slightly ahead of the United Arab Emirates, Thailand, and Finland (World Bank 2011). In 1970 South Africa held the 18th position in the world. Normalized against a population of 47.4 million (making it the 24th most populous country in the world) South Africa's GDP per capita was US$5,733 in 2009 – 85th in a global ranking on this score, just behind Botswana and immediately ahead of the Maldives and Serbia. In 1970 the country was at the 43rd position, just behind Portugal, Saudi Arabia and Trinidad and ahead of Malta, Uruguay and Barbados.

South Africa's economy is especially important in a sub-Saharan African context. Its 2009 production accounted for 29.8 percent of the region's entire GDP after it peaked at 47.3 percent in 1994. It also had the region's sixth ranked GDP per capita (behind Botswana, Gabon, Mauritius, Seychelles, and Equatorial Guinea), with 38 of the remaining 39 countries in the region producing less than $2,000 per capita that year. In 1970 South Africa enjoyed the second highest GDP per capita after Gabon; ahead of the Seychelles, Cote d'Ivoire and Liberia.

The sectoral shares in contributing to the national output have also changed significantly over time. In 1910 the mining sector was the largest sector and contributed R18.3 billion (US$2.9 billion), or 27.7 percent, followed by the agricultural sector standing at R13.9 billion (US$2.2 billion), which represents 21.0 percent of the countries' GDP. The manufacturing sector at the time represented only 4.0 percent, but over the subsequent decade its contribution nearly doubled. By 1940 the contribution of the manufacturing sector nearly equalled that of agriculture of R20.3 billion (US$3.2 billion) but by 1960 it took up the lead position with 20.5 percent (R76.7 billion, US$ 12.1 billion) followed by mining (13.7 percent) and then agriculture (12.4 percent). In 2010, the output of the manufacturing sector exceeded R260.4 billion (14.6 percent) compared to the R44.6 billion (2.5 percent) of the primary agricultural sector.

The success of agricultural development initiatives is clearly reflected in the trends in agricultural output by value over the various stages of development. From 1910 to 1928, real agricultural output grew by 2.6 percent per year from R10,874.4 million (US$1,709.3 million) in 1910 to R17,327.6 million (US$1,594.0 million) by 1928, representing 17.3 of total economic output. This growth was largely aided by increased commodity prices during the First World War (Lumby, 1990). After the depression of the early 1930s and a severe drought for four years that ended in 1934, the agricultural economy then experienced a period of strong growth in conjunction with expanded farmer settlement and agricultural development support and reached R49.9 billion (US$7.9 billion) in 1951, an increase of 8.09 percent per year for the 1934 to 1951 period representing about 17.1 percent of total economic output.

From 1951 to 1974, output growth slowed to an average of 1.14 percent per year reaching a peak of R64,921.5 million (US$10,204.9 million) in 1974. With the implementation of the Conversion of Marginal Lands program following the drought of the early eighties the agricultural economy declined from R47,470.8 million (US$7,509.0 million) to reach R36,929.1 million (US$5,804.8 million) in 1992. This was the era during which numerous deregulation initiatives were implemented and government support to farmers was reduced which, coupled with the introduction of sanctions against exports from South Africa meant that the economy declined (Vink 1999).

With the removal of sanctions against South Africa from 1992 agricultural output rebounded to reach R52.4 billion (US$8.2 billion) in 2002, after which international market pressures, changing domestic agricultural policies and economy-wide influences, and adverse weather conditions drove a period of decline reaching R41.0 billion (US$6.4 billion) in 2010. These trends can be ascribed to government withdrawing its support to agriculture starting with an initial re-organization and deregulation in the early 1980s and then reduced support to the point where no subsidies were paid to commercial farmers by the end of the 1990s. Coupled to the institutional changes under the new constitution (Vink and Kirsten 2003) and the tough competition farmers faced in a subsidized global market the sector's contribution to the economy stagnated and decreased to levels a little less than that of the post war period. In so doing the country slipped on its international standing on this measure. In 2009, South Africa's agricultural GDP thus was US$7.8 billion, placing it 37th worldwide on this score — down from 25th in 1981 (World Bank 2011).

Up to 1980 the agricultural sector was the largest single employer in the economy, however, after reaching a peak of 2.48 million of the economically active population this started to decline to reach

1.18 million in 2010. In 1920 it employed about four times as many of the economically active population as the manufacturing sector, but this declined to about the same as the manufacturing sector since 1980.

2.3 THE EVOLUTION OF SOUTH AFRICAN AGRICULTURE

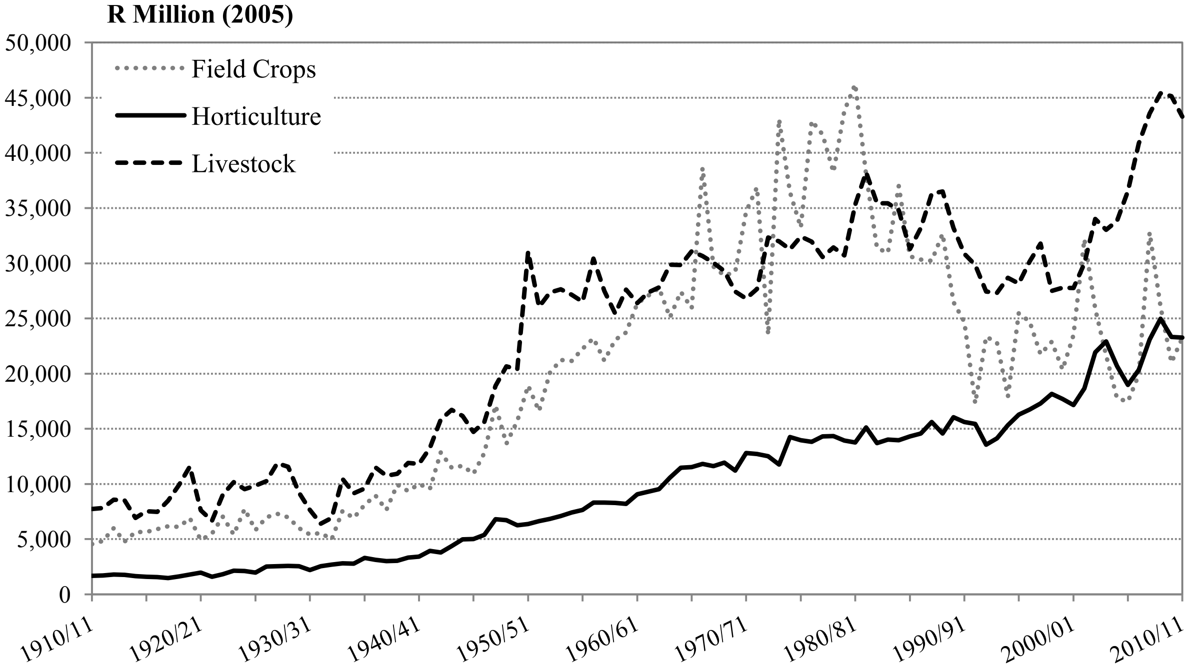
The changes in the relative importance of the agricultural sector have been accompanied by some equally strong changes in the structure of the agricultural sector itself over the past century. Broad trends in the agricultural economy measured at ten year intervals are highlighted in Table 2.2.

2.3.1 Changing composition of the agricultural economy

The mix of agricultural output changed markedly over the years (see Table 2.2 and Figure 2.1, Panels a and b). In 1911 about 55.1 percent of the value of South African agricultural output was livestock products, with wool (20 percent), dairy (19 percent) and cattle and sheep (each contributing 15 percent) accounting for 68 percent by value of livestock production. By 2010 the livestock share had shrunk to 50.6 percent, with poultry production accounting for 55 percent of this total. The share of horticultural output expanded consistently over the entire period since 1911; starting at 12.0 percent that year and increasing to 29.3 percent by 2005 and averaged about 25 percent since. Up until the late 1980s the growth in the value of horticultural output was steady, averaging 2.85 percent per year — aided in part by improvements in cold chain management. After a brief reversal in output growth from 1989 until 1993, the sector had impressive rates of growth in the wine, deciduous and citrus fruit industries in response to improved access to international markets as rest-of-world sanctions against imports from South African were scrapped.

The field crops share was 32.8 percent in 1911, grew to 49.6 percent in 1974 (due largely to an expansion of cereals and sugarcane production), declined significantly to 23.9 percent in 2006 and then regained some market share to reach 32.9 percent in 2008, but again declined to 23.8 percent in 2010 — the lowest share since 1911. A reduction in maize and wheat production accounted for most

Panel a: Gross value of agricultural production



Panel b: Share of output value

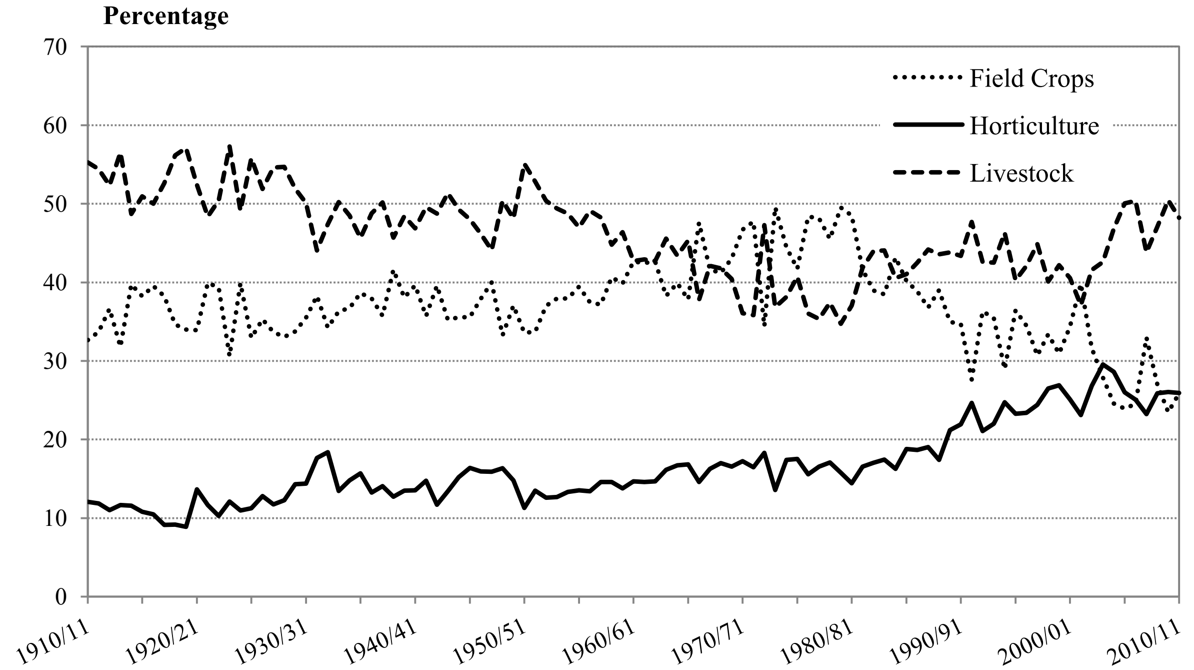


Figure 2.1: Changing Composition in Agricultural Production in South African Agriculture, 1910 — 2010.

Source: Own calculations

Table 2.2: Structural Changes in the South African Agricultural Economy, 1910-2010

Indicator	Unit	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Agricultural GDP Contribution												
-Rand (current)	million	47	115	72	112	452	615	861	3,654	12,184	27,451	59,543
-Rand (2005)	million	10,874	14,070	12,336	19,308	42,708	45,079	45,212	54,499	45,694	38,752	41,017
-US$ (2005)	million	1,709	2,212	1,939	3,035	6,713	7,086	7,107	8,567	7,183	6,091	6,447
-2005 International Dollar	million	2,809	3,634	3,186	4,987	11,030	11,642	11,677	14,075	11,801	10,008	10,593
Net Farming Income	Rand Million					129	247	511	2,096	6,685	3,902	40,201
	Rand Million (2005)					12,216	18,119	26,851	31,266	25,071	5,508	27,693
	US$ million (2005)					1,920	2,848	4,221	4,915	3,941	866	4,353
Agricultural Trade												
Agricultural Exports (% of Ag GDP)	%	41	44	58	42	51	48	50	56	38	57	74
Agricultural Imports (% of Ag GDP)	%	26	24	17	12	10	8	16	10	16	35	55
Value of Production	Rand Million (2005)	13,975	14,522	15,276	25,257	56,361	61,860	74,289	95,313	71,141	68,402	89,069
	US$ million (2005)	2,197	2,283	2,401	3,970	8,859	9,724	11,677	14,982	11,182	10,752	14,001
Share of Production												
Livestock	%	55	52	50	47	55	43	36	37	43	41	50
Crops	%	33	34	36	40	34	43	47	49	35	34	24
Horticulture	%	12	14	14	14	11	15	17	14	22	25	26

Table 2.2: (continue)...

Table 2.2: (Continued)

Indicator	Unit	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Land Use												
Cropland	000 hectare	2,525	4,093	6,705	6,369	7,397	9,533	9,114	8,733	8,120	6,079	5,660
Commercial/White Owned	000 hectare	1,955	2,793	2,793	5,141	6,291	8,203	8,296	8,154	7,575	5,599	5,124
Homelands	000 hectare	506	1,300	1,300	1,230	1,120	1,492	475	449	639	539	544
Orchards & Plantations	000 hectare	154	303	419	529	640	1,096	1,225	1,405	1,485	1,644	1,560
Pasture & Grazing	000 hectare	74,778	75,631	75,575	79,649	78,297	79,521	78,147	74,932	70,455	73,408	74,026
Domestic Field crop production												
Annual Observations	'000 ton	2,482	3,937	6,450	7,681	9,507	15,835	25,405	40,799	38,132	42,486	41,430
10 year Average	'000 ton	3,131	4,419	6,408	7,906	11,786	20,565	35,483	40,737	38,372	41,280	
Agricultural Employment												
Seasonal	1000	228	271	467	542	696	702	775	484	456	407	407
Regular	1000	413	405	600	767	739	751	788	669	728	509	355
AgGDP per capita	Rand Million (2005)	-	52,108	41,715	10,093	28,870	26,690	18,209	41,730	28,311	26,148	34,526
	US$ million (2005)	-	8,191	6,557	1,587	4,538	4,195	2,862	6,559	4,450	4,110	5,427
Fertilizer use	Rand Million (2005)			284	331	521	1,161	1,946	2,829	1,948	2,012	1,728
Tractors	Number		515	3,684	9,388	48,423	114,766	157,127	172,725	151,774	75,276	69,700

Sources: See text

of the post-1974 decline. This reduction came in response to adverse market conditions and in recent decades the active discouragement of expansion in area planted. The first came as a result of the initiative to reduce areas planted to field crop in marginal production areas in the 1980s (Vink 1999). This was followed by changes to the support policies of the control boards, most importantly the maize and wheat boards in the 1990s to make domestic prices to farmers more responsive to international price trends (Vink and Kirsten 2003).

The effect of these interventions (and the need for them) is evident by comparing the trend in land used for field crop production with the volume of production of field crops since 1960. Area under field crops increased from 2.5 million hectares in 1911 to a peak of 10.2 million hectares in 1964. It fluctuated around 9.2 million hectares up to 1980, but then decreased to 8.1 million in 1991. At the turn of the century it has decreased to 6.2 million hectares and in 2006 reached 4.5 million hectares, from where it recovered to 5.5 million hectares in 2010. The quantity of output, however, almost doubled over the decade since 1970 and stagnated at this level ever since. Comparing the annual observations on quantity of production against the average for the decade it appears that the variability of production has declined over the period.

Agricultural trade constituted 3.0 percent of South Africa's GDP in 2010, with agricultural exports accounting for about 7.8 percent of total exports (DAFF 2012). This is significantly less than its export share in 1932, when agriculture accounted for 80.6 percent of total South African exports. Since then, agricultural exports as a share of the country's total exports declined steadily, to bottom out at 6.5 percent in 1993, after which the agricultural share grew to an average of 8.2 percent for the period 1994 to 2010.

South Africa has always been a net exporter (by value) of agricultural products. In 1975, agricultural exports exceeded imports by R29.2 billion (US$ 4.6 billion) in inflation adjusted terms, or 50.1 percent of its GDP contribution (Figure 2.2). Thereafter its net exports declined to R1.1 billion (US$0.2 billion) by 1992 from where it recovered to R12.7 billion (US$1.9 billion) by 2002. However, the lingering effects of sanctions on imports from South Africa due to the apartheid regime followed by a failure to remain internationally competitive have left the country barely able to sustain its net agricultural exporter status in recent years.

Summary statistics on the commodity mix of the value of agricultural exports show that in 1960, the share of wool was by far the most important export commodity taking up 36 percent, followed by grapes, citrus and preserved fruit (22 percent) and maize (8 percent). By 2005 fruit exports have become the most important export commodity representing 38 percent of export value. This was followed by wine (15 percent), sugar (8 percent) and other food preparations (5 percent). A distinguishing feature of the fruit exports is that about 90 percent of the exports were in fresh form, as opposed to earlier in the century when fresh fruit exports were a rarity as a result of a lack of cold storage technology and air transport.

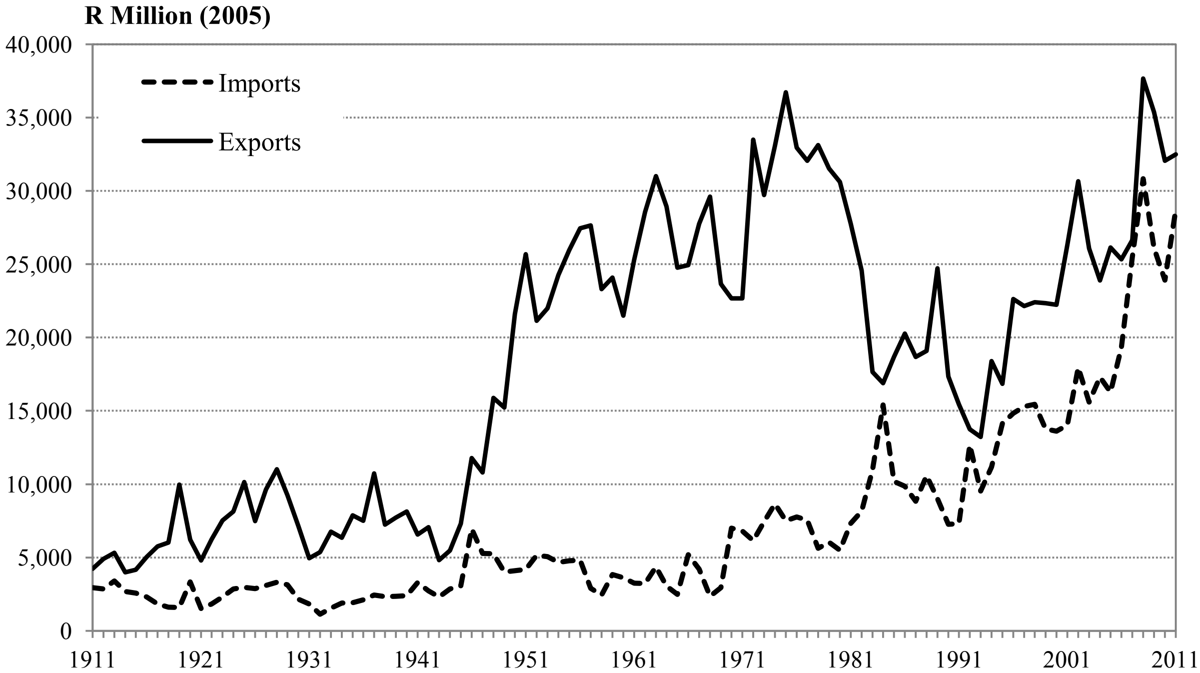


Figure 2.2: Trends in Agricultural Trade, 1910 - 2010

Sources: Own calculations

2.3.2 Agricultural employment; regular and seasonal labour trends

The total number of people employed on South African farms (excluding domestic workers) increased from 781,359 in 1910 to a peak of 1,801,525 in 1961[1]. Thereafter, it decreased to about 832,348 in 2010. The mix of regular and seasonal labour in agriculture has also undergone some marked changes over the past century. In 1910 it is estimated that seasonal labour represented about 35.6 percent of the hired labour force. This grew to about 50.8 percent in 1970, whereafter it decreased to about 32.4 percent of the hired labour force of 0.89 million in 1994. Thereafter it increased to 53.4 percent in 2010, the first time in history that seasonal labour represented a larger share of the hired labour force.

[1] The total employment in agriculture of the economically active population peaked in 1970 at 2.4 million (see Table 2.1). The discussion here focus on the employment of farm workers directly on-farm.

Due to uncertainties in the labour market that arose from the provisions of the Basic Conditions of Employment Act (Act 147 of 1993) and legislation regarding the Extension of Security of Tenure (Act 62 of 1997) the sector has experienced a rapid decline in employment. Here it is shown that it was accompanied by a shift in favour of seasonal labour.

The estimated number of proprietor and family workers in 1953/54 were 154,271, or 14.42 percent of the combined total of full-time farm workers actually involved in farming activities (excluding domestic servants) (BCS 1956). Their share declined to 8.77 percent of the aggregate of the combined total of full-time farm workers by 1993 (CSS 1998).

Owner and family labour, including relatives of the farm owner or occupier, were for the first time reported as 50,996 in the 1945-1946 agricultural census (OCS, 1949). Due to the influence of World War II, when many rural adult males were still in military service, this can be regarded as abnormally low. In 1937, the whites employed as full-time farm labour amounted to 205,261, with the non-white component of the labour force totalling 764,945 (OCS 1939). This changed to 15,460 white workers in 1946 (706,733 non-white), or 7.53 percent of the regular labour force recorded in 1937. In 1958, the occupier and relatives category was enumerated again for three years, then standing at 132,560 and climbing to 158,475 in 1960 (BCS 1960; 1961; 1962). Thereafter, it reappeared in the 1985-1986 agricultural survey as 82,861 and was enumerated as proprietor (64,042) and family labour (17,473) (CSS 1987; 1988). In 2007, owner and family labour declined to 47,570. As a proportion of the full-time labour force, this segment varied between 8.68 percent in 1946 and 18.95 percent in 1958, and by 2007 was around 11.5 percent (Stats SA 2011).

Agricultural GDP per economically active person engaged in agriculture in inflation-adjusted (2005 prices) terms was R52,108 (US$8,191) in 1920. This decreased by 2.15 percent per year to reach R18,209 (US$2.862) in 1970. Given the strong reduction in the number of economically active population over the next 10 years and a recovery in the Agricultural GDP this increased sharply to R41,730 (US$6,559) in 1980, but decreased to R28,311 (US$4,450) in 1990 from where it continued to grow to R34,526 (US$5,427) per capita in 2010.

2.3.3 Farm number, size and ownership trends

The various agricultural census reports report only statistics on the number of farm and farming area held by white farm owners. The total farmed area grew from 77.6 million hectares in 1918 to a peak of 91.8 million hectares in 1960, declining steadily to 82.2 million hectares in 1996, where it has more or less stabilized since (Figure 2.3). Total commercial farm numbers followed a similar pattern, peaking in 1953 at 119,600, and declining at an average rate of 1.23 percent per year thereafter, so that by 2007 the number of farms had dropped to about a third the number that prevailed in 1953.[2] The interplay between changing farm numbers and the total area in farms meant that average farm size declined during the first half of the 20th century (from 1,019 hectares in 1910 to 730 hectares in 1952) and increased during the second half of the century to average 1,640 hectares in 2000. Average farm size has continued to grow, and in 2007 was 2,113 hectares per farm.

These changes in the national average size of a farm mask the huge shifts in average farm size over time (See Table 2.3). Comparisons of the distribution of farm size are complicated by both the changes in farm size categories specified in Agricultural Census reports and the change in units of measurement after 1970. Here the farm size distribution is compared between the pre-1960 period — when farm area was still measured in morgen — and the post-1960 period. In 1926 about 48.4 percent of the farm units were smaller than 300 morgen, with 30.9 percent falling in the size group of 215 to 257 hectares (OCS 1928). By 1946 farms smaller than 257 hectares increased to 59.6 percent with 32.5 percent falling in the 215 to 257 hectares category (OCS 1948). In 1926, 27.7 percent of farms were larger than 857 hectares, changing to 22.1 percent in 1946. The promulgation of the Soil Conservation Act (Act 45 of 1946), which placed restrictions on the sub-division of farms, reversed this trend so that by 1959 farms smaller than 257 hectares represented 45.46 percent — farms larger than 857 hectares increased to 24.8 percent.

2 The statistical basis for enumerating farms changed over time. Up to and including the year 1953/54 a farm encompassed the activities of farmers "…whose farming activities extended over more than one farm or tract or piece of land within the same magisterial district, were at liberty to complete separate returns for each such farm or tract or piece of land or, on the other hand, to consolidate all their farming activities in one return." This changed in 1954/55, where after the census instructions were that "Only one form must be completed in respect of each farming unit, irrespective of whether farming activities are carried on [sic]on one or more farms or tracts of land and whether the farms are adjoining or not, provided the farms are situated within the same magisterial district." Thus some share of the substantial decline in the reported number of farms, especially during the period 1952/53 to 1955/56, is likely due to this statistical consolidation (BCS 1958).

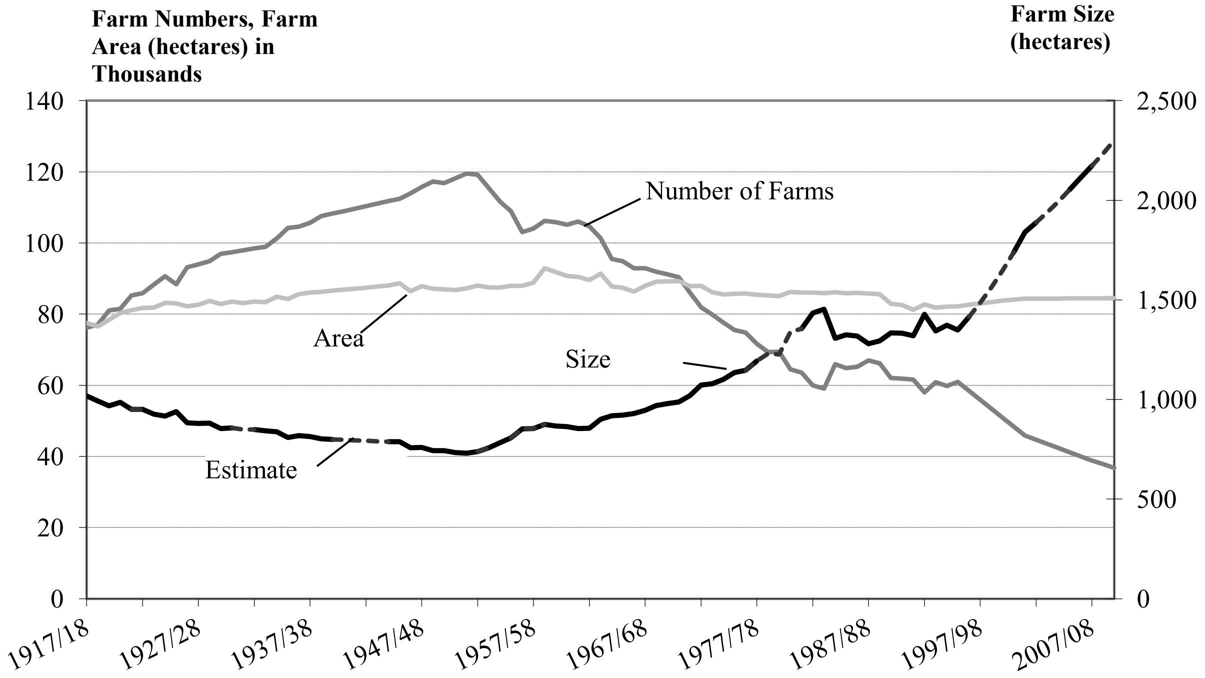


Figure 2.3: Number, Total Area and Average Size of Farms, 1918-2010

Source: Compiled from Agricultural Census Reports, Stats SA (2011) and DAFF (2012)

Table 2.3: Changing Farm Structure; Farm Size

Size Category (Hectare)	1926	1959	1981	1993
	Number of Farms			
< 4.9	2,457	4,374	2,175	912
5 - 9.9	0	5,950	2,209	1,360
10 - 19.9	5,661	5,764	2,388	1,668
20 - 85.6	7,329	14,529	9,557	8,318
85.6 - 256.9	27,307	17,543	9,734	9,202
256.9 - 428.2	0	13,648	6,921	6,570
429.1 - 856.5	18,540	18,009	10,846	10,094
857.3 - 2 140.4	13,096	15,892	8,995	8,775
2 141.3 - 4 282.6	8,279	6,141	7,785	7,445
4 283.5 - 8 565.3	2,193	3,127	3,820	2,553
8 565.3 >	888	1,202	0	1,083
Undivided	2,624	41	0	0
Total	88,374	106,220	64,430	57,980
	Percentage			
< 428	48.4	58.2	51.2	48.3
> 428	51.6	41.8	48.8	51.7

Sources: OCS (1928); BCS (1961); CSS (1987, 1998).

Notes: Due to change in measuring land area from morgen (prior to 1970) to hectare (since 1971) an exact match in size categories is not possible. Size categories were grouped to the closest approximate category of morgen.

In 1981, only 40.5 percent of farms were smaller than 257 hectares, with those larger than 857 hectares representing 32.0 percent. This changed to 37.0 and 34.2 percent respectively by 1993 (CSS 1998).

The form of ownership also changed significantly over time. A surprising 24.4 percent of farms were rented in 1918 and only 58.1 percent were classified as individual ownership (Table 2.4). The picture has changed fundamentally. By 1959 only 0.5 percent of the farms were rented and 93.1 percent were owned by individuals. In 1993, individual ownership declined to 82.4 percent and corporate ownership (companies and closed corporations) represented 16.1 percent. It seems that these forms of ownership have largely stabilized around these proportions since, however, the share of income generated seem to have shifted very strongly in favour of privately incorporated companies since 1993.

Table 2.4: Changing Farm Ownership According to Farm Area/Units

Type of Ownership	1918		1960		1993		2007	
	Number	**Share**	**Number**	**Share**	**Number**	**Share**	**Number**	**Share**
Close Corporation					2,093	3.6	2,259	5.7
Family					0	0.0	874	2.2
Individual	44,240	58.1	98,487	93.1	47,755	82.4	33,249	83.2
Partnership/Shares	6,872	9.0	5,626	5.3	4,449	7.7	2,167	5.4
Private company	6,469	8.5	1,156	1.1	2,809	4.8	237	0.6
Other/rented	18,568	24.4	557	0.5	873	1.5	1,180	3.0
RSA	76,149		105,826		57,979		39,966	
				Income				
	R'000	**Share**	**R'000**	**Share**	**R'000**	**Share**	**R'000**	**Share**
Close Corporation					1,201	6.1	5,595	7.0
Family					0	0.0	1,206	1.5
Individual					9,953	50.7	41,727	52.4
Partnership					4,346	22.1	3,459	4.3
Private company					1,990	10.1	26,704	33.5
Other					2,131	10.9	914	1.1
RSA					19,620		79,605	

Sources: OCS (1919); BCS (1961); CSS (1998), Stats SA (2010).

2.3.4 Black versus white sub sectors

These aggregate economic changes fail to reveal the different development paths followed by black versus white farmers. Throughout most of the post-unification period (specifically from 1913, but intensively so from the 1930s), the sustained and substantial government support to agriculture was biased towards white commercial farmers. Lacking a commensurate amount of public support, black farmers suffered as a consequence. The Natives Land Act of 1913 (Act 27 of 1913) and the Co-operative Societies Act (Act 28 of 1922 are two key examples of discriminatory public policy. The Natives Land Act confined land ownership by blacks to dedicated native reserves, while the Co-operatives Act effectively excluded black farmers from participating in farmer cooperatives. In 1925 the Farmer Assistance Board (the predecessor of the Agricultural Credit Board) was established to assist farmers with soft loans in the aftermath of the recession of the early 1920s. Black farmers were once again excluded from accessing these government backed credit programs, and they were also excluded from participating in the farmer settlement programs introduced in the late 1930s. After the 1970s government support structures within the homelands and the self-governing territories were to take care of the needs of black farmers, but in fact these programs either failed to materialize or were never developed to the extent they were for the white commercial farming community.

The effect of these discriminatory policies over time is shown in Table 2.5 where the current relative contribution of black farmers to national production and land ownership is compared with its share in national farming activities pre-1960 (prior to the establishment of the homeland and self-governing territories). The share of farmed area owned by black farmers varied little from 1918 to 1991, averaging around 15 percent. According to the 2000 Survey of Large and Small Scale Agriculture this share then doubled to almost 31 percent of total farmed area (Stats SA 2002)[3]. The share of maize, wheat, sorghum and pumpkin output produced by black farmers was substantially less in 2000 compared with earlier years. Likewise, the share of the country's cattle and poultry stock held by black farmers had contracted a little by 2000, although the sheep population on black-owned farms had marginally increased from 1960 to 2000.

In addition to the Land Reform and Restitution initiatives that were implemented beginning in 1994, the South African government established several programmes to support black farmers. These include the Land Redistribution for Agricultural Development programme (launched in 2000), the Comprehensive Agricultural Support Programme (CASP) that provides post-settlement support to targeted black farmers, whether they acquired land through private means or as part of a land reform

[3] The 2002 Survey of Large and Small Scale Agriculture is not directly comparable with the data of earlier agricultural census and survey reports as the definition of a farmer used in this survey included anything starting from garden plots.

Table 2.5: Share of Black Farmers of Area Farmed and Planted, and in National Production of Selected Crops in South Africa: 1918-2002

Year	Area of Farms	Planted	Corn	Wheat	Sorghum	Pumpkins	Number of Cattle	Number of Sheep	Number of Poultry
	Percentage								
1918	16.4	27.2	23.2	3.5	74.3	36.3	24.5	14.4	34.9
1930	-	-	23	-	77	-	51.1	10.8	-
1937	-	-	-	-	81	-	-	9.9	-
1950	-	-	18.8	1.7	46.4	-	41	11.7	31.3
1960	15.4	16.9	13	1.5	34.7	-	38.8	9.5	38.8
1991	14.4	15.2	-	-	-	-	-	-	-
2002	30.9	14.4	3	0	0.1	17.3	30.1	10.1	29.1

Sources: OCS (1919, 1932, and 1939), BCS (1952, 1963), CSS (1992), and Stats SA (2002).

programme, and the Micro-Agricultural Financial Institutions of South Africa (MAFISA) programme that extends micro-finance services to economically active poor rural households, small farmers, and agribusinesses. MAFISA provides loans to emerging farmers not served by the Land Bank although the program is administered by the Land Bank on behalf of the Department of Agriculture (DOA 2009). The roll-out of these programmes to date has been slow, and it is too early to judge their effectiveness.

2.3.5 Shifting patterns in area planted and production

Table 2.6 shows the strong shifts in the patterns of production of field crops, horticulture and livestock according to the new provincial boundaries in South Africa for the years 1918, 1960, 1993 and 2007. Field crop production was spread over 2.87 million hectares in 1918 with the Free State Province representing 34 percent of the share of area planted, followed by the Western Cape Province (15 percent) and Mpumalanga (13 percent). In 1960, with the Free State province (30 percent) still being the most prominent, the North West (17 percent) and Eastern Cape provinces (12 percent) took up the second and third position in terms of area planted to field crops. The creation of the homelands under the separate development policy put an end to the growing prominence of the Eastern Cape and by 1993 it represented only 2.3 percent of the area planted. In terms of physical volume of production the province of KwaZulu-Natal always enjoyed the first position. In 1960 it was responsible for 47 percent of the total output of 19.66 million tons of field crop produce, with the provinces of Mpumalanga and the Free State in second and third position respectively. By 2007 its share has increased to 51 percent of the total physical output of 29.20 million tons with the Northern Cape and Mpumalanga following in second and third position.

Table 2.6: Changing Provincial Distribution of Agricultural Production, 1918, 1960, 1993, 2007

Province	Year	Field Crops		Horticulture		Livestock						
						Cattle	Sheep & Goats	Pigs	Poultry	Wool & Mohair	Milk	Eggs
		Tons	Hectare	Tons	Hectare	Number on Farm				Kg	Litres	Dozen
		Thousands		Thousands		Thousands				Millions		
Eastern Cape	2007	413.6	95.8	938.3	35.8	604.6	3,806.1	36.5	2,331.1	12.7	853.2	27.5
Free State		4,286.3	1,450.2	585.3	22.7	1,259.1	2,077.2	53.2	29,733.4	7.7	440.8	48.9
Gauteng		275.0	78.2	174.8	7.3	358.4	29.1	131.1	10,644.9	0.0	131.4	95.3
KwaZulu-Natal		14,883.5	392.2	477.7	20.7	594.2	203.7	168.9	19,824.5	0.5	524.1	76.9
Limpopo		316.6	121.9	1,550.8	63.6	311.6	60.1	111.3	49,768.4	0.0	29.8	23.5
Mpumalanga		4,529.4	596.3	1,176.7	40.8	576.9	432.9	122.2	65,176.4	1.8	116.3	50.9
North West		2,096.0	796.1	337.8	13.9	825.9	182.1	181.7	39,138.5	0.3	134.5	47.5
Northern Cape		1,021.3	174.1	443.6	32.1	353.4	4,045.2	6.7	220.1	3.5	19.1	5.1
Western Cape		1,381.1	495.6	5,786.2	245.9	394.7	1,835.5	98.1	26,087.0	8.7	645.5	101.4
South Africa		29,202.9	4,200.6	11,471.3	482.8	5,278.8	12,672.0	909.5	242,924.3	35.4	2,894.7	476.9
Eastern Cape	1993	339.3	163.8	491.2	33.6	195.2	1,579.8	47.7	9,984.6	21.6	241.9	26.1
Free State		2,452.9	2,283.9	245.3	31.3	619.1	2,196.5	161.2	3,944.8	16.9	376.8	8.5
Gauteng		342.7	215.5	139.2	12.6	269.7	76.1	318.0	77,862.8	0.6	85.2	68.8
KwaZulu-Natal		11,240.6	456.8	401.3	24.6	463.6	476.8	332.6	78,545.7	2.7	317.2	26.2
Limpopo		178.0	223.4	723.6	64.8	318.7	36.6	117.5	4,781.0	0.1	19.8	1.4
Mpumalanga		2,980.1	886.9	604.8	45.3	458.1	603.9	213.6	21,458.4	7.8	200.6	14.6
North West		1,015.1	1,515.0	143.6	15.7	707.5	181.0	204.8	54,706.1	0.5	215.8	20.5
Northern Cape		550.8	130.4	285.1	19.1	138.1	3,277.8	14.4	1,399.5	8.9	26.8	2.4
Western Cape		1,144.3	714.3	2,717.3	337.5	158.8	1,356.3	284.1	69,791.5	12.6	383.7	46.7
South Africa		20,243.8	6,589.9	5,751.5	584.6	3,328.7	9,784.8	1,694.0	322,474.4	71.7	1,867.8	215.3

Table 2.6: (continue)...

Table 2.6: (Continued)

Province	Year	Field Crops		Horticulture		Livestock						
						Cattle	Sheep & Goats	Pigs	Poultry	Wool & Mohair	Milk	Eggs
		Tons	Hectare	Tons	Hectare	Number on Farm				Kg	Litres	Dozen
		Thousands		Thousands		Thousands				Millions		
Eastern Cape		425.0	1,207.8	-	36.2	760.7	13,338.4	604.0	4,243.3	36.2	-	6.9
Free State		460.2	2,959.5	-	13.3	1,642.2	9,631.9	133.8	2,983.2	28.3	-	21.4
Gauteng		1,147.2	381.5	-	20.5	300.1	260.3	74.7	1,658.8	0.3	-	8.7
KwaZulu-Natal		9,208.7	861.2	-	50.7	962.4	2,570.3	128.8	3,163.1	3.9	-	8.8
Limpopo	**1960**	695.4	788.0	-	43.4	693.4	460.1	86.0	1,044.2	0.0	-	3.4
Mpumalanga		2,714.0	1,050.3	-	61.2	728.1	2,750.0	109.5	1,526.1	6.9	-	9.5
North West		1,113.4	1,669.9	-	14.2	1,426.5	1,483.2	106.3	1,641.5	1.4	-	11.2
Northern Cape		3,484.6	142.9	-	5.7	695.6	7,253.2	19.1	291.7	17.5	-	2.2
Western Cape		408.1	962.5	-	186.1	309.4	6,099.2	118.5	2,438.5	20.2	-	19.5
South Africa		19,656.6	10,023.7	-	431.2	7,518.4	43,846.5	1,380.7	18,990.4	114.8	-	91.6
Eastern Cape		-	276.3	-	23.2	1,801.2	11,690.3	347.4	2,646.3	20.8	-	-
Free State		-	967.7	-	27.1	1,595.6	8,724.3	146.3	1,482.3	19.6	-	-
Gauteng		-	200.7	-	9.5	297.8	372.8	56.5	790.3	0.4	-	-
KwaZulu-Natal		-	205.2	-	20.8	1,030.9	2,629.5	123.6	1,365.3	3.0	-	-
Limpopo	**1918**	-	47.0	-	3.9	395.0	619.1	47.9	541.4	0.0	-	-
Mpumalanga		-	368.7	-	16.7	636.9	2,266.0	66.5	651.5	4.1	-	-
North West		-	336.2	-	11.3	631.2	1,594.8	139.8	687.4	2.0	-	-
Northern Cape		-	27.4	-	2.2	175.9	5,301.3	16.2	308.0	5.1	-	-
Western Cape		-	445.3	-	47.9	283.5	4,704.8	163.1	1,249.9	6.0	-	-
South Africa		-	2,874.5	-	162.6	6,848.1	37,902.9	1,107.2	9,722.4	61.1	-	-

Sources: OCS (1918); BCS(1960); CSS (1995) Stats SA (2010)

Notes: Production of farmers in the districts of the homelands excluded during 1993

The area under horticultural production has increased from 162,579 hectares in 1918 with almost a third of this in the Western Cape, followed by the Free State and the Eastern Cape. By 1960 the leading position of the Western Cape in the horticultural industries was well established with it having the largest share in area planted (43 percent), but KwaZulu-Natal and Mpumalanga have taken over the second and third positions, whilst the share of the Eastern Cape in the national total area planted to horticultural crops declined to 8 percent.

In 1918 the Eastern Cape possessed the largest share of the number of all species of livestock, a position that it maintained up to 1960 with the exception of cattle, where it ceded first place to the Free State. By 1993 the situation has changed completely, with the Eastern Cape then only holding the lead position over other provinces in terms of the possession of sheep and goats. However, in the production of wool and mohair the Eastern Cape has retained the lead position through the periods monitored here, whilst gaining the lead position in terms of milk production by 2007.

2.4 CONCLUSION

In the century since 1910 the agricultural sector has experienced huge and sometimes contrasting changes in the structure of its production. The development of stable markets around the major urban centres in the interior regions of South Africa were a fairly recent development which only gained momentum in the late 19th century spurred by the development of mining towns around the diamond and gold fields of the Cape colony and Transvaal. This was aided by the construction of railway lines connecting these mining centres with the main export harbours — a dedicated effort to expand the railway connections to regions not served by the main arteries only gained momentum from the 1930s. The first properly organized agricultural produce markets only began to become a familiar sight in the decade immediately after the Anglo-Boer War along with the evolution of mostly privately owned local or regional co-operative marketing bodies. A profusion of marketing structures and legislation to support these organizations ensued and efforts to harmonize this were taken in 1937 with the promulgation of the Agricultural Marketing Act (Act 26 of 1937). A host of control boards were established under this act, especially after the Second World War.[4] Accompanied by a number of other regulatory changes and the introduction of farmer support measures around the same time these laid the foundation for the subsequent expansion of the sectors' contribution to the economy by

[4] This is discussed in more detail in Chapter 5.

unlocking the productive potential of agriculture in the remote areas of the country and improving access to domestic and international markets in general.

Taken together these developments had a marked and lasting effect on the structure of production in agriculture. The number of farms increased by 38.9 percent from 1918 to reach 105,826 in 1959 with average farm size decreasing to 729 hectares in 1951 with about 75 percent of the farms being between 20 and 857 hectares in size and largely in private individual ownership. Thereafter average farm size steadily increased and reached (a questionable)[5] 2,367 hectares in 2010, with ownership by privately incorporated companies becoming a prominent feature. These events have seen the mix of agricultural commodities expand markedly with horticultural production averaging the same levels of production by value as field crops by 2010. Over the century production agriculture has also experience a growing reliance on purchased inputs as reflected here by the expenditure on fertilizer and the use of tractors. This has led to a more than twofold increase in the use of hired labour from 1910 to 1961, but mechanization has seen a decrease in farm employment to numbers approaching that of the 1910s with hired seasonal labour now being the most prominent category of labour.

Much of these structural developments and the reversal of the trends experienced over the early half of the century came about as a result of the financial and fiscal constraints the country's economy experienced from the 1970s. This forced a new phase in the sector's development with the introduction of various deregulation measures from the early 1980s and the decrease in government support to farmers through to 1994. With the advent of the new democratic constitution in 1994 almost all control boards were closed, support payments and programs were scrapped, and the sector exposed to the full brunt of market forces through the market liberalization measures introduced as a central theme of the latest policy changes. This has led to several changes in the sector's input use and the mix of commodities it produces. It is to these developments that I now turn.

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[5] The basis used by Stats SA to sample farms to be included in the agricultural Census introduces an upward bias in the measurement of average farm sizes. See Chapter 4 where the trends in farm size is discussed in greater detail.

CHAPTER 3

AGRICULTURAL OUTPUTS

3.1 INTRODUCTION

Developing consistent measures of national average output prices and quantities for the components of South African agricultural production is one thing: forming meaningful aggregate price and quantity measures is altogether another thing. Past aggregate output measures (e.g. Thirtle et al. 1993; Schimmelpfennig et al. 2000; and Liebenberg and Pardey 2010b) used a hybrid Laspeyres cum Törnqvist-Theil aggregation approach. Using this approach a series of sub-aggregate output quantity indexes formed using Laspeyres aggregation methods for various base years were spliced together for the livestock, field crops and horticulture sub-sectors. Finally, the sub-aggregate quantity indexes were aggregated into a measure of the total quantity of output using a Törnqvist-Theil procedure. Thirtle et al. (1993) and subsequent studies referred to the results of this 'hybrid' aggregation procedure as a Törnqvist-Theil index. To avoid any confusion with the conventional Törnqvist-Theil approximation of the Divisia index this indexing method will be referred to as the Thirtle index in the remainder of this study.[1]

This practical, but nonetheless ad hoc procedure relied on the sub-aggregate quantities reported by the Department of Agriculture. For the aggregate output measures reported in this study I compiled price and quantity estimates for each of the individual measured components of agricultural output spanning the period 1910 to 2010 and then applied consistent Fisher Ideal aggregation methods to minimize the potential for introducing index number bias into the resulting agricultural price and quantity aggregate measures. These Divisia aggregates (and their components) were compared with other measures reported by prior studies using different data and aggregation methods to examine the extent of bias in the

[1] The author thanks Colin Thirtle for kindly providing the data he and colleagues developed for the 1947-1997 period. This study develops an entirely new series constructed from different data sources and using different methods. There are a host of measurement issues requiring attention in the official statistics as discussed in chapters 3 and 4. For example, historical capital input and livestock inventory estimates were developed from surveys with especially low participation rates in the national agricultural censuses conducted since 1992/93. Moreover, DOA statistical agencies have adopted alternative estimation methods that resulted in significant changes to the previously reported national capital and livestock inventory estimates back to the 1980s (Blignaut 2009). This study also made an effort to correct for significant inconsistencies in the officially reported data on agricultural labour attributable to the inconsistent inclusion of seasonal and domestic labour and added estimates for proprietor and family labour.

measures hitherto reported and to re-examine and recalibrate our measured understanding of the long-run performance in South African agriculture.

South African agricultural production grew quite rapidly during the 20th century, especially since the late 1930s and the composition and location of production changed substantially as well. Different measures of agricultural output give different perspectives on these changes. This chapter provides a detailed assessment of the temporal patterns in the value and quantity of South African agricultural production and its composition. In constructing these output estimates, numerous adjustments were made to the production accounts data in order to include previously omitted products and to correct for inconsistent or erroneous estimates of production (with particular reference to the dairy industry). The chapter concludes with a presentation of the Fisher Ideal output quantity indexes and juxtaposes this against the output quantity indexes compiled using the procedures followed by Thirtle and others.

3.2 DATA DEVELOPMENT AND SOURCES

The statistics reported in the *Abstract of Agricultural Statistics* form the basis for the estimation of the national income derived from agriculture. The origins of the System of National Accounting trace back to the 1947 report of the Sub-Committee on National Income Statistics of the League of Nations Committee of Statistical Experts. This report emphasized the need for international statistical standards for the compilation and updating of comparable statistics in support of a large array of policy needs (UNSD 2011). In agriculture, the need to define international statistical standards already enjoyed attention at the British Empire Statistical Conference of 1920 (OCS 1922). From this one can conclude that the basis for collecting and processing agricultural statistics was in a process of evolution for at least the first half of the 20th century. Thus, when compiling and presenting long-run statistics as is done in this study, one needs to pay close attention to changes in the scope, definition, sampling and processing details of the reported data to maximize their consistency and comparability over time.

Through to 1995, the commodity-specific data tables on agricultural output quantity reported in the *Abstract of Agricultural Statistics* excluded production from the former homelands, or former native reserves (DAS 1995)[2]. In 1995 the Department of Agriculture revised the commodity specific data series to include production originating from the homeland areas in concordance with the *new* sub-national boundaries that were introduced in 1994 (Directorate Agricultural Statistics 2012). As the *Abstract of Agricultural Statistics* only reports observations for the past 30 to 40 years, observations obtained from

[2] For ease of reference, output coming from black squatters and black farmers operating in the native reserves will be referred to as production *originating from homeland areas*. Production attributed to black farmers on white-owned farms were generally included with that of homeland farmers, whilst production by white, coloured and Indian squatter farmers was counted as production by white holders, albeit not consistently so.

earlier editions of the *Abstract of Agricultural Statistics*, especially for years prior to 1970/71, would require revision to include homeland production.

Similar to Simkins (1981) this study is based on published statistical sources and carefully tracks the production of squatters on white owned farms and the reserves. Simkins, however focussed on production by black farmers in the homelands only (referred to as Reserves by Simkins). The Directorate of Agricultural Statistics based its information on production in the homelands on information obtained from both the Development Bank of Southern Africa and annual reports of the Departments of Agriculture (and Forestry) of the various Independent States. However, it is only in the case of Tables 5 and 6 in the *Abstract of Agricultural Statistics* that reference is made to the Development Bank of Southern Africa as the source of information on homeland land use and the number of farms (Blignaut 2013, personal communication)

A little known feature of the summary table on gross value of production statistics — reported toward the end of the *Abstract of Agricultural Statistics* — is that this table has always included production originating from the former homeland areas. It is these statistics that form the basis for the derivation of the national income accounts.[3] Based on the national food balance account, the national gross value of production account (distinct from the crop, or product-specific production accounts) also includes estimates of on-farm production for own use, intermediate use and production by farm workers for own use. Output from these sources is not included in the quantity of production data reported elsewhere in the *Abstract of Agricultural Statistics*, but is included in the 'physical volume of production indices' reported in the *Abstract of Agricultural Statistics*.[4] In most cases, records on the original food balance accounts are no longer available from departmental sources for the years prior to 1947/48. The only ledger file discovered in which the gross value and physical quantity (volume) of production data are recorded provides spotty data for years prior to 1947/48, and then mostly as rounded off numbers. Information from the ledger data was used to form the output estimates for the earlier years presented in this study when no other information was available (DAS 2009).

The weights for the base years in the volume of production indexes differ from those used for the Producer Price Indexes as the categorization of commodity categories differs in some instances, e.g., quinces and prunes are included with summer fruits (melons and berries) (Strydom 2012). It is these reported aggregate physical volume of production indexes that constituted the sub-aggregate measures of output used in past productivity studies to form a long-run aggregate measure of output.

3 This fact is not spelled out in the explanatory notes to the data tables in the various issues of the Abstract of Agricultural Statistics since it first appeared in 1958.

4 The *Abstract of Agricultural Statistics* follows the somewhat confusing practice of referring to production quantities as 'physical volume'. The practice followed here is to refer to the reported quantity of production index as the "physical volume of production index", or more usually label it the output quantity index in line with international practice.

A further problem with the physical volume of production indexes, however, is the inconsistent inclusion of commodities in the reported field crops, horticulture, and livestock sub-aggregates. For example, prior to the 1947/48—1949/50 base-year horticultural products were included as part of field crops and no index measure of fruits or vegetable production was provided (DAEM 1961). Potatoes was shifted from field crop production to the horticultural sector index in the 1958/59—1960/61 base-year (DAEM 1972). The system of measurement was clearly in a developmental phase prior to World War II and over time a growing number of products were also added to the list of enumerated commodities, introducing the risk of index number bias if fixed weight indexes with different base years were spliced together.

Table 3.1 summarises the changes in the basket of commodities used by the Department of Agriculture to form the first reported output index (1936/37—1938/39 base-year). The number of vegetables grew from four (potatoes, sweet potatoes, onions and dried beans) in the 1936/37—1938/39 base-year index, to eight (also including tomatoes, gem squashes, cabbage, carrots and green beans) in the 1947/48—1949/50 base-year, and the index currently includes only 17 of the 22 vegetable products for which data are regularly compiled. The coverage of the index falls (well) short of the commodities being produced in South Africa at any point in history. For example, the agricultural census provides information on the production of sweet potatoes and the number of pumpkins produced from the 1917/18 crop year, but both these crops were excluded from the national income accounts for agriculture until 1958. The regular enumeration of most vegetable commodities only began in 1958.

Moreover, prior to 1958 the production of fresh fruits other than mangoes and pineapples was not enumerated in the census and survey reports. This was due to a lack of standardization of packaging (units of measurement) (OCS 1919). The establishment of the various control boards regulating the marketing of these commodities helped to address this problem. However, an analysis of statistics on the value and quantity of exports and the purchases of horticultural products for canning suggests that a substantial quantity of horticultural production was not included in the reported gross value of agricultural production estimates for the years prior to 1958 (DAEM 1961).

A similar situation prevailed for the livestock sector. Although the income from dairy farming included fresh milk, butter and cheese production (condensation milk products, i.e. condensed milk and milk powder, was added from 1927) the quantity of fresh milk produced was excluded from the physical volume of production index prior to the base year 1958/59—60/61 variant of the index. In the case of poultry products, the production value of broilers was reported only after the 1946/47 production year, and was only included in the physical volume of production index beginning with the base year 1958/59—60/61 index.

Table 3.1 Crops Included in the Volume of Production Indexes, Selected Base Years

Commodity	Field Crops For base years			
	36/37-38/39	47/48-49/50	58/59-60/61	2005
Summer Grains				
Maize	X	X	X	X
Sorghum	X	X	X	X
Winter Cereals				
Wheat	X	X	X	X
Oats	X	X	X	X
Barley		X	X	X
Rye	X	X	X	X
Oilseeds				
Canola[1]				X
Sunflower		X	X	X
Soya				X
Groundnuts		X	X	X
Hay				
Lucerne	X	X	X	X
Lucerne Seed				
Teff	X	X	X	X
Other Hay				
Beans				
Dry Beans	X[2]		X	X
Lentils				
Peas				
Other				
Cotton				X
Chicory				
Sugar			X	
Tobacco				X
Wattle Bark				
Number of crops	8	10	12	15

Sources: DAEM (1958; 1967; 1972; 1985) DAS (1997); DAFF(2012)

Notes: Details on the construct of the Physical Volume of Production Index are not provided in the Abstract. It is assumed that this would follow that of the Producer Price Index. Data files shared shows 1) that quantity data is first converted to the same unit of measurement for all products (e.g. tons) before constructing aggregate indices; (2) that the combination of crops in a category may deviate from that of the Producer Price Index, e.g. Quinces, Prunes, Figs and Cherries are included under summer fruits. Initially all crops were treated as field crops. Soya added in 1976

[1] Canola (oilseed) replaced rye in the winter cereals quantity index from 2000 instead of being included under oilseeds.

[2] Dry Beans, potatoes, Onions and sweet potatoes grouped as other.

Table 3.1 (continued)

Commodity	Horticulture For Base years			
	36/37-38/39	47/48-49/50	58/59-60/61	2005
Vegetables[3,4]				
Potatoes	F	F	X	X
Tomatoes		X	X	X
Gem Squashes		X	X	X
Pumpkins				X
Green Mealies				X
Onions	F	F	X	X
Sweet Potatoes	F	F	X	X
Green Peas				
Beetroot				
Cauliflower				
Cabbage		X	X	X
Carrots		X	X	X
Green Beans		X	X	X
Deciduous Fruit[5]		X	X	
Apples				X
Apricots				X
Grapes				X
Pears				X
Peaches				X
Plums				X
Prunes				
Figs				X
Cherries				
Quinces				
Citrus Fruit[6]		X	X	
Oranges				X
Lemons				X
Grapefruit				X
Naartjies				X
Tropical Fruits[7]		X	X	
Avocado's				X
Bananas				X
Granadillas				X
Litchi				X
Guavas				X
Loquats				
Mangoes				X
Pawpaws				X
Pineapples				X
Tropical				
Summer Fruit[8]				
Strawberries				
Watermelons				
Number of crops	3	18	21	32

Notes:
3 Crops indicated with "F" were included under Field Crop Index before a separate index was reported for the Horticultural industries.
4 2005, lettuce, cucumbers, and mushrooms added
5 Up to 1947/49 Viticulture represented by good wine and wine for distilling — no data on table grapes. Before 1958–60, no detail on which fruits were included.
6 Before 1958–60, no detail on which fruits were included.
7 Before 1958–60, no detail on which fruits were included.
8 Never Included.

Table 3.1 (continued)

Commodity	Livestock Base years			
	36/37-38/39	47/48-49/50	58/59-60/61	2005
Pastoral Products				
Wool	X	X	X	X
Mohair	X	X	X	X
Karakul				
Ostrich Feathers				
Dairy & Dairy Products[9]				
Fresh Milk			X	X
Butterfat	X	X	X	
Cheese	X	X	X	
Condensing milk			X	
Slaughter Stock				
Cattle	X	X	X	X
Sheep	X	X	X	X
Pigs	X	X	X	X
Poultry & Products				
Poultry[10]			X	X
Eggs	X	X	X	X
Turkeys	X	X	X	
Number of crops	10	10	12	8

Notes: [9] Butterfat, cheese milk, condensing milk and fresh milk until August 1988; from September, 1988 only butterfat and fresh milk. From January 1995, only fresh milk included. All dairy products first converted to fresh milk equivalents before forming the index

[10] Prior to 1947/48, Gross Value listed as a total for poultry; as of 1947/48 separately listed for egg and broiler production. The combined total in 1947/48 for poultry industry increased to double that of 1946/47.

Another salient feature of the physical volume of production indexes reported in the various issues of the *Abstract of Agricultural Statistics* is the infrequent re-basing of the indexes. Prior to the 1990s, up to 15 years elapsed between the re-basing of the indexes, contrary to the practice of doing so every 5 years, for example, with the consumer price index. One consequence of this is a classic index number bias problem as the index moves further away from the base year (see next section).

In addition to the changing definition of the field crop sector (mentioned above) the number of commodities enumerated since 1910/11 expanded from eight in the 1936/37—38/39 base year to 12 by the 1958/59—60/61 base year. Over the following 40 years another three commodities were added to the basket to reach a total of fifteen commodities in the 2005 base year.

When forming an index for a category of products, such as pastoral products, the Department of Agriculture converts the quantity data to an inter-temporally consistent unit of measurement prior to forming the index for the category. For example, the number of karakul pelts is converted to ton equivalents before combining them with the production estimates for wool and mohair to create the combined index for pastoral products. This approach introduces the risk of using inconsistent and outdated technical conversion factors, a number of incidences of which were apparent in unpublished files provided to the author by the Department of Agriculture (DAFF 2012).

In summary, there are four notable measurement issues that should be borne in mind when assessing the long-run pattern of agricultural production using the volume (i.e. quantity) of production accounts reported by the Department of Agriculture:

- The statistical concepts of agricultural production, and associated data survey and data processing methods are continuously evolving, and were especially fluid during the first half of the 20th century;
- Changes in the sectoral (field crops, horticulture, and livestock) definitions and the associated changes in the scope of products to include in the sector totals reported in the physical volume of agricultural production indexes and gross value of agricultural production accounts are a source of (sometimes serious) measurement error;
- Inconsistencies (some indicated above, some expected, but yet to be confirmed) in the adjustments made in converting quantity data to an inter-temporally consistent unit of measurement in the reported production quantities introduce additional measurement errors into the volume of production accounts; and,
- Finally, the legacy of the previous political dispensation, under which production by black farmers was excluded from the national commodity specific production data, calls for careful revision of past production statistics. All of these measurement matters are of particular importance if productivity analysis is done using indexing methodologies based on the underlying price and quantity data reported in the national production accounts. To get a more complete and inter-temporally consistent measure of agricultural output, the reported production quantity data were augmented to include the on-farm production for own use (i.e. inclusive of use by farm workers) and homeland farmers where relevant.

To address all of these issues, an entirely new set of national production accounts was constructed using the available Agricultural Census and Survey reports. The production by black farmers in the homelands is mostly only available for agricultural census years. The agricultural surveys conducted in the intervening years only provide information on the production of commercial agriculture (i.e. white farmers). Additional information was available from unpublished ledger files made available to the author by the Directorate of Agricultural Statistics and were used to adjust the production estimates coming from the agricultural surveys so that estimates of production from the former homelands could be added in to the respective output measures (DAS 2009). Two other sources of information on production, trade and price statistics provided additional data and were used to generate a revised set of national agricultural production accounts reported in this study. One was the *Handbook of Agricultural Statistics*

(DAEM 1961) and the other was the *Union Statistics for Fifty Years: Jubilee Issue, 1910-1960*[5] (BCS 1960)

The procedures used to construct the revised production accounts are as follows:

i) An initial, detailed compilation of data for the production years 1910/11 through 2010/11 was constructed on a commodity by commodity basis using data obtained from the Agricultural Census and Survey reports. These data included the reported estimates of area planted, (and area harvested, where applicable), the quantity of production and, where available, prices received. The area and production data were identified by type of producer so that adjustments for the years in which production from the homelands was excluded could be made. For the pre-1970 period, the agricultural census data on production quantities served as the primary source of verification of the data published in the *Abstract of Agricultural Statistics*. Where deviations between the two sources occurred, the census statistics served as the preferred source, unless the reason for the deviation was the exclusion of homeland agriculture during a particular census node, or additional data obtained from control boards and various commodity organisations were deemed to be more reliable.

ii) Commodity specific estimates of production and area under cultivation in the homelands were made using the trend in the reported production (area planted) to estimate the level of production (area planted) of homeland farmers. When appropriate, the production and area planted by squatters on white-owned farms were also estimated in the same manner.[6] This is of particular importance in the case of sugar cane production, where Indian squatters on white-owned farms produced a significant share of the country's total production of sugar cane. For example, in 1946/47 production by squatters represented 17 percent of the national production of sugar cane, Indian farmers produced a little over a half of this proportion (OCS 1949).

iii) Using the gross value of production records from the Directorate of Agricultural Statistics in conjunction with the corresponding quantity of production, an implicit national average price was imputed for each commodity. The motivation for this is that, unlike the gross value of production reported in the commodity specific data tables of the *Abstract of Agricultural Statistics,* the gross value of production estimates used in estimating the contribution of the agricultural sector to national income includes estimates for homeland production. Moreover, the reported value of homeland production was sometimes valued differently from the prices used for commercial farmers to reflect perceived differences in quality.

5 In the remainder of this study referred to as the *Union Statistics.*

6 This approach differs from the procedure followed in earlier years by the Directorate of Agricultural Statistics in as much as the Directorate made simple linear projections between the census nodes.

For wool, poultry products, and milk I revised the estimates of the value of production to address errors in the estimates made by the Directorate of Agricultural Statistics. For wool, the data reported in the Abstract of Agricultural Statistics in some years do not correspond to the data from the Wool Board, and more recently Cape Wools (2012). Wool production in the homelands was previously reported in the *Abstract of Agricultural Statistics* under the heading 'Adjacent Countries' (neighbouring states that sell their wool through SA outlets) and excluded from the production estimates for South Africa. In the 1995 revision of the wool production estimates, to include the production from the former homelands in the total wool production of South Africa, Lesotho was sometimes erroneously included. In the wool production account used in this study, both the quantity and value of production estimates were corrected for this error.

Oddly, the gross value of production of poultry products made by the Directorate of Agricultural Statistics excluded the production of poultry meat prior to 1947/48. The estimated production value of poultry products for 1947/48 is about double that of 1946/47. An analysis of information available from the Union Statistics showed that the 1946/47 production value reported by the Department of Agriculture is roughly the same as the value of egg production for this year. Using price data available from the Union Statistics and the egg production estimates reported in Agricultural Census reports for the years prior to 1947/48, the gross value of production account for poultry products were adjusted accordingly.

The reported quantity of milk production suffered from an egregious double-counting problem. Data on the aggregate weight of industrial milk production (milk used in the processing industries) reported in the Abstract of Agricultural Statistics, when converted to fresh-milk equivalents, do not match the quantity of production figures reported in the census, or the production estimates reported by the Dairy Board. In converting the weight of butterfat, cheese and condensation products to fresh-milk equivalents, the Directorate of Agricultural Statistics apparently failed to validate its estimates against that of the Dairy Board. Consequently, the total milk production for South Africa reported in the Abstract of Agricultural Statistics, peaked much earlier than that claimed by the Dairy Board (Coetzee 2012).

The Directorate of Agricultural Statistics includes estimates for on-farm production and use in its estimates of milk production, which may explain some of the difference in milk production estimates. The extent of the difference is, however, questionable if one takes into account that on-farm production of cheese and butter has become much less prominent since the 1960s. Deemed undesirable by the Dairy Board in view of inconsistent quality assurance problems faced by milk processing factories, the practice of on-farm production of butterfat was actively discouraged (OCS 1926; Dairy Board 1992).

The need to include estimates for on-farm production is particularly significant in the dairy industry, albeit less important today than a century ago. The 1911 population census reported that 56.6 percent of the total butter production in the country was produced on-farm. This declined to 47.0 percent (4,347.9 tons) by 1923/24 of total production in the country with sales representing 65.8 percent of on-farm production (OCS 1926). The delivery of butterfat by farmers to factories ceased by 1991/92 (Dairy Board 1992, p.12). The situation may have changed since the closure of the Dairy Board. Unfortunately, there currently are no reliable statistics regarding on-farm production of milk products.

The method followed by the Directorate of Agricultural Statistics in estimating the quantity of milk used in the production of butterfat, cheese and condensation products (condensed milk and skimmed milk powder products) is to convert the weight of butterfat, cheese, condensed milk, and skimmed milk powder to fresh milk equivalents. However, this leads to potential double counting of the fresh milk equivalent as the same milk serves as the feedstock to produce the processed derivatives.[7] The problem is restricted to milk produced and delivered to factories (industrial milk) for the period 1956 through 1997 when milk produced for fresh consumption and milk produced for industrial utilization were priced and managed differently (Lucas et al.1979).

The approach followed here was to include condensed milk and all of the factory butter production originating from RSA sources. Converting this to fresh-milk equivalents correlates with major benchmarking points in the total production of milk claimed in the Annual Reports of the Dairy Board. Estimates by the Directorate of Agricultural Statistics, when converted to fresh milk equivalents, pre-dates these benchmarks by as much as 10 years.

iv) Prior to 1958, horticultural production — in this instance all fruits and vegetable production other than potatoes, onions, sweet potatoes and green mealies — was estimated by the Directorate of Agricultural Statistics by indexing the growth in the sales at fresh produce markets against the growth in population. Actual fresh fruit production data was for the first time reported in 1958. Like vegetables, estimates of fresh fruit production were made by using trends in per capita consumption indexed against sales at fresh produce markets plus exports and purchases for processing. The per capita consumption trends were occasionally and abruptly recalibrated without phasing in the change, thus giving rise to structural breaks in the

7 An analysis of the production account data of the Directorate of Agricultural Statistics also showed an error in the use of the technical conversion factors to estimate the milk equivalent of cheese and butter fat. In some instances, statisticians used the *inverse* of the appropriate conversion factors. Whether this was simply an error in the specific data processing template provided to the author, or whether this error is evident in the quantity of production estimates used in forming the Physical Volume of Production Index reported in the *Abstract of Agricultural Statistics* is uncertain as this version of the template is no longer in use.

resulting quantity of production series. In this study, the change in per capita consumption is incrementally phased-in between the nodes.

According to the data available from the census reports prior to 1970, the yield per tree varied very little. In this study the 1958 yield per tree was used to estimate the production for each census node. For the inter-census years the trend in the estimated production, as done by the Department of Agriculture, formed the basis for interpolating production for the inter-census nodes.

Following these procedures it was possible to develop plausible estimates of the amount of production for all the commodities, the results of which is discussed in Section 3.4.1.

3.3 INDEXING METHODOLOGY

Constructing an aggregate measure of agricultural output (q) from the physical quantities produced is difficult — and doubly so if the aggregate is to have any economic meaning. For one, the different types of output are not directly comparable or additive due to differences in their units of measurement.

One way around this problem is to convert all commodities to the same unit of measurement prior to aggregation — as is done by the Directorate of Agricultural Statistics (Strydom 2012). For example, an estimate of "pastoral products" (consisting of wool, mohair and karakul pelts) is formed, where the number of karakul pelts is first converted to tons. The average karakul pelt weighed 130 grams around the late 1940s and the same weight factor is still used. Another example is the conversion of fresh milk, butterfat, butter, cheese, condensed milk and various types of skimmed milk production into tons of fresh-milk equivalents for the "dairy products" category (Blignaut 2011). A seemingly similar, but nonetheless problematic approach is to use relative prices to express output in a base-commodity equivalent for purposes of aggregation. See Hayami and Ruttan (1971) for an analysis of aggregate output expressed in "wheat-equivalent" units, and Craig, Pardey and Roseboom (1990) for a critique of this approach. Ideally these conversion factors should be updated regularly. Mostly this is not the case.

Another aggregation approach is to derive an aggregate output index from a set of sub-indexes representing the aggregation of various sub-sectors of the agricultural economy. The logic for this approach is that since the sector is made up of individual industries — each with its own set of outputs or products — changes in the output of the agricultural sector as a whole reflect the combined changes in the outputs of individual commodities. The difficulty lies in aggregating the respective sub-indexes to form a single index that reflects changes in the output of the entire sector (BTS 2012). Intuitively, the aggregate index should be calculated as a weighted average of the output indexes of the component commodities.

Two commonly used quantity indexes are the Laspeyres and Paasche indexes. (The price index variant of the Laspeyres is well known in the monitoring of consumer price trends.) The Laspeyres output quantity index uses fixed weights in which prices in the base year form the values used to weigh output in all periods analysed. The Paasche quantity index uses comparison (current) period prices as weights. Following the nomenclature of Craig et al. (1990) let q_{it} = quantity of output item i = 1,2,…,N, in year t, p_{it} = the price of item i in year t, and p_{i0} = price of item i in the base year = 0. A Laspeyres quantity index (Q_L), using base period (or initial year) prices as weights, is defined as:

$$Q_L \equiv \frac{\sum_{i=1}^{N} q_{i,t} p_{i,0}}{\sum_{i=1}^{N} q_{i,0} p_{i,0}} \quad (3.1)$$

and the Paasche quantity index (Q_P), using current (or final year) prices as weights is defined as:

$$Q_P \equiv \frac{\sum_{i=1}^{N} q_{i,t} p_{i,t}}{\sum_{i=1}^{N} q_{i,0} p_{i,t}} \quad (3.2)$$

Although easy to compute, both indices indicate changes in aggregate output attributable to changes in output alone and, thus, do not distinguish between changes in the product mix (substitution effects) and changes in the level of production (expansion effects). As Craig and Pardey (1990) state; "In any economy or sector with multiple outputs aggregate quantity changes may reflect movements along an unchanged transformation surface, or shifts in the transformation surface. Without precise knowledge of the transformation surface, we cannot construct an index number that discriminates between the two types of changes." The problem is the Paasche and Laspeyres indexes give qualitatively and quantitatively different pictures of the same event if relative prices or quantities have changed. If relative prices do change over the period analyzed, as one would expect to happen in a long-run analysis such as this study, one expects that optimizing producers in a competitive market will change their product mix. Although both indexes have been widely used they will, in general give different answers of the same behaviour even if there is no change in the underlying technology governing resource use (IMF 2009).

Several methods exist to arrive at an estimate of the quantity change between two periods. An early variant of the Fisher ideal index is one example of an index that seeks to address the index number bias problem by forming the geometric mean of the conventional Laspeyres and Paasche indexes. It is defined as:

$$Q_F \equiv \left(\frac{\sum_{i=1}^{N} q_{i,t} p_{i,t}}{\sum_{i=1}^{N} q_{i,0} p_{i,t}} \right)^{\frac{1}{2}} \left(\frac{\sum_{i=1}^{N} q_{i,t} p_{i,0}}{\sum_{i=1}^{N} q_{i,0} p_{i,0}} \right)^{\frac{1}{2}} \qquad (3.3)$$

Notably, if there are no relative price changes, all three indices are equal. In the presence of relative price changes the contrary indications of the Paasche and Laspeyres index may cancel each other since the Fisher ideal index is a geometric average of the Laspeyres and Paasche indexes.

The choice of value weights is, however, critical for the calculation of explicit aggregate indices as it is the possibility of relative price variability either over time or across entities being compared that complicates our measurement of real quantity changes. The method proposed for minimizing the errors in forming an aggregate quantity index over an extended time period is the use of Divisia indexes because of their invariance property: if nothing real has changed the index itself is unchanged. That is, the only quantity changes involve movements along an unchanged transformation surface, along an unchanged isoquant, or along an unchanged indifference curve (Craig and Pardey 1990).

Divisia indexes are defined for continuous time and require continuous measurement of values and quantities. Thus, in practice a discrete approximation to these indexes must be made. In the discrete approximations to the Divisia index the indexes are chain-linked, i.e., in each year the current prices are used as a base in estimating the rate of growth to the following year. The process is followed for each successive year and the year-to-year rates of growth are linked into a chain index (Jorgenson and Griliches 1971).

Following Richter (1966), Craig and Pardey (1990) defined the Laspeyres approximation to the Divisia index as:

$$Q_L \equiv \frac{\sum_{i=1}^{N} q_{i,t} p_{i,t-1}}{\sum_{i=1}^{N} q_{i,t-1} p_{i,t-1}} \qquad (3.4)$$

In a similar way the Paasche approximation to the Divisia index is defined as:

$$Q_P \equiv \frac{\sum_{i=1}^{N} q_{i,t} p_{i,t}}{\sum_{i=1}^{N} q_{i,t-1} p_{i,t}} \tag{3.5}$$

which then yields a modern variant of the Fisher Ideal variety:

$$Q_F \equiv \left(\frac{\sum_{i=1}^{N} q_{i,t} p_{i,t}}{\sum_{i=1}^{N} q_{i,t-1} p_{i,t}} \right)^{\frac{1}{2}} \left(\frac{\sum_{i=1}^{N} q_{i,t} p_{i,t-1}}{\sum_{i=1}^{N} q_{i,t-1} p_{i,t-1}} \right)^{\frac{1}{2}} \tag{3.6}$$

The Törnqvist-Theil index is another approximation of the Divisia-index that uses both current and previous period value shares in weighing quantity changes. Following the nomenclature used by Craig and Pardey (1990) the Törnqvist-Theil approximation of the Divisia index QI_t^{DT} , is defined as:

$$QI_t^{DT} = QI_{t-1}^{DT} \prod_{j=1}^{n} \left(\frac{q_{j,t}}{q_{j,t-1}} \right)^{\bar{s}_{j,t}} \quad \text{where} \quad \bar{s}_{j,t} = \frac{1}{2}\left(s_{j,t} + s_{j,t-1} \right) \tag{3.7}$$

Where the weight for commodity j in period t is its output revenue share:

$$s_{j,t} = q_{j,t} p_{j,t} \Big/ \left(\sum_{j=1}^{n} q_{j,t} p_{j,t} \right) \tag{3.8}$$

This index is undefined if any quantity ,q_{jt}, equals zero. Thus, when commodities are only reported for part of the sample period one option is to omit these commodities from the aggregate estimate for the entire period (Craig and Pardey 1996 a and b). The problem of missing data is typically exacerbated the more the data are disaggregated. Examples of commodities that entered the reported mix of commodities at some point include sunflower in 1948, soybeans in 1969, and canola in 2004. On the other hand, rye was dropped from the production accounts in 2002 when production of this crop fell to insignificant amounts. The Fisher Ideal approximation of the Divisia index can practically accommodate zero valued observations. It thus became popular, especially when working with finely disaggregated panel data. According to Alston et al. (2010), bias from the procedure used to aggregate inputs and outputs can be kept to a minimum by choosing an appropriate index, carefully selecting value weights for all inputs and outputs, and disaggregating inputs and outputs as finely as possible.

Throughout this study the modern variant of the Fisher Ideal discrete approximation to a Divisia index (referred to as the Fisher index for short) is used and compared with the hybrid Törnqvist-Theil approximation of the Divisia index (referred to as the Thirtle index) following past methods of forming the index.

3.4 Value and Composition of Agricultural Production

The analysis of the structural changes in the South African economy discussed in Chapter 2 was based on the gross value of production and agricultural GDP statistics estimated by the Department of Agriculture. In this chapter and the remainder of this thesis a new set of data on agricultural production is used that address a number of problems in the previously published official estimates, not the least the inconsistent inclusion of homeland agriculture. Two of the more significant, additional, problems in the official estimates that are corrected here are a) a failure to include egg output in the gross value of livestock production estimates, and b) corrections for a clearly upwardly biased estimate of the quantity of milk production.

3.4.1 Long-term trends

Figure 3.1 plots the real value (2005 prices) of South African livestock, horticulture and field crops output for the century since 1910/11. The dark coloured plot (designated livestock) is the series including revised wool, dairy milk and egg production. The series designated recorded livestock is the official series reported by the Department of Agriculture. The revised value of livestock estimates are 3.6 to 10.7 percent greater than the official statistics for the period prior to 1947. After 1947 the revised estimates range from 1.8 percent higher to 5.1 percent lower than the official estimates attributable to revisions of the wool and milk production estimates. Notably, for the period 1969 to 1996, the revised estimates are consistently smaller than the official estimates, which overestimate the milk used for industrial purposes when forming these estimates of total milk production.

Prior to 1947/48, and especially prior to 1936/37, the number of vegetable crops enumerated in the national gross value of agricultural production was limited to commodities for which production was more readily measured. Pumpkin production, for example, was reported according to the number produced rather than the weight produced and thus was excluded from the reported gross value of agricultural production. Other examples of vegetables with significant quantities produced, but not enumerated in the gross value of vegetable production includes, tomatoes, cauliflower, cabbage, carrots, beetroot, green beans, and peas. The only vegetables whose *total* production were included in the reported gross value of production estimates of the Department of Agriculture are potatoes, sweet potatoes, onions and green mealies. For the remainder, only the quantities (and value) purchased by the canning industries, as well as the sales on fresh produce markets, such as tomatoes, melons, and garlic were included in the gross value of production estimates. The on-farm use of the latter products presents an undercount in the true quantity (and value) of production that needs to be addressed in future studies.

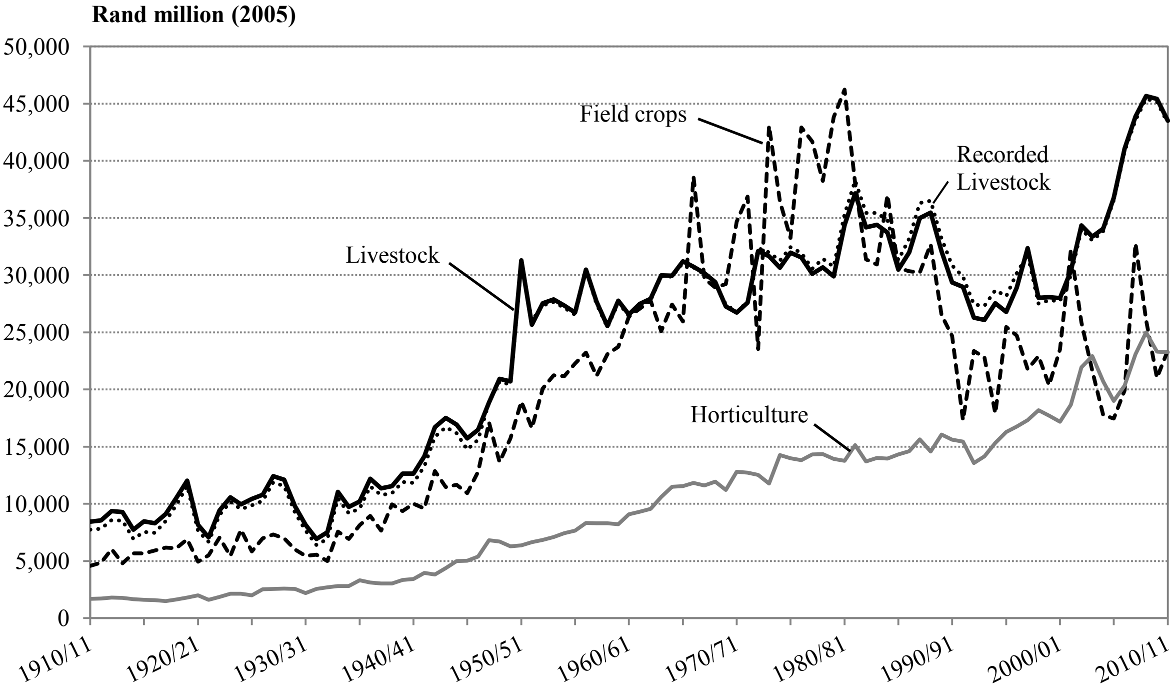


Figure 3.1: Output Value Trends, 1910–2010

Source: Revised Gross Value of Production Account, Own Calculations.

Notes: The dotted line represent estimates of the Department of Agriculture of the value of livestock output.

Likewise, nuts and tea, and especially, indigenous herbal tea production was only reported by the Department of Agriculture beginning in 1969/70 and 1971/72 respectively, although the census reports indicate substantial production occurred much earlier than that. For example, the 1924/25 agricultural census reports a total of 144,000 almond trees (OCS 1926). The same is true for tea, with total acreage of 1,267 ha and production of 1,898 tons that same year. Although the Department of Agriculture reports value of production estimates for specialty crops, including flowers and bulbs, no price or quantity data could be found for the components of this value aggregate. Price and quantity estimates could be formed for tea production, but not for nuts and specialty crops production. This is unfortunate, as these industries often exhibit comparatively rapid growth elsewhere in the world and the same may be true for South Africa (NPC 2011). For example, Alston et al. (2010) showed that the value share of specialty crops in the U.S.A. agricultural production increased from 13 percent prior to 1980 to 20 percent of total value of production for the nine years ending in 2005. Within specialty crops, nursery and greenhouse products accounted for 7.1 percent of the value of output in 2005, well above their 1.3 percent share in 1924.

As indicated, omitting commodities from the reported value of production understates this series (by upwards of 10.7 percent in the case of livestock), especially during the first half of the 20th century. This omission also tends to overstate the rate of growth in the real value of production, especially during the 1950s when the rate of growth of the official series was 2.92 percent per year for the period to 1958 versus 2.82 percent per year for the revised series, which in addition to milk used for cheese processing also included, eggs, and tea that are missing from the official statistics.

Table 3.2 provides summary information on the value of production for the major categories of output included in this study. Figure 3.2, shows the long-run trends in the share of output. Livestock was the dominant sector by value of production in South African agriculture through to 1959/60. Thereafter, through to 1965/66, the value of field crop production (grains, oilseeds, sugar, tobacco and fibre) first equated then surpassed the value of livestock production. The post-World War II surge in production value stemmed from the strong drive to 'industrialise' agricultural production through mechanization (Van Zyl et al. 1987; Vorster and Grobler 1952; DOA 1960), the promotion of new industries, such as oilseed production and fibre crops (Sellschop, 1952), and varietal improvement (Sim 1952). This led to an increased availability of feed to the livestock industries while the introduction of new genetic material spurred livestock production (Sellschop 1952; Bonsma 1952). However, the post-war period also saw the introduction of a host of Control Boards (but most introduced in 1937) that managed the marketing of key commodities, such as maize, wheat, meat, and sugar. The Directorate for Inland Market Improvement, established in 1936, advised on the substantial investment of public funds in the development of road, rail, storage and other types of market infrastructure (DOA 1960:118). These initiatives were accompanied by the introduction and expansion of direct farmer support programs, including of a host of producer and consumer subsidies (discussed in chapter 5).

Livestock production, by value, regained its prominence over field crop production after 1985/86, fuelled by strong growth in broiler production. This in part reflected policy initiatives taken to deregulate the agricultural sector (Vink et al. 1998), which encouraged the conversion of marginal areas for field crop production into planted pastures, and livestock farming, and changes to marketing support programs to make it more responsive to changing market signals. By 1991/92 horticultural production started increasing to the extent that it became more or less equal to the value of field crop production by 2002/03. Another notable feature of field crop production is the substantial variation in the value of output, especially after the mid-1960s (Figure 3.1). This coincides with the period when South African maize exports as a proportion of domestic consumption regularly exceeded 30 percent, reaching 70 percent at times (DAEM 1980). The expansion of field crop production into marginal production areas around this time is one factor that likely contributed to the increased variability in production value.

Table 3.2: **Summary of Production, Average Annual Value with Annual Average Percent Change, 1910–2010**

Period 10 year interval	Adjusted Data: Field Crops Value	Field Crops Share of Total	Field Crops Growth Rate	Horticulture Value	Horticulture Share of Total	Horticulture Growth Rate	Livestock Value	Livestock Share of Total	Livestock Growth Rate	Total Value	Total Growth Rate
	R million (2005)	Average percentage	Percent per year	R million (2005)	Average percentage	Percent per year	R million (2005)	Average percentage	Percent per year	R million (2005)	Percent per year
Revised data											
1910/11 — 1919/20	5,662	34.3	5.4	1,668	10.1	0.9	9,169	55.6	4.5	16,499	4.2
1920/21 — 1929/30	6,373	34.2	1.2	2,192	11.8	4.3	10,067	54.0	-0.4	18,632	-0.1
1930/31 — 1939/40	7,451	36.4	6.3	2,885	14.1	3.1	10,127	49.5	4.1	20,463	4.3
1940/41 — 1949/50	12,577	36.2	6.7	5,074	14.6	7.0	17,058	49.1	5.4	34,709	5.7
1950/51 — 1959/60	21,149	37.5	4.7	7,515	13.3	2.8	27,791	49.2	4.3	56,455	4.0
1960/61 — 1969/70	28,610	41.8	3.5	10,812	15.8	3.3	29,066	42.4	-0.1	68,489	1.5
1970/71 — 1979/80	37,444	46.1	8.0	13,447	16.6	2.5	30,291	37.3	1.1	81,182	3.1
1980/81 — 1989/90	33,397	40.8	-4.1	14,572	17.8	1.6	33,879	41.4	1.0	81,848	-1.3
1990/91 — 1999/00	22,126	33.3	-0.4	16,033	24.1	1.1	28,235	42.5	-1.0	66,395	-1.0
2000/01 — 2010/11	23,821	28.9	3.6	21,209	25.8	3.2	37,316	45.3	5.1	82,346	3.6
Official (reported)data											
1910/11 — 1919/20	5,662	35.9	5.4	1,666	10.6	0.9	8,457	53.6	5.2	15,785	4.5
1920/21 — 1929/30	6,373	35.1	1.2	2,191	12.1	4.3	9,575	52.8	-0.5	18,138	-0.1
1930/31 — 1939/40	7,451	37.5	6.3	2,884	14.5	3.1	9,526	48.0	4.2	19,861	4.4
1940/41 — 1949/50	12,577	36.9	6.7	5,072	14.9	7.0	16,415	48.2	5.9	34,065	6.1
1950/51 — 1959/60	21,149	37.5	4.7	7,513	13.3	2.8	27,673	49.1	4.4	56,335	4.1
1960/61 — 1969/70	28,610	41.8	3.5	10,812	15.8	3.3	28,984	42.4	0.0	68,406	1.6
1970/71 — 1979/80	37,444	45.9	8.0	13,447	16.5	2.5	30,718	37.6	1.3	81,609	3.2
1980/81 — 1989/90	33,397	40.3	-4.1	14,572	17.6	1.6	34,974	42.2	1.1	82,944	-1.3
1990/91 — 1999/00	22,126	33.0	-0.4	16,033	23.9	1.1	28,957	43.1	-1.6	67,116	-1.2
2000/01 — 2010/11	23,821	29.0	3.6	21,209	25.9	3.2	37,011	45.1	5.1	82,041	3.6

Sources: Own calculations
Notes: Growth rates calculated as average of annual change.

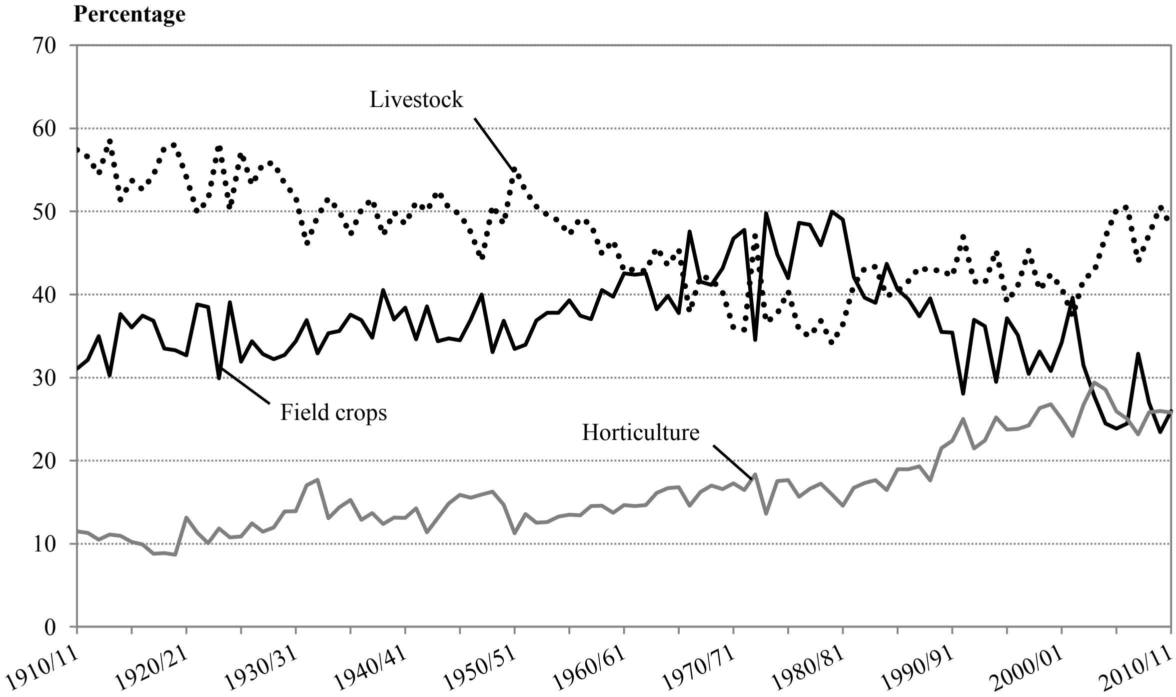


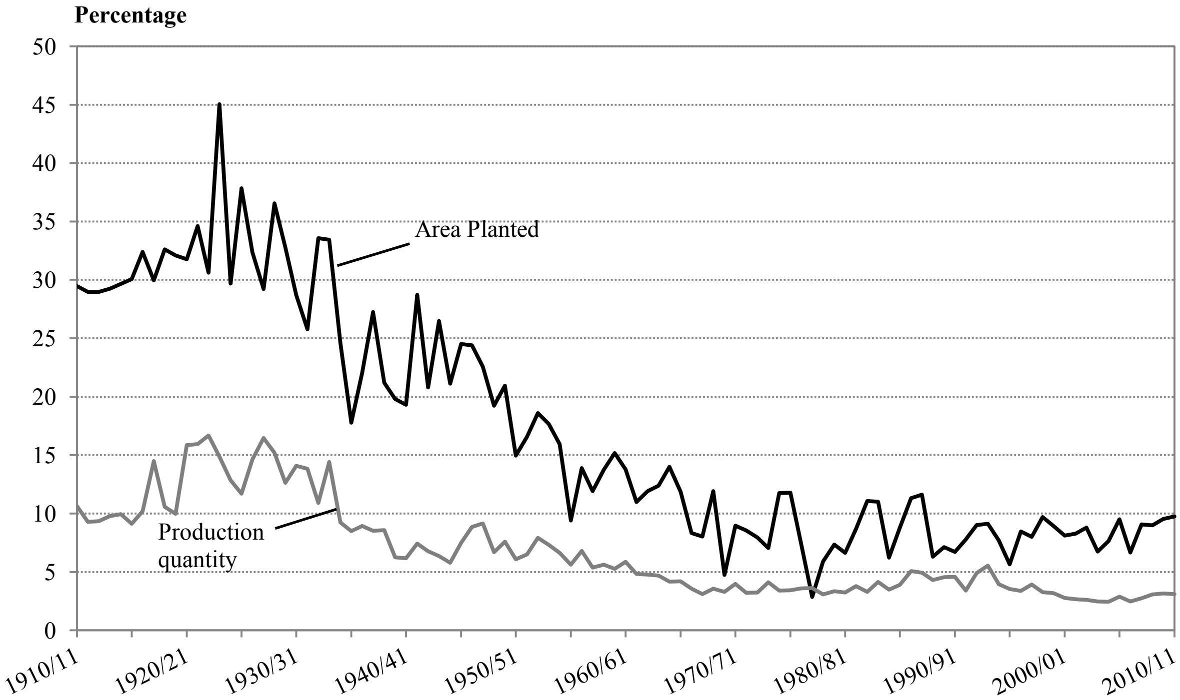
Figure 3.2: Value Shares of Output Categories, 1910–2010

Sources: Revised Gross Value of Production Account, Own Calculations

3.4.2 Production trends in the former homelands

The significance of homeland production becomes evident from Figure 3.3, Panels a and b. Data collected on the area planted and production of black farmers on white farms and black farmers in the homelands were excluded from the commodity statistics of the Department of Agriculture prior to the 1995 edition of the *Abstract of Agricultural Statistics*. My efforts to develop long-run estimates of the share of production and area planted attributable to black farmers is shown in Figure 3.3, Panel a. In 1910/11 the share of total field cropped area in the homelands was 23 percent. This share grew significantly during the Great War (1914 – 1918) as production by white farmers was disrupted due to First World War and the rebellion of 1914. The share of homeland area peaked at 45.1 percent in 1923/24 and then declined to 19.8 percent in 1937. During World War II, and probably as a result of many white farmers joining the war effort, their share again increased to 28.7 percent in 1942/43 and

Panel a: Homeland agriculture: share of area planted and production of field



Panel b: Homeland share of the cattle, sheep and pig herd of South Africa

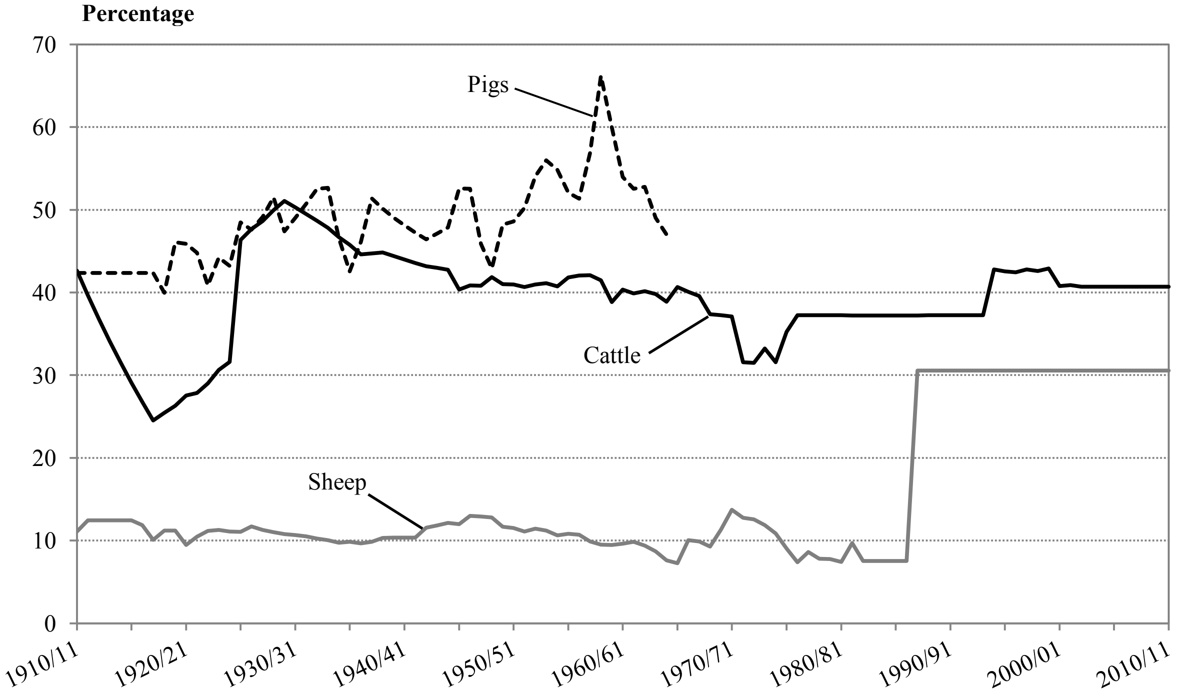


Figure 3.3: Changing Share of Homeland Farmers in Agricultural Production; 1910–2010

Sources: Own calculations, DAFF (2012)

Note: Information available to the Department of Agriculture on the herd size of cattle (since 1976/77) and sheep (since 1982/83) has become limited and the numbers were either kept constant, or were adjusted on a spurious basis.

hovered around 25 percent through to 1946/47. Thereafter the homeland share steadily declined to reach 11.8 percent in 1975/76, at which time the self-governing homelands administrations were established. The first of these homeland administrations was Transkei, and others followed through to1984. Even with the land restitution and land reform initiatives introduced since 1994 the share of black farmers of area planted has not recovered to the levels observed earlier in the century and still fluctuated around 8.4 percent during the first decade of this century[8].

Homeland farmers have consistently accounted for a much smaller share of national crop production (Figure 3.3, Panel a). Beginning with 10.2 percent of national production in 1910/11 the homeland share peaked at 16.7 percent in 1922/23. Even during the Second World War their production share averaged 6.9 percent, well below their 1918 to 1934 average of 13.7 percent.[9]

Cattle from homelands were 31.8 percent of the total weight of slaughtered cattle in 1955/56 (prior to this date statistics on livestock meat production originating from homelands are not available). This declined to 15.8 percent in 1984/85 (reflecting in part the drought of the previous year) and rebounded in 1994/95 — the last year for which data are available (DAS 1997). Figure 3.3, Panel b shows the homeland's share of livestock ownership since 1910/11. The linear segments of the plots since 1970 indicate interpolated estimates arising from a lack of data. Clearly homeland farmers owned a substantial share of the country's pig and cattle herds. Their share of the national cattle herd grew from a low of 25 percent in 1917/18 to 51.1 percent in 1929/30. Thereafter it declined to 37.4 percent by 1968/69 and appears to have stayed at the same level since then. The 1921/22 agricultural census noted that even though black farmers owned a significant share of the national herd, they made little contribution to the commercial slaughtering of livestock. Concern over the growth in livestock numbers were raised with respect to the erosion of grazing areas in the homeland areas (OCS 1923). Although homeland farmers (both in terms of quantity produced and area planted) accounted for a reduced share of the national totals — especially during the latter half of the 20th century — they had measureable consequences for an analysis of long-run production and, especially, land use trends.

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8 As the census fails to capture data on farms with a turnover less than that required for tax registration purposes, the production activities of smaller farmers (both black and white) are no longer enumerated (See Stats SA 1996-2010 for details on the changing threshold for tax registration). As a result, the participation of these farmers is probably underrepresented in national statistics.

9 The estimated shares presented for the years since 1970 is based on production originating from homeland areas as reported by the various commodity organizations as the census reports since 1975 had little information on this metric.

3.5 INDEXES OF THE QUANTITY AND PRICE OF AGRICULTURAL OUTPUT

To illustrate the nature and magnitude of the biases involved in using fixed base indexing procedures, the Laspeyres, Paasche and Fisher Ideal quantity indexes are compared with the Laspeyres, Paasche approximations of the Divisia and the modern variant of the Fisher Ideal (Fisher in short) approximation of the Divisia index. A conventional Törnqvist-Theil approximation of the Divisia index is also presented along with the Thirtle quantity of output index to illustrate the extent of bias inherent in this indexing procedure.

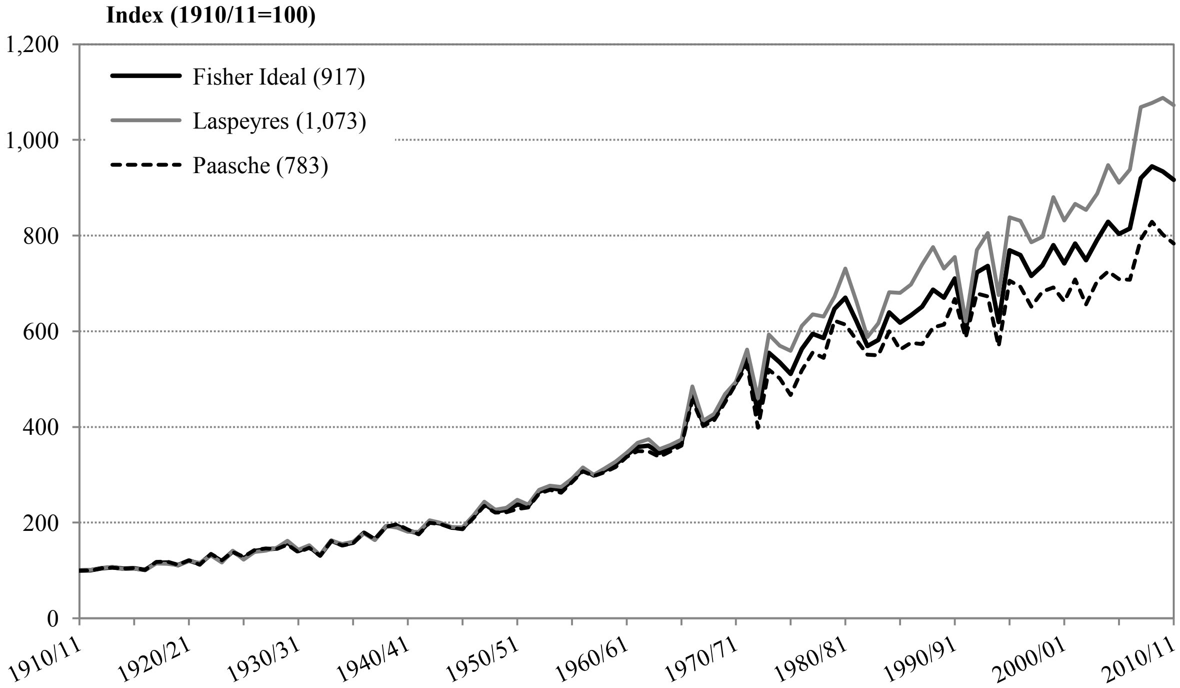
3.5.1 National trends in agricultural output: different indexing methods

In Figure 3.4 (Panels a and b) I use the same underlying data to reveal the consequences of pre-aggregated Laspeyres indexes of field crop, horticulture, and livestock output quantity in conjunction with deploying different indexing procedures to track long-run changes in South African agricultural output. The comparative statistics of the different output quantity indexes are shown in Table 3.3.

Panel a plots the fixed base year Laspeyres and Paasche quantity indexes (base year 1910/11) from 1910 through to 2010 along with the conventional Fisher Ideal index. The results show how the Laspeyres quantity index overstates the rate of growth in output quantities (2.37 percent per year) reaching a terminal value of 1,073 percent in 2010. The Paasche quantity index shows an annual growth rate over the whole century of 2.06 percent per year and reaches a terminal value of 783 percent in 2010. The Fisher Ideal quantity index in Panel a track the geometric mean of the Laspeyres and Paasche indexes and reaches a terminal value of 917 percent with an annual growth of 2.22 percent.

In Panel b the trends in the chain-linked versions of the Laspeyres, Paasche and Fisher Ideal approximations of the Divisia output quantity indexes is compared along with the Törnqvist-Theil approximation of the Divisia output quantity index. These indexes were formed from the same underlying price and quantity data. The Laspeyres and Fisher Ideal approximations indicate higher annual growth rates in output quantity of 3.59 and 2.75 percent respectively compared with the fixed base year versions shown in Panel a. The terminal values of the indexes are also higher at 2,422 and 1,089 respectively. The trend for the Paasche shows a lower growth rate of 1.93 percent per year, compared to the 2.48 of its fixed base year version in Panel a. Taken together these dissimilar trends with the fixed base indexes show the extent to which the growth in the sector is underestimated when using fixed base year indexes.

Panel a: Fixed base-year indexes



Panel b: Discrete approximations of the Divisia Index

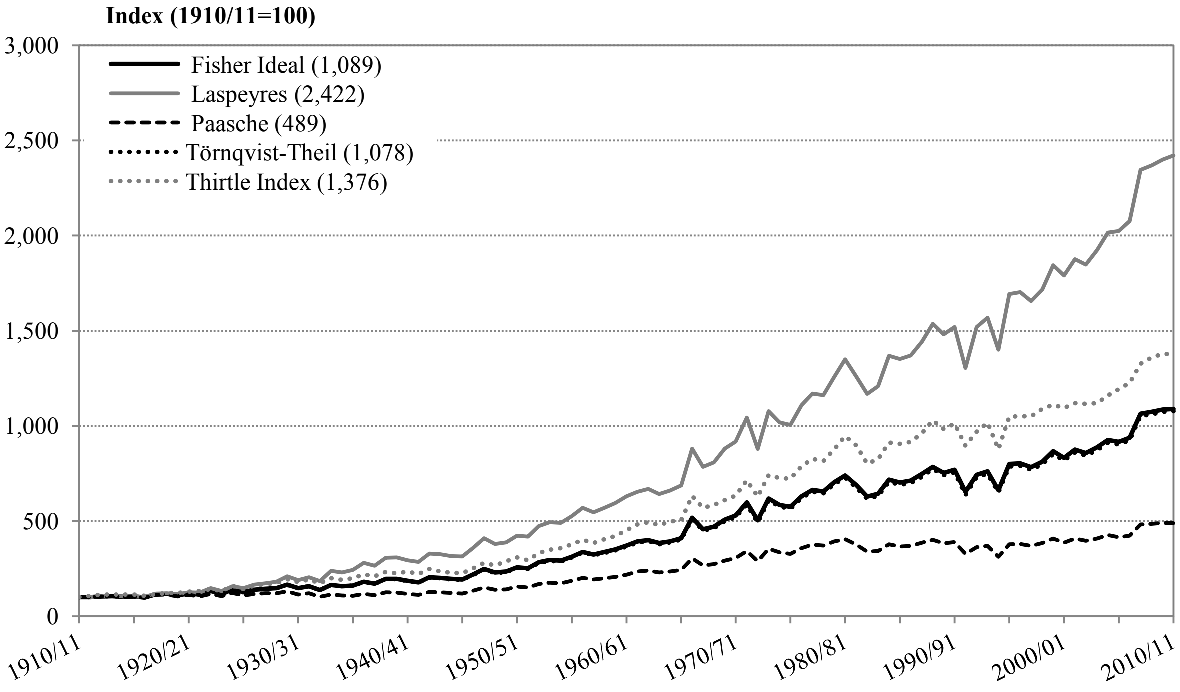


Figure 3.4: Aggregate Agricultural Quantity Index; Comparative Trends in Different Indexing Methods, 1910—2010

Sources: Own calculations

The Törnqvist-Theil approximation of the Divisia output quantity index in this instance follows a similar trend to that of the Fisher Ideal approximation of the Divisia output quantity index.[10] The growth rates for the two variants of the Divisia index differ by 0.01 percent over the whole period and reach terminal values in 2010 that differ by only 11 percentage points.

The Thirtle output quantity index exceeds the trend of the Törnqvist-Theil index for the whole period and reaches a terminal value of 1,376 in 2010/11 — 299 percent higher than the *true* Törnqvist-Theil output quantity index. It also exhibits higher values in terms of range, standard error, sample variance and its coefficient of variation. Its annual growth rates over the periods presented in Table 3.3 are also higher than that of the Fisher except for the period 1980 to 1994.

Table 3.3: Comparative Statistics of Different Output Quantity Indexes

Statistic	Chained Fisher	Törnqvist-Theil	Thirtle Index	Chained Laspeyres	Chained Paasche
Mean	444.4	438.8	557.9	832.4	244.3
Standard Error	29.5	29.0	38.8	66.5	12.6
Median	370.7	366.4	451.7	629.9	218.2
Standard Deviation	296.3	291.8	389.5	668.8	126.2
Sample Variance	87,782.3	85,131.0	151,719.7	447,237.0	15,915.7
Coefficient of Variation	66.7	66.5	69.8	80.3	51.6
Range	989.4	980.3	1,278.9	2,321.5	393.8
Correlation	1.0000	1.0000	0.9988	0.9941	0.9902
	Average Annual Growth				
1910—2010	2.75	2.74	2.90	3.59	1.93
1910—1937	2.39	2.34	3.05	4.13	0.71
1937—1980	3.80	3.79	3.82	4.20	3.40
1980—1994	-0.44	-0.45	-0.26	0.60	-1.47
1994—2010	3.33	3.38	2.96	3.64	3.02

Sources: Own calculations

The average annual growth rates for the Fisher and Törnqvist-Theil indexes correlate well with each other. However, the Thirtle index exceeded the growth trends of both the Törnqvist-Theil and Fisher indexes in all growth phases selected in Tables 3.3 and 3.4 except for the years 1994 to 2010 which is the result of a problem in the rebasing of the reported quantity of production index reported in the *Abstract of Agricultural Statistics* (DAFF, 2012).

[10] In the remainder of the study the Fisher Ideal approximation of the Divisia index will be referred to as simply the Fisher index.

Table 3.4: Aggregate Output Quantity Index: Different Methods of Indexing, 1910—2010

Year	Chained Fisher	Törnqvist-Theil	Thirtle Index	Chained Laspeyres	Chained Paasche
1910/11	100.0	100.0	100.0	100.0	100.0
1911/12	100.4	100.4	107.8	100.9	99.9
1912/13	103.9	103.9	114.4	104.6	103.2
1913/14	106.0	106.0	114.5	106.9	105.1
1914/15	102.5	102.5	113.2	103.0	102.0
1915/16	103.2	103.1	114.6	104.3	102.2
1916/17	99.2	99.2	107.7	101.4	97.1
1917/18	115.4	115.4	115.8	119.0	111.9
1918/19	117.1	116.8	122.9	121.3	113.1
1919/20	109.7	109.3	122.6	115.6	104.2
1920/21	118.7	118.7	128.9	126.4	111.4
1921/22	113.8	114.4	133.1	124.5	104.0
1922/23	131.7	131.3	141.8	147.3	117.7
1923/24	118.6	118.1	132.7	132.5	106.1
1924/25	139.4	137.9	158.7	158.2	122.8
1925/26	127.0	126.3	142.0	148.1	108.9
1926/27	139.9	139.5	160.9	166.7	117.4
1927/28	144.0	143.6	167.0	172.9	120.0
1928/29	147.2	147.7	174.3	180.3	120.3
1929/30	165.4	164.6	194.5	209.6	130.6
1930/31	147.1	146.9	180.0	190.2	113.8
1931/32	157.3	157.2	192.8	204.4	121.1
1932/33	137.3	138.0	172.5	185.1	101.9
1933/34	164.8	164.8	198.9	237.7	114.2
1934/35	158.0	158.2	191.0	230.1	108.5
1935/36	161.8	161.1	199.7	242.6	107.9
1936/37	181.5	180.0	219.5	279.6	117.8
1937/38	170.5	169.2	209.4	264.9	109.7
1938/39	196.9	195.5	233.5	307.2	126.2
1939/40	196.2	194.5	225.0	309.7	124.2
1940/41	185.6	183.9	234.3	293.6	117.4
1941/42	178.6	176.7	222.2	285.7	111.6
1942/43	204.8	202.6	248.5	328.7	127.6
1943/44	201.6	199.3	235.3	325.2	124.9
1944/45	195.7	193.6	228.3	315.3	121.5
1945/46	193.4	191.1	227.3	313.9	119.2
1946/47	220.0	217.2	251.9	360.2	134.4
1947/48	248.5	245.5	280.0	410.5	150.5
1948/49	230.2	227.3	267.1	380.0	139.5
1949/50	234.4	231.5	288.2	388.1	141.5
1950/51	257.6	254.7	308.8	423.6	156.7
1951/52	251.0	248.2	293.2	417.9	150.7
1952/53	283.3	280.0	332.8	473.6	169.5
1953/54	294.7	291.2	348.9	493.7	176.0
1954/55	291.3	287.8	357.6	489.9	173.2
1955/56	312.6	308.9	378.5	526.0	185.8
1956/57	338.1	334.1	402.0	569.0	200.9
1957/58	324.4	320.5	385.1	545.3	192.9
1958/59	337.7	333.3	404.6	569.3	200.3
1959/60	351.0	346.2	421.5	595.0	207.0
1960/61	370.7	365.7	451.7	629.9	218.2
1961/62	392.4	386.3	482.7	653.8	235.5
1962/63	400.4	394.1	493.1	668.6	239.8
1963/64	384.5	378.3	478.2	642.6	230.1
1964/65	393.8	387.4	496.5	659.9	235.0
1965/66	409.2	402.3	505.7	687.0	243.8
1966/67	517.8	509.4	632.1	881.1	304.3
1967/68	457.7	449.5	569.1	784.2	267.2
1968/69	469.9	461.6	584.9	807.8	273.4
1969/70	507.5	498.3	610.3	880.0	292.7
1970/71	529.5	520.0	634.2	918.2	305.4
1971/72	597.3	586.5	714.8	1,043.3	342.0
1972/73	504.6	493.0	628.0	879.2	289.6
1973/74	618.0	608.9	741.8	1,076.6	354.7
1974/75	584.6	575.5	725.7	1,018.6	335.5
1975/76	574.0	564.7	722.3	1,004.4	328.1
1976/77	630.2	620.9	788.2	1,108.5	358.3
1977/78	663.7	653.9	826.5	1,169.5	376.6

Table 3.4: (continue)…

(Table 3.4: continued.)

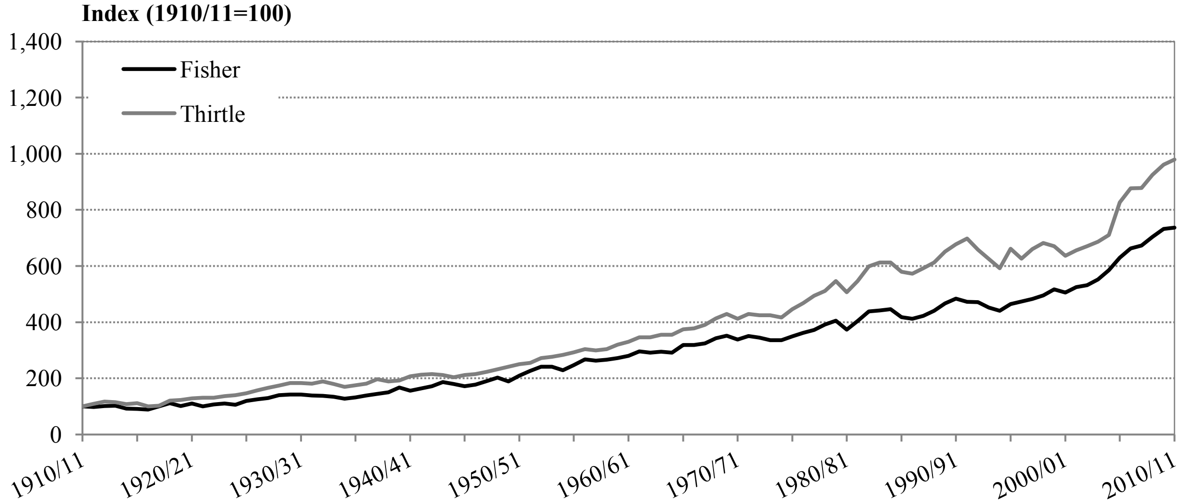
Year	Chained Fisher	Törnqvist-Theil	Thirtle Index	Chained Laspeyres	Chained Paasche
1978/79	655.8	645.9	815.1	1,161.0	370.5
1979/80	703.5	693.7	877.9	1,257.0	393.7
1980/81	738.7	727.9	946.8	1,350.5	404.1
1981/82	688.1	675.9	896.9	1,258.3	376.3
1982/83	628.7	616.9	801.1	1,168.0	338.4
1983/84	643.4	631.0	825.7	1,208.5	342.5
1984/85	718.3	706.2	912.9	1,368.5	377.0
1985/86	702.8	690.0	905.7	1,351.0	365.6
1986/87	711.9	699.0	916.4	1,369.6	370.1
1987/88	747.1	733.5	962.1	1,442.1	387.0
1988/89	785.5	772.3	1,027.9	1,536.3	401.6
1989/90	753.5	740.7	983.7	1,480.7	383.4
1990/91	769.6	756.4	1,011.4	1,520.0	389.6
1991/92	652.8	637.4	896.2	1,304.6	326.6
1992/93	742.1	730.6	969.7	1,519.0	362.5
1993/94	760.4	748.4	1,016.3	1,567.7	368.9
1994/95	661.8	649.8	877.2	1,399.4	313.0
1995/96	799.7	787.1	1,048.2	1,692.0	377.9
1996/97	803.2	790.1	1,049.7	1,703.2	378.8
1997/98	782.9	769.5	1,050.4	1,655.6	370.2
1998/99	811.6	797.8	1,089.0	1,716.2	383.8
1999/00	866.7	851.4	1,111.5	1,844.3	407.3
2000/01	832.6	818.1	1,093.5	1,791.0	387.0
2001/02	875.2	860.7	1,119.4	1,875.4	408.5
2002/03	856.3	842.8	1,115.3	1,848.2	396.8
2003/04	886.7	872.5	1,119.6	1,922.8	408.9
2004/05	926.7	911.4	1,159.1	2,016.0	426.0
2005/06	916.5	903.0	1,193.3	2,024.0	415.0
2006/07	937.7	923.9	1,224.9	2,076.0	423.5
2007/08	1,063.3	1,051.3	1,325.6	2,345.2	482.1
2008/09	1,073.3	1,061.2	1,359.4	2,369.0	486.3
2009/10	1,085.3	1,073.3	1,378.9	2,399.5	490.9
2010/11	1,088.6	1,077.5	1,376.1	2,421.5	489.4
			Policy Phases		
1910—2010	2.75	2.74	2.90	3.59	1.93
1910—1937	2.39	2.34	3.05	4.13	0.71
1937—1980	3.80	3.79	3.82	4.20	3.40
1980—1994	-0.44	-0.45	-0.26	0.60	-1.47
1994—2010	3.33	3.38	2.96	3.64	3.02

Sources: Own calculations

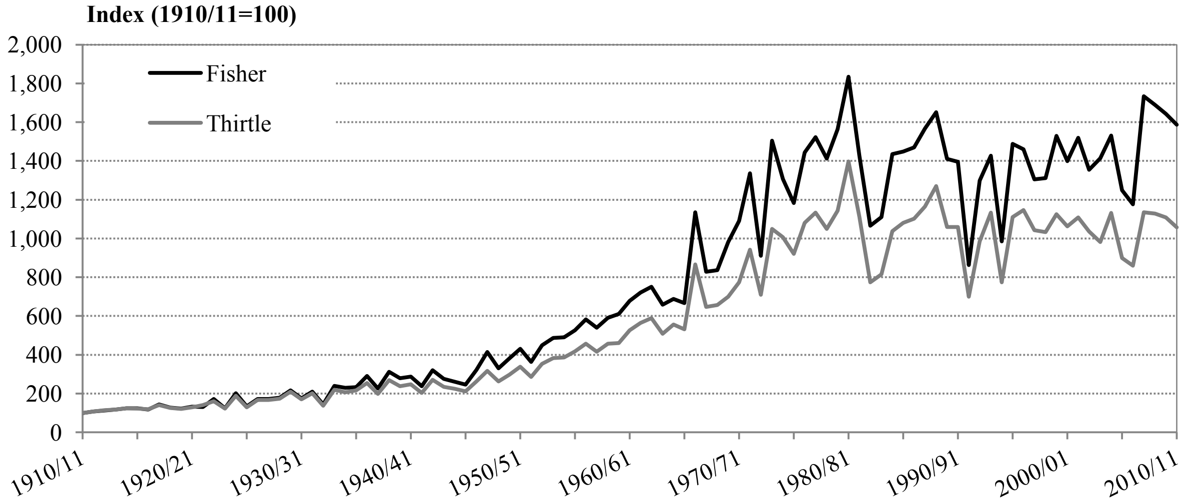
Notes: Growth rates based on the average of year-on-year change in index values.

The differing trends between the Thirtle index and the Fisher index are shown in more detail in Figure 3.5, Panels a through c. Whereas the Fisher field crop quantity indexes (Panel b) show higher index values than the Thirtle index throughout the century, the horticulture (Panel c) and livestock (Panel a) indexes exhibit significantly different trends. The reason is that the number of commodities included in the published aggregate index for field crops remained largely the same over time, whereas for horticulture and livestock this was not the case (see Table 3.1). Revisions made to the quantity index for field crops are limited to re-allocating vegetable crops (potatoes, green mealies, and onions) to the horticulture category. In order of magnitude, the value and quantity of production of these vegetable crops were relatively small compared to the total value and quantity of field crop production and thus had little influence on the field crop category. However, this had the opposite effect on the

Panel a: Livestock sector



Panel b: Field crop sector



Panel c: Horticultural sector

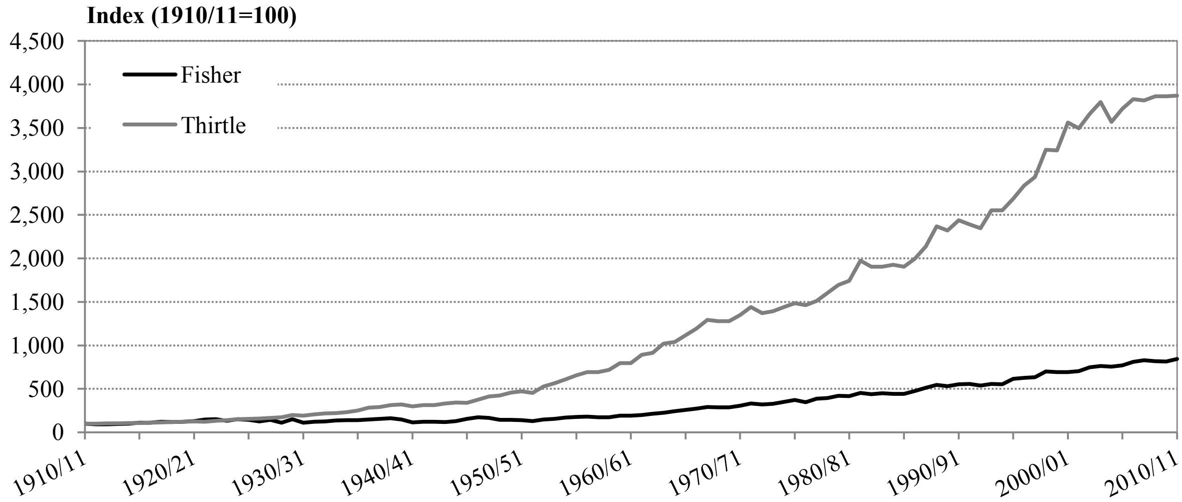


Figure 3.5: Fisher and Thirtle Quantity Indexes, 1910—2010

Sources: Own Calculations

horticulture category as vegetable production represented, on average, 41.8 percent of the production value of horticulture in the period 1910 to 1947. This declines to a third for the period 1947 to 1980 — the period in which the published horticultural quantity of production index first included vegetable production as part of the horticultural category. This explains the huge growth from the 1950/51 crop year in the Thirtle output quantity index compared to the Fisher index. More pertinently, the Thirtle index for horticulture overstates the growth in horticultural output by almost 53.4 percent over the century, with the largest variation during the 1910 to 1917 and 1937 to 1980 periods being 76.7 and 66.4 percent respectively.

In the case of livestock, the basket of products included in the quantity index changed little over the earlier published index. However, fresh milk and industrial milk were excluded up to the 1958/59—1960/61 base period. Thereafter it was included until the 2005 base year from where only fresh milk equivalents were included in the published quantity of production index. An analysis of the accounting procedures followed in estimating the fresh milk equivalents reveal that the inclusion of skimmed milk products process result in a significant double count of the actual quantity of milk produced — a mistake corrected in the Fisher index. As a result, the Fisher index yields an annual growth rate from 1910 to 2010 that is 11.3 percent lower than the Thirtle index. During the 1910 to 1937 period the Fisher index yields a growth rate that is 41.5 percent less than the Thirtle index.

The degree of aggregation bias between different indexing methods is further emphasised in Table 3.4, in the average annual growth rates during the selected policy phases since 1910/11. At the sector level the Thirtle index overstated the rate of growth in output when compared to both the Fisher and the Törnqvist-Theil Divisia indexes. This holds true for both the horticultural and livestock industries in particular.

In the remainder of this chapter the trends in the Fisher output quantity indexes are discussed and the effects of specific adjustments to the underlying production data are illustrated.

3.5.2 National quantity of output trends for commodities

Figure 3.6 reports trends in national indexes of aggregate quantities for the field crops, horticultural crops and livestock sector and for agriculture as a whole for the past century. In aggregate the field crops quantities produced were roughly double that of the horticultural sector which in turn was a third higher than the livestock sector. After 1937 and especially after the Second World War field crop production grew at 6.87 percent annually until 1980. After the bumper maize crop of 1981 it experienced a decline in production of 1.72 percent per annum until 1994 from where it recovered to grow at 4.5 percent. The horticultural sector grew throughout the period, with higher growth rates recorded after the 1960s, coinciding with the time when technology became available to ripen fruit whilst in cold storage (Black 1952; DOA 1960:128-129). Except for the period from 1980 through 1994, the livestock industries in aggregate experienced a relatively consistent growth over the whole period, averaging 2.14 percent per annum over the century. The growth of the agricultural sector was thus largely driven by the growth of the field crop industries, followed by the horticultural industries.

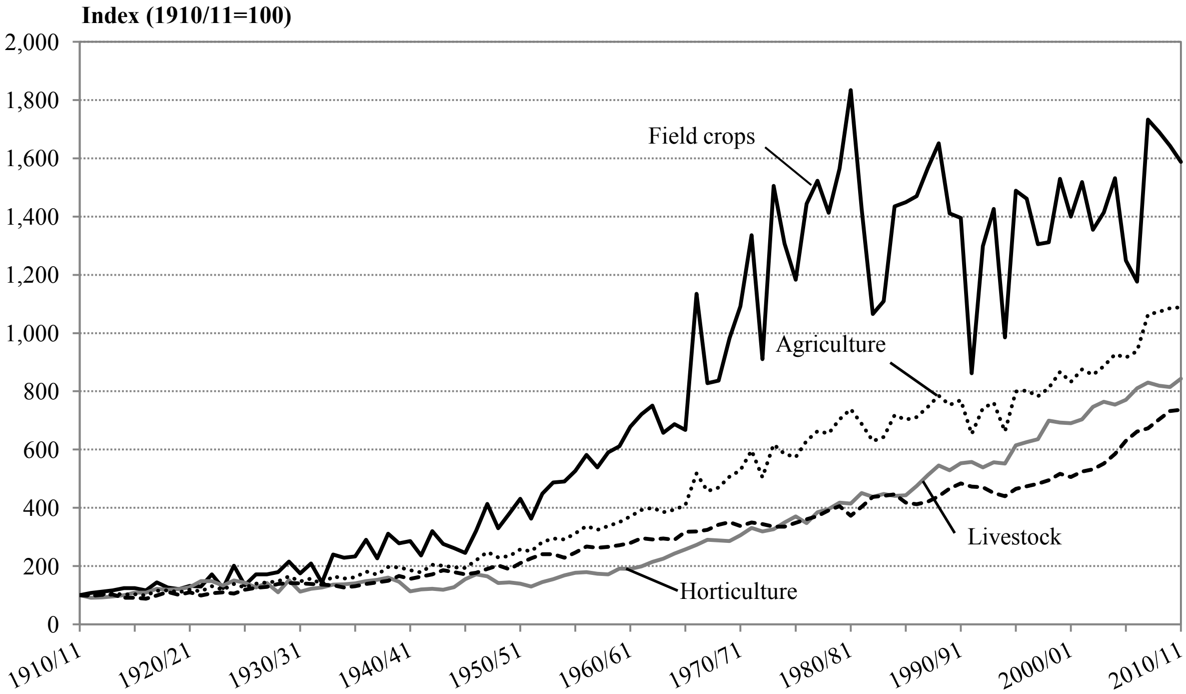


Figure 3.6: Trends in Aggregate Quantity Indexes of Agricultural Output, 1910—2010

Sources: Own Calculations

The growth in crop production in the post-war period, at least initially, was aided by the commodity control boards established since 1937 with the purpose of improving the domestic marketing of their produce. Each had its own marketing scheme under the enabling Agricultural Marketing Act (Act 26 of 1937, later replaced by the similarly named Act 59 of 1968). Most of these schemes provided for a single channel market (meaning that the farmer could only sell through the control board which then served as the only seller from that point on). The pricing mechanisms varied from fixed price mechanisms through to floor price mechanisms. In general, these schemes aimed to improve price stability either through the control of the price, or the control of the supply to the market. By 1979, the 23 control boards marketed four fifths of the value of agricultural production (Lucas et al. 1979). The revision of these support mechanisms in the 1980s was part of a larger process of deregulation during this period of policy development in the country.

Although field crops generally experienced high growth rates after the Second World War, the phases of growth differed remarkably amongst the commodity categories. Summer grains grew by 13.24 percent per annum during the three and a half decades from 1945. The annual rate of growth in the production of winter cereals was 4.81 percent until 1966, but then increased to more than double that rate from 1965 to 1980. Thereafter all commodities experienced a decrease in production from 1981 to 1989, except for sugar, which expanded its production by 5.98 percent. From 1991 to 2010 only winter cereals, sugar and hay experienced a growth rate of less than 3.50 percent per year. From Figure 3.7 it is apparent that the growth in the field crop industry was aided strongly by the expansion in production of sugar cane and oilseeds.

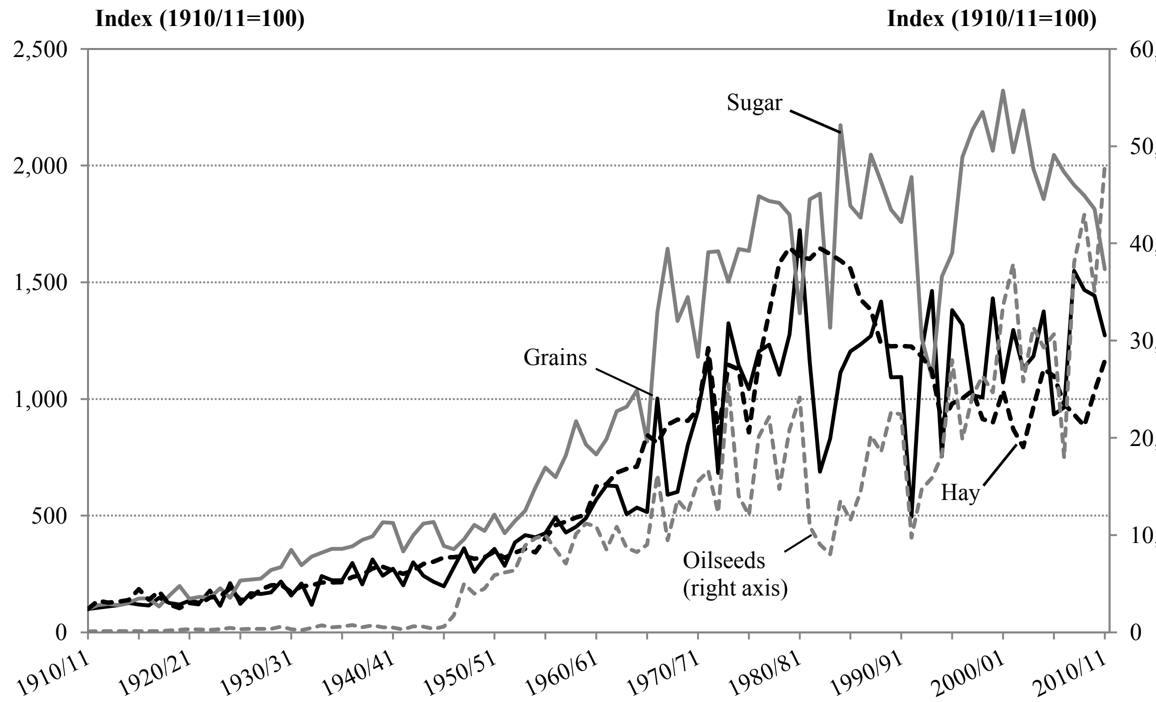


Figure 3.7: Selected Fisher Quantity Indexes for Field Crop Products, 1910—2010

Sources: Own Calculations

The production of oilseed commodities received special policy attention after the Second World War through government promotion of production of vegetable oil in response to the fear of a repeat occurrence of a shortage of vegetable oils in the aftermath of the war as was the case after 1918 (Sellschop, 1952). In anticipation, a breeding program was introduced to develop new groundnut cultivars with improved oil content and higher yield potential from cultivars that were mostly grown by black farmers. Starting in 1946, guaranteed prices were introduced to raise the interest of farmers to grow groundnuts, which led to an eightfold increase in production from 1947 to 1955 (DOA 1960: 73).

The growth patterns in the horticultural industries over the past century showed equally dissimilar trends (Figure 3.8). Prior to World War II a lack of suitable cooling, packaging and storage facilities represented a major constraint to the growth in exports from these industries. The drying and canning of fruit formed a major market outlet for these industries until after World War II. The high prices in the aftermath of the war provided the first incentive to boost the expansion of these industries. However, as pre-cooling tunnels, cold storage facilities at the harbours, container transport and the interventions of the Deciduous Fruit Board (established in 1947) to better organize exports begun to take effect these industries experienced higher growth since the 1960s (PPECB 2003; Black 1960). The deciduous fruit industries were the first to experience an increase in exports, followed by the tropical fruit industries and in the 1980s the citrus industry.

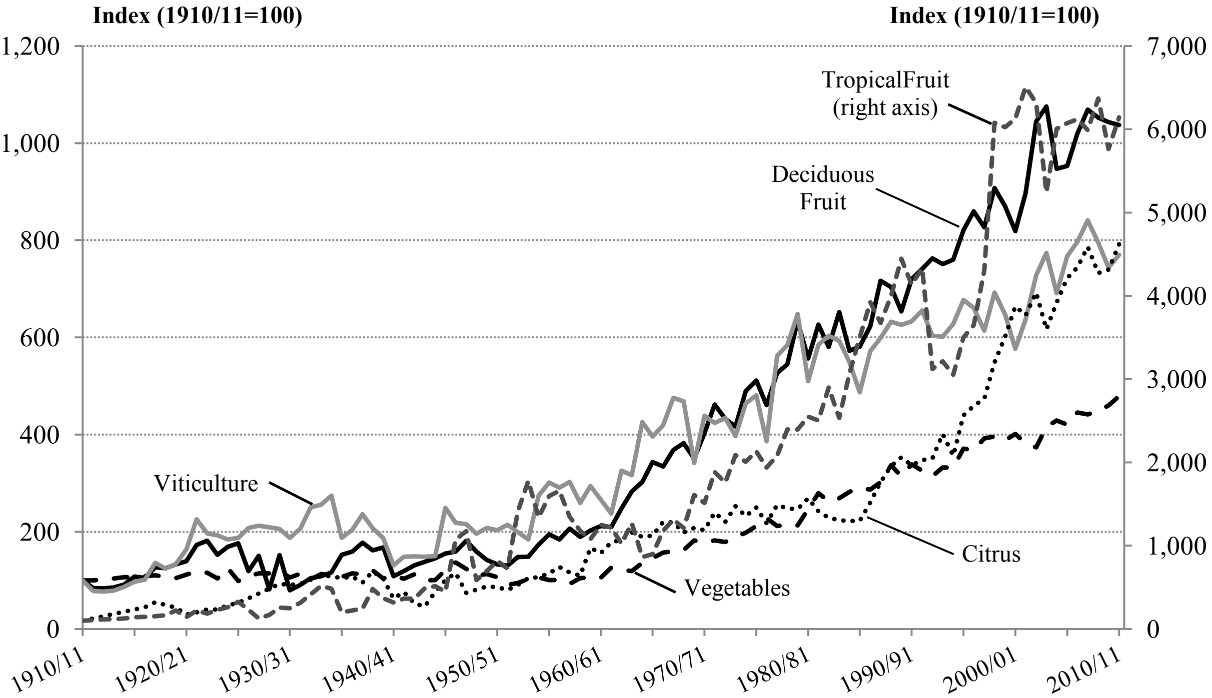


Figure 3.8: Selected Fisher Quantity Indexes for Horticultural Products, 1910—2010

Sources: Own Calculations

The comparatively low growth performance of the livestock sector hides some remarkable changes in the structure of output of the livestock sub-categories (Figure 3.9). The rate of growth in red meat production (sheep, pigs, and cattle) was quite rapid through to 1969, but slowed thereafter. The decline in red meat output coincided with the upswing in broiler production. While red meat production grew from 1992 this coincided with a decline in dairy production from the same year and that lasted until 1999. Since then the red meat, dairy and poultry industries all experienced a comparatively rapid rate of growth in output. However, the decline in the production of pastoral products (wool, mohair and ostrich feathers) slowed the overall rate of growth of the sector.

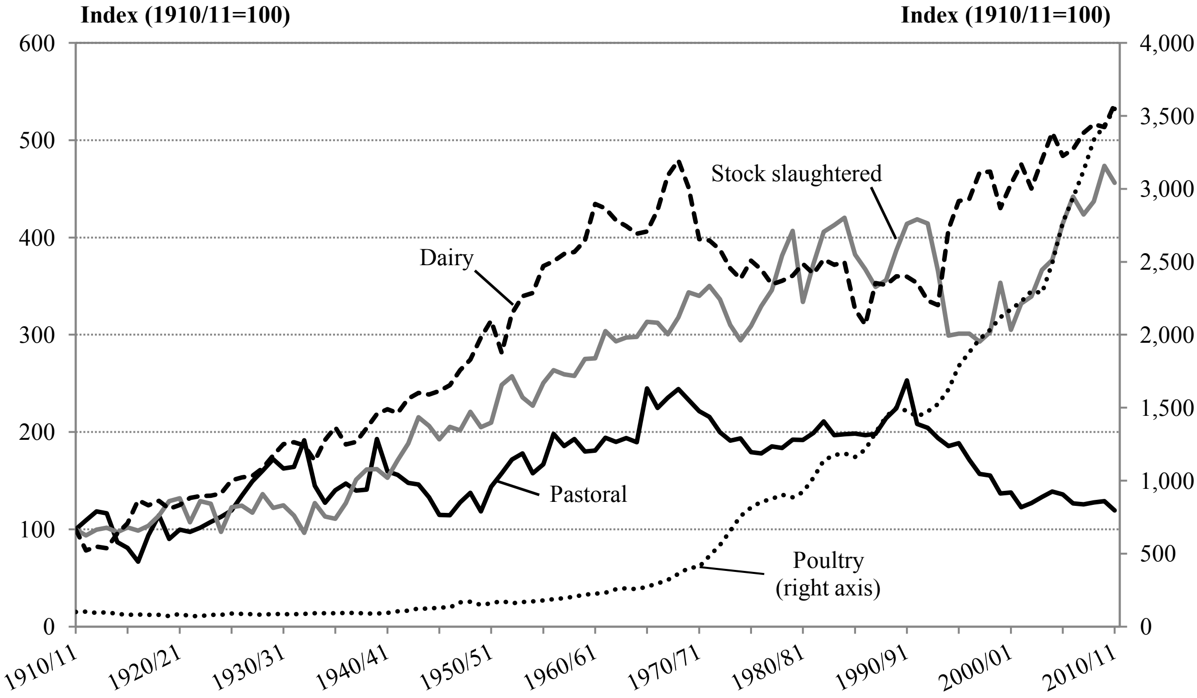


Figure 3.9: Selected Fisher Quantity Indexes for Livestock Products, 1910—2010

Sources: Own Calculations

Notes: Stock slaughtered represents red meat production; Pastoral includes wool, mohair and ostrich feathers.

Whereas the output price index of pastoral products published by the Department of Agriculture include only mohair and wool prices, its quantity of production index of pastoral products also includes karakul pelts and ostrich feathers (all converted to ton equivalents). The quantity index shown in Figure 3.10 includes the trends for wool and ostrich feathers. Changing consumer preferences greatly influenced the performance of the ostrich industry as shown by the wide fluctuations in the trend of ostrich feather production. With the outbreak of the Great War in 1914 prices dropped from the high levels experienced since the late 1890s (NAMC 2003). This has seen the number of birds decrease from 776,313 in 1914 to 314,265 birds in 1917. By 1929, the national ostrich herd had fallen to 31,618 birds from where it slowly increased over the ensuing four decades to reach 70,670 birds reported in the 1970/71 census. The strong increase in the output quantity index from 1986 to 1992 is the result of the inclusion of ostrich meat in the gross value of production estimates of the Department of Agriculture.

The growth in the ostrich meat industry, however, is a relatively recent event. The Department of Agriculture's data fails to capture the growth of the ostrich skins industry, which precedes the emergence of the ostrich meat industry. The reported gross value of production of the ostrich industry thus underestimates the total production of the industry. Estimates by the National Agricultural Marketing Council in 2003 indicate that ostrich feather production today represent less than six percent of the total value of production of the industry. Meat production accounts for between 30 and 45 percent of the production value of a bird, up from 15 percent in 1993 (NAMC 2003).

The quantity index for wool, shown in Figure 3.10 reports a high rate of growth in the aftermath of the wool price boom of 1950/51 when the average price of wool doubled from R888.43 per ton in 1949/50 to R1,759.91 per ton in 1950/51. The 1949/50 price was already 4 times higher than price received immediately after the war (See Figure 3.13). Prices decreased in the subsequent year to the 1949/50 level and thereafter slowly decreased to reach wartime levels by 1967/68. This partly explains the growth in wool production up the late 1960s. World market trends since then has seen the production of wool in South Africa decline ever since.

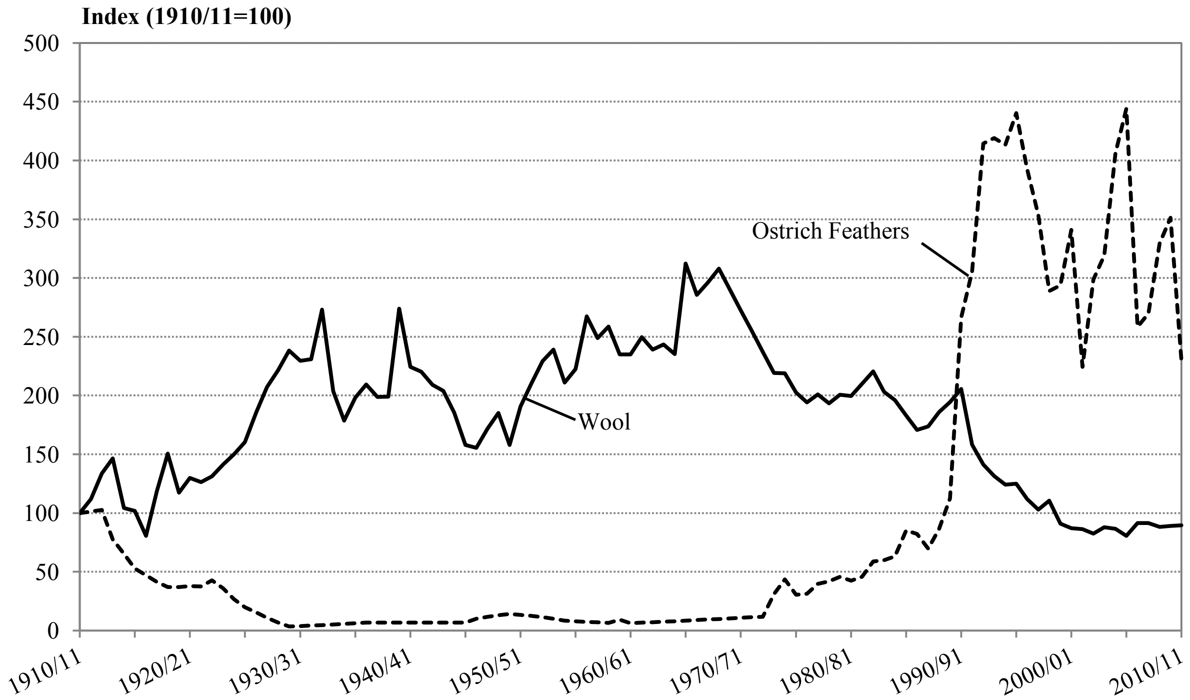


Figure 3.10: Fisher Quantity Indexes for Wool and Ostrich Industries, 1910—2010

Sources: Own Calculations

Figure 3.11 shows the trends in milk production for the Fisher index for dairy output as based on the reported (original) milk production data, the estimates of fresh milk equivalents done by the Department of Agriculture to form the Laspeyres based quantity of production index, and my own estimate using the price and quantity data for fresh milk, butterfat, cheese and condensed milk). The reported data of the Department of Agriculture since 1910 indicates trend breaks in milk production with each revision of the methods followed in estimating the total quantity of milk produced. These trend breaks are repeated in the Thirtle quantity index for dairy products, which is formed from the quantity of production indexes reported in the *Abstract of Agricultural Statistics*. Prominent trend breaks occurred in 1960 and again in 1979.

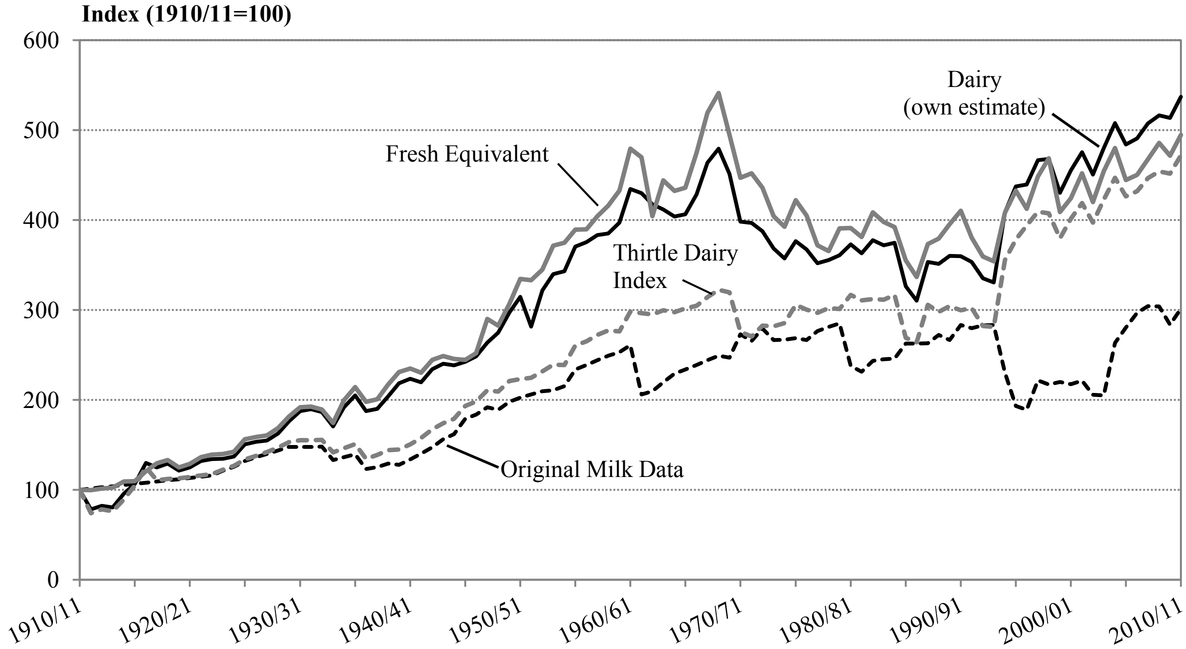


Figure 3.11: Fisher Quantity Indexes for Dairy: Comparing Results, 1910—2010

Sources: Own Calculations

In this study, the estimates of fresh-milk equivalents reported by the Department of Agriculture merely served to validate the estimated total production of milk reported by the Dairy Board. The output quantity index, derived for this study, is formed using the underlying data on the price and quantity of production of butterfat, cheese, and condensed milk. The production of skimmed milk and whole milk powder products was excluded from the analysis to avoid double counting the milk used to produce both butterfat and milk powder (i.e. it is essentially derived from the same milk). The need to include estimates of on-farm production is particularly significant in the dairy industry, albeit less so today than a century ago. In the 1911 population census, 56.6 percent of the total butter production in the country was produced on-farm. This declined to 47.0 percent (4,347.9 ton) by 1924; 65.8 percent of which was sold (OCS 1926). Butterfat production on-farm for sale to factories was deemed undesirable by the Dairy Board in view of inconsistent quality assurance problems faced by the factories (Dairy Board 1992). Thus, by 1991/92 the delivery of butterfat by primary producers to butter factories ceased (Dairy Board 1992: 12), although the situation may have changed since the closure of the Dairy Board. No reliable statistics on on-farm production of butterfat, butter and cheese are available from the agricultural census, or, as yet, MilkSA (the new industry forum).

3.5.3 Trends in commodity price indexes

The growth in agricultural output since the Second World War was spurred by an increase in the domestic producer prices for all agricultural commodities as shown in Figure 3.12. Much of this increase is likely attributable to the protectionist marketing schemes and trade policies discussed in Chapter 5. The exception is the horticultural industries where marketing schemes for these industries generally aimed primarily at the development and maintenance of quality standards and not price support (DOA 1960; Lucas 1979).

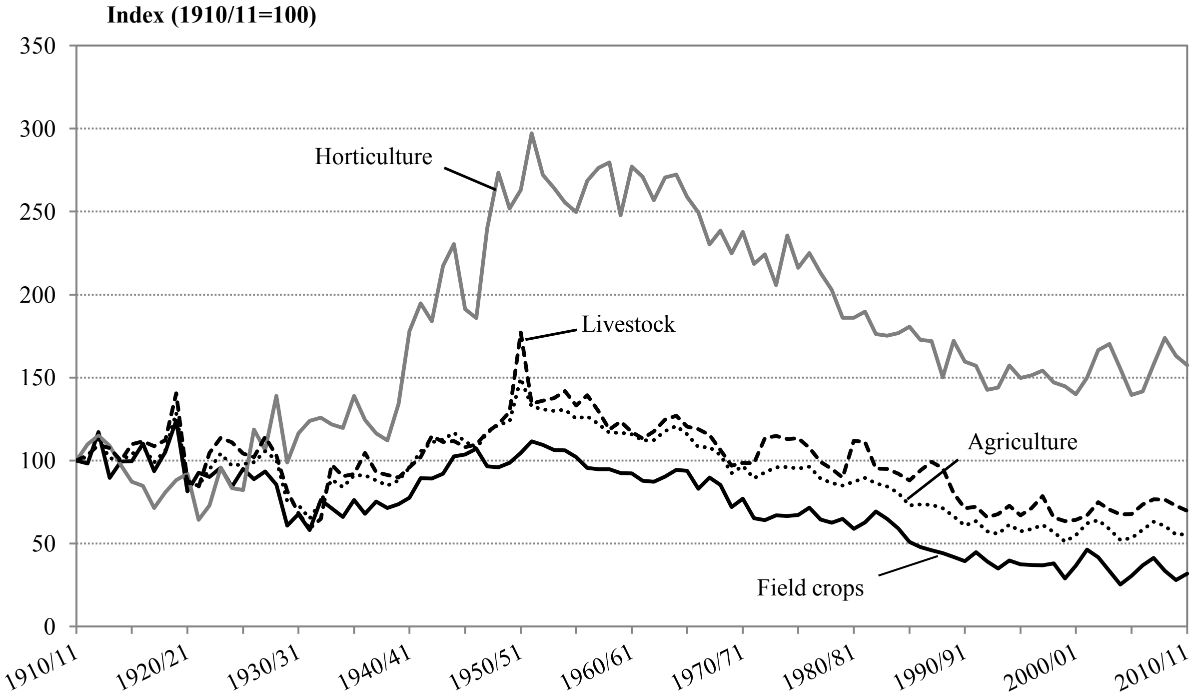


Figure 3.12: Trends in Aggregate Price Indexes of Agricultural Output, 1910 — 2010

Sources: Own Calculations

Real prices for horticultural products grew by 7.32 percent annually from the start of World War Two to peak in 1951/52. For the following decade or so they stalled, but from 1963/64, to 1992/93 it declined at an annual average rate of 1.97 percent down to almost half the price level in 1963. After 1992/93, it began to increase slightly in response to increased access to world markets after sanctions against South African exports were lifted. The livestock and field crop commodities followed similar but less pronounced trends. Since 1992, however, average prices for these commodities have stagnated in real terms.

Figure 3.13 shows the trend for field crops if the effect of direct price subsidies were excluded from the analysis. The first direct subsidies were introduced in 1941/42 and lasted until 1986/87. These subsidies played a very significant role from the end of the war through to the early 1970s whereafter they tapered off and were phased out by the mid 1980s. Crops subjected to this form of support were summer grains and wheat.

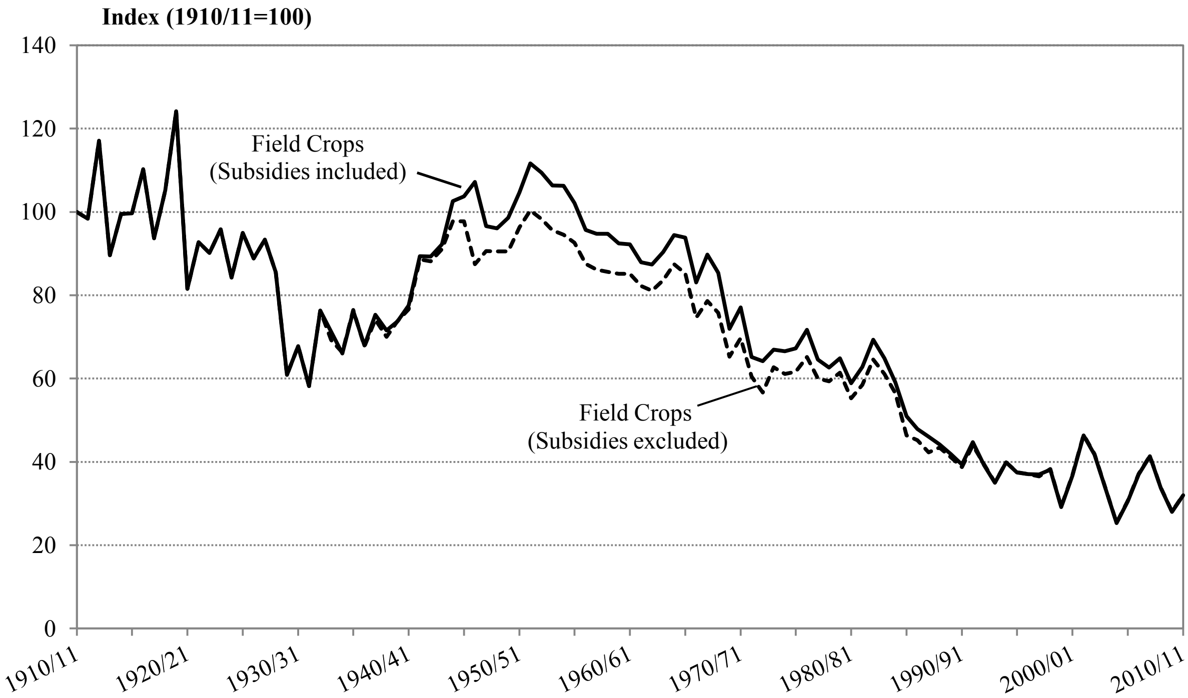


Figure 3.13: Field Crop Price Indexes: With- and Without Subsidies, 1910 — 2010

Sources: Own Calculations

3.6 Conclusion

In this chapter output quantity indexes for the South African agricultural sector were constructed using an entirely new, purpose-built set of long-run production accounts. These accounts differ from ostensibly similar accounts reported by the Department of Agriculture, in that production originating from homeland farmers and black farmers on white-owned farms, were included in this series whereas they are not included in the Department of Agriculture's accounts. In addition, industries previously not enumerated in the national production accounts were included to the extent possible. Statistics on the quantity of milk produced were also revised to account for an overstatement of milk production in the Department of Agriculture's measures arising from the inappropriate inclusion of certain condensation milk products in the production estimates of butterfat.

The aggregation errors arising from the use of various indexing procedures were investigated, and the results compared with the *physical volume of production index* reported in the *Abstract of Agricultural Statistics*. The composition of the basket of commodities included in the physical volume of production index has changed markedly over time and the practice of splicing the reported Laspeyres output quantity indexes for the different base years to form a long-run index yields an index that overstates the growth in aggregate agricultural output during the period studied here, 2.75 percent per year for this study, versus 2.90 percent per year using the Thirtle indexing procedure. The practice of using the physical volume of production index to form the Divisia indexes thus results in an overstatement of the output performance of the sector. All other things equal, overstating the rate of growth in aggregate agricultural output would upwardly bias the rate of growth of South African agricultural productivity.

Although substantial efforts were made to correct for inconsistent methodologies used in the construction of the official production accounts, further effort along these lines is required. Here it was assumed that official gross value of production estimates were correct and, as claimed by the Department of Agriculture, inclusive of the production of the homeland farmers. The procedure followed in this study was to correct the quantity of production estimates for inconsistent inclusion of homeland farmers, and prices were then imputed from the gross value and quantity series so constructed. However, as was shown in the case of dairy and ostrich industries, the existing official data do not correctly account for the total production of these industries, leading one to be suspicious about the extent to which the same may be true of other industries. Also, the production of specialty products and nuts is very poorly enumerated and may be underestimated — especially with vegetables prior to 1958 — leading to a possible underestimation of the 'true' contribution made by the agricultural sector to the national income.

CHAPTER 4

AGRICULTURAL INPUTS

4.1 INTRODUCTION

Detailed data on agricultural input expenditures were first recorded in the agricultural census of 1949/50. More information is available from the Department of Agriculture beginning in 1936/37 on the price index for farming requisites (BCS 1951; DAEM 1961). The records available from the Department of Agriculture, however, are only sub-aggregate input expenditure estimates dating from 1947/48 as recorded in the *Abstract of Agricultural Statistics* with aggregate estimates for the earlier years back to 1910/11 available from ledger files. Inter-temporal comparisons between the different sources soon reveal that the same process of evolution in forming these statistics is evident, as was experienced with the statistics on agricultural production. Previous studies on agricultural productivity all used the published intermediate (materials/purchased) input and capital formation accounts published in the *Abstract of Agricultural Statistics*, supplemented by unpublished data on wage and rent payments available from the Department of Agriculture (Thirtle et al., 1993; Liebenberg and Pardey 1910).[1] With the exception of Liebenberg (2012) and Liebenberg and Pardey (2010) none of the studies made a concerted effort to critically evaluate and where necessary adjust the official estimates in light of revealed errors in these estimates.

In this study the published data on agricultural inputs are first evaluated against the information contained in various agricultural censuses and survey reports and adjusted as necessary. In particular, adjustments were made to account for changes in methodology used by the Department of Agriculture in the construction of its capital formation and materials input expenditure accounts. Special attention was also given to the construction of a new series of capital used in agriculture. As capital assets are used over an extended period of time the service flow from the available capital inputs is the appropriate measure of capital use (Anderson et al. 2011; Fuglie et al. 2012). This mean that the stock of capital by class on-farm, the imputed sales, rental rates and the value of the flow of services from these assets are estimated and presented here. This deviates from past studies of South African agriculture productivity where the service flow estimates are based on expenditure on depreciation, interest payments and the change in livestock inventory.

[1] To avoid confusion with international literature, intermediate inputs will be referred to as purchased (materials) inputs in the remainder of this study. Intermediate inputs implicitly means that inputs produced on-farm is included, whereas the statistical records of the Department of Agriculture do not include this.

In the remainder of this chapter, each of the input categories of capital, land, labour and materials inputs are discussed in greater depth highlighting the limitations of existing data and the steps made to construct an improved set of input use estimates. The chapter concludes with an overview of the changing structure of input use in South African agriculture.

4.2 REPORTED TRENDS IN CAPITAL STOCKS AND CAPITAL FORMATION

The Agricultural Censuses only began recording investments in capital equipment and fixed improvements (as well as expenditures on purchased inputs) in the 1949/50 crop year (BCS 1952). Prior to this, only stock counts were reported for the more important capital items, such as tractors, machinery and implements, but no data on farm infrastructure was available. In addition, no indication was given whether or not the machinery and equipment were newly purchased. Since 1965, the situation has changed and more detailed and comprehensive data are available. It is also safe to say that the longer-run data on capital inputs presented here still mostly reflects developments in the commercial sector, although since 1975 data from the homelands may be included to an uncertain extent.

Table 4.1 summarises the on-farm stock of key capital inputs for selected Agricultural Census years from 1911 to 1981 — the last year in which on-farm numbers of asset counts were enumerated[2]. In 1918 there were only 231 steam and oil burning tractors on South African farms. The number of oil burning tractors more than doubled with each quinquennial agricultural census until 1937, trebled during World War II, and again doubled with each five year period until 1955. From the mid-1950s to the mid-1970s the rate of growth slowed (5.44 percent per year from 1955-1960, 3.12 percent from 1971-1976) and thereafter the number of tractors on farms began to decline. The effect of the post-Boer War development initiatives is evident from the distribution of tractor ownership between the various provinces (see Chapter 2). In 1918, 76.6 percent of the country's tractors were located in the Cape and Natal provinces. This share declined to 41.9 percent by 1950 as investment in the Transvaal and Orange Free State gained momentum. Similarly, only 42.2 percent of ploughs in 1911 were from farms in the Transvaal and Orange Free State provinces. By 1950 these two provinces represented 59.6 percent of the ownership of ploughs (DAEM 1961). This general pattern of growth and shifting spatial distribution of tractors and ploughs is emblematic of the changing structure of machinery on South African farms more generally.

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[2] Data reported in the census reports is reported by crop years. Here I follow the practice of referencing to the first year, i.e. 1936/37 crop year is referred to as 1936, for ease of reference. Up to 1988 the statistical records referred to the crop year, but thereafter it refers to the first year of the financial year.

Table 4.1: On-Farm Stock of Selected Capital Inputs, 1910 to 2010

Capital Item	1910	1918	1921	1926	1930	1937	1946	1950	1955
Land in Farming (ha)	-	77,556	80,287	83,039	82,801	85,575	88,637	86,918	87,468
Farms (Number)	-	76,149	81,432	88,374	96,940	104,554	112,453	116,848	111,586
Labour ('000)	990	987	1,067	1,185	1,268	1,471	1,314	1,615	1,540
					Number				
Cars	-	-	-	-	-	52,000	56,558	63,603	66,675
Trucks	-	-	-	-	-	8,568	21,256	31,308	52,077
Wagons & Trollies	142,864	159,068	-	84,915	87,820	99,302	102,892	72,132	43,762
Trailers	-	-	-	-	-	-	-	19,915	45,543
Tractors	-	231	515	1,302	3,684	6,019	20,292	48,423	87,451
Tillage (3-share equivalents)	221,319	228,239	183,529	303,757	383,392	441,591	550,606	541,013	537,367
Planters	7,850	13,135	-	58,134	71,351	78,793	104,488	123,797	168,954
Pest Control	-	-	-	-	-	2,673	2,267	4,076	6,337
Combines	-	-	-	-	-	581	1,722	5,304	8,513
Pickers	-	-	-	-	-	-	-	-	-
Threshers	1,503	1,428	6,926	8,404	8,602	10,112	11,111	12,681	14,959
Mowers	28,328	17,916	-	40,006	41,289	74,783	40,043	57,208	92,288
Balers	3,558	14,987	-	14,539	16,512	19,349	14,995	12,436	14,200
Pumps	-	-	-	43,704	59,518	77,175	101,330	123,104	151,194
Electrical Motors	-	178	283	1,085	1,435	4,484	7,900	5,154	42,550
Engines	-	4,522	4,155	6,253	9,732	12,361	20,645	46,341	54,639

Table 4.1: (continue)...

Table 4.1: Continued

Capital Item	1960	1965	1971	1976	1981	1990	2000	2010
Land in Farming (ha)	91,790	87,795	89,298	85,719	86,267			
Farms (Number)	105,859	95,538	90,422	75,562	64,430			
Labour ('000)	1,343	1,501	1,516	1,184	1,069			
				Number				
Cars	77,807	75,057	67,735	67,069	59,510			
Trucks	69,376	74,631	94,649	115,101	111,189			
Wagons & Trollies	23,175	11,244	-	-	-			
Trailers	139,326	166,810	-	97,859	101,998			
Tractors	114,766	134,435	157,127	173,570	161,549	151,774	75,276	69,700
Tillage (3-share equivalents)	562,082	637,432	-	421,931	405,723			
Planters	150,677	156,794	-	122,867	127,120			
Pest Control	8,598	36,169	-	33,033	31,236			
Combines	10,223	13,065	16,028	23,767	21,362			
Pickers	4,242	6,091	-	4,885	4,985			
Threshers	16,586	13,818	-	17,252	13,844			
Mowers	98,260	63,175	-	79,278	68,112			
Balers	13,062	18,084	-	15,732	16,003			
Pumps	249,165	255,210	-	238,419	257,571			
Electrical Motors	21,058	24,457	-	62,297	91,390			
Engines	83,816	83,309	-	106,215	82,629			

Sources: DAEM (1958; 1967; 1972; 1985; 1997; 2012) AGFACTS (2011)

Following the general approach used to compile a new agricultural output series, constructing the capital input series involved a process of reconciling the data published in the *Abstract of Agricultural Statistics* against information reported in the various agricultural census reports, supplemented with other relevant information. Explanations for any differences were sought from personnel in the Department of Agriculture. Figure 4.1 plots estimates on capital formation (investment in capital) obtained from the census reports against the corresponding figure obtained from the *Abstract of Agricultural Statistics*. In inflation adjusted terms, the capital formation expenditures reported in the *Abstract of Agricultural Statistics* ranged between 60.8 and 16.3 percent higher than the census estimates, with the exception of 1950 when the *Abstract of Agricultural Statistics* estimate was 6.9 percent lower than the corresponding census estimate.

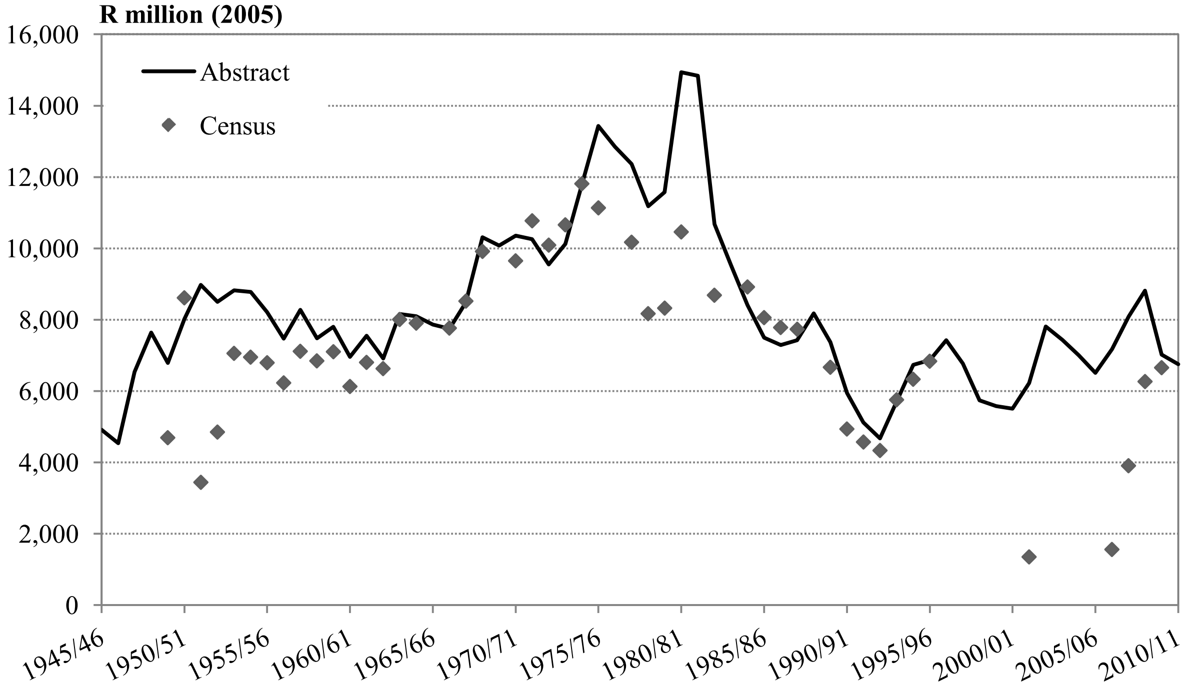

Figure 4.1: Trends in Capital Formation, Abstract versus Census, 1945 — 2010

Sources: Stats SA (2011); DAFF (2012)

Notes: Abstract (*Abstract of Agricultural Statistics*)

The censuses did not always capture the full range of capital inputs, as capital items such as pumping equipment, electrical equipment and loose tools and equipment were often not enumerated. From 1958 the difference decreased with the *Abstract of Agricultural Statistics* estimates exceeding the census estimates by 13.6 percent in 1961 declining to 2.0 percent in 1964. Thereafter the *Abstract of Agricultural Statistics* and the Census estimates were comparable, except for the 1974 to 1983 period when the *Abstract of Agricultural Statistics* reported aggregate capital formation expenses that were 29.4 percent in 1976 and 52.5 percent in 1981 greater than the corresponding census figures. These differences are attributable to the fact that the Department of Agriculture began using a Survey of Agricultural Mechanization (Retail Sales) as the basis for forming their estimates of machinery and equipment expenditures. From 1990 until 1995 the only difference between the census and the *Abstract of Agricultural Statistics* estimates arose from differing interpretations of the financial year (that changed in the census from September through August to March through February) and the manner by which the Department of Agriculture accounted for this in its own estimates.[3] It is thus rather inexplicable, at least to the author, that whilst the Survey of Agricultural Mechanization was still being conducted the estimates on capital expenditure reported by the Department of Agriculture started to match the agricultural census from 1985 to 1994.

Beginning in 1995, the aggregate capital formation estimates deviated markedly between the Census and the *Abstract of Agricultural Statistics,* which may be ascribed to changes in the sampling strategies used to select the farms that were to be enumerated in the census surveys (see Chapter 3).

It is unclear precisely how the Department of Agriculture developed its annual estimates of investment in farm machinery and equipment. Moreover, if one were to form a credible estimate of the value of the service flows derived from the use of these items of capital a more detailed categorization of capital would be required, commensurate with the changing composition of the structure of stock on farms in South Africa. To achieve this, the capital investment series of the Department of Agriculture was adjusted for consistency in its estimation procedures before it was disaggregated to form the detailed series used in forming the quantity of capital used index.

4.2.1 Revising the reported capital data

The aggregate capital series developed for this study was constructed from disaggregated data pertaining to investments on fixed improvements, machinery and equipment and breeding stock. Some additional detail was obtained from the Directorate of Agricultural Statistics on the subdivisions of each category. Information is available for fixed improvements on residential (owner and farm worker) dwellings, non-residential (animal housing, barns, store-rooms, garages and all other outbuildings), new construction (pit silos, dipping tanks, kraals, plastic tunnels, roads, bridges and power-lines) and orchards and plantations (tea, coffee, sugar-cane, banana and pineapple plantations, orchards and vineyards, including the purchase of plant material, young fruit trees and vines and trellising material, and the preparation and fertilization of soil, but excluding forestry and wattle plantations). The tractor, machinery and implements category (machinery for short) is separated into motor vehicles (passenger vehicles, pickups, and trucks) and machinery, implements and tools and equipment.

[3] Reporting on input expenditure in the census changed from a crop year to a financial year in the 1987/88 agricultural census (Stats SA 1993).

In census reports, expenditure is reported separately for vehicles, tractors, and machinery and implements up to 1996, with more detail being sporadically provided on machinery purchases. For some census nodes detail of spending on tractors, motor vehicles (sometimes also motor cycles and aeroplanes), trucks, combines, machinery (soil cultivation equipment, crops and hay harvesting equipment, harvesting and processing of vegetables and fruit, new loose tools and implements, pumping equipment, electricity transmission) and an unspecified category of other equipment is available. This detail was used to calibrate the disaggregation of census nodes where little other detail was provided, following the procedure described below.

To disaggregate the vehicles and tractor, machinery and implements categories the detailed data on stock numbers were used to form a long-run series of asset values. Vehicles were disaggregated into 3 different categories, i.e. passenger vehicles, pickups (light trucks with a load capacity of less than 1.5 tons) and trucks (load capacity of 1.5 tons and more). Pickups and trucks stock numbers were converted to total tonnage and divided by the numeraire load capacity; i.e. 1 ton for pickups, and 8 ton for trucks. The value of the stock of pickups and trucks was then calculated using the price of a Toyota Hilux and a Toyota Hino respectively. The price of the Toyota Hilux was traced back to its introduction in 1970 and prior to that the average price of a Chevrolet and Ford one tonner was used. The price of the eight ton Toyota Hino was back-cast pre-1992 using the farming requisites price index of heavy trucks available from the Department of Agriculture. The average price of passenger vehicles purchased in 1970/71 was reported in the agricultural census (DOS, 1974). A price index on passenger vehicles was used to project the price of new vehicles for the years prior to and after 1970/71.

Using the relative proportions in the estimated stock value of passenger vehicles, pickups and trucks the aggregate expenditure on motor vehicles reported by the Department of Agriculture were disaggregated. The same methodology was used to disaggregate the machinery and implements expenditure series into expenditure on tractors, trailed and self-propelled combines, mowers, balers, ploughs, wheat and maize planters, crop sprayers, and wagons up to 1966/67. As off 1967/68 the relative proportions of the *Survey of Agricultural Mechanization Sales* were used to disaggregate the expenditure on machinery (DAMS 1968-1994).

Detailed data on stocks is available from the agricultural census reports from 1917/18 through to 1982/83. From 1983/84 the reported vehicle expenditure was disaggregated using the relative proportions of new vehicle registrations. With the transfer of the *Survey of Agricultural Mechanization Sales* to the SA Agricultural Machinery Association in 1995, detailed information on the structure of sales ceased to be available and disaggregation for the various categories of farm machinery and implements was based on the proportions used by AGFACTS[4].

The history of the *Survey of Agricultural Mechanization Sales* needs to be understood to avoid the erroneous use of this information, especially as it forms the basis for the disaggregation done here and formed the basis for the Department of Agriculture to project its estimates of expenditure on machinery and implement sales from 1975 to about 1983. The *Survey of Agricultural Mechanization Sales* was first conducted in 1968 by the Directorate of Agricultural Mechanisation Services. In 1994, the research arm of the directorate was transferred to the newly established South African Agricultural Research Council and the responsibility for the survey was transferred to the South African Agricultural Machinery Association and specifically its AGFACTS information service (J. Rankin, Edenvale, Secretary SAAMA, 2010, personal communication).

A notable feature of the statistics was that both the value and quantity of sales of essentially all the items of machinery and implements reported in the survey consistently exceeded estimates obtained through the agricultural censuses. In the case of tractors, the reported expenditure in the census varied between 36.0% and 80.5% of the sales value reported by the *Survey of Agricultural Mechanization Sales* from 1975/1976 through 1995/1996 – the last year in which reliable data on tractor purchases could be obtained from the agricultural census. Data for the *Survey of Agricultural Mechanization Sales* were collected from the suppliers of agricultural machinery and equipment and, though imports and re-exports were accounted for, the survey did not account for the possibility of sales to either the homelands or to non-agricultural equipment users, such as municipalities, construction companies, etc. It is also uncertain whether, in accounting for trade, exports to Southern African Development Community member states were accounted for.[5]

The coverage of the *Survey of Agricultural Mechanization Sales* changed significantly over time since its first inception. In 1973, for example, 24 respondents was listed as plough manufacturers with reported sales of R6.6 billion, increasing to 26 respondents with reported sales of R15,3 billion in 1975. By 1980, the number of respondents was 27 with reported sales of R26.8 billion. If the same trend holds for all input categories, the shifting sample of respondents would explain the high growth in the expenditure estimates made by the Department of Agriculture during the 1975 through to 1980. Even if the new entrants presented a marginal contribution to overall sales in machinery and equipment, using the relative change in annual sales could lead to a significant overstatement of the expenditure trend.

[4] Total expenditure on agricultural machinery is imputed by AGFACTS using the relative share of tractor sales of the total for the last 5 years of the *Survey of Agricultural Mechanization Sales* up to 1994. At that time tractor sales constituted 60 percent of total machinery sales. Census reports since 1994 indicated that the share of tractor purchases by commercial farmers could vary between 38 and 80 percent of the reported sales of AGFACTS, thus casting doubt on the appropriateness of this methodology to derive the total overall sales of agricultural machinery.

[5] SADC is a regional trade agreement that promotes economic integration among its 15 member states.

As an alternative, the estimates on machinery sales were revised to reflect the estimates reported in the census as, with hindsight, it is better to stick to what is known from the census rather than to use trend projections from a survey which in itself has some procedural problems in its design and the evolution of its implementation. This is justified in the light of the effort made by the Department of Agriculture to again reflect the level of expenditure reported in the census from 1985.

Expenditure on Pumping equipment and Electricity generation and transmission was reported separately from 1953/54 through 1987/88. Thereafter it was merged with loose tools and equipment under the heading Other. In the absence of any other alternative, expenditure on these two capital items was estimated using the trend in area under irrigation for pumping equipment and expenditure on electricity for electricity generation and transmission.

Investment in fixed improvements in turn, proved especially difficult to analyse and adjust for consistency over time. Prior to 1962, the agricultural census estimates of capital investment did not include investments in farm residential property, although this was included in *Abstract* estimates. Lacking sufficient information on the exact content and in view of the changing definitions followed over time it was decided to use the data available from the Abstract on fixed improvements as is.

Table 4.2 summarizes the changes made to the capital expenditure along with the methods followed and the motivation along with the methods followed by the Department of Agriculture. The Department of Agriculture calculates depreciation on the aggregate value of assets of the previous year. For the machinery assets depreciation is estimated at 10 percent of the aggregate value of assets and for fixed improvements a rate of 2 percent is used. The caveat of this approach is that it assumes a homogenous distribution of the age and unit value of on-farm assets which is clearly an invalid assumption. An alternative to this approach is introduced in section 4.4

Since vehicles are partly used for private purposes the expenditure series is pro-rated. The rate of pro-rating done by the Department of Agriculture is 70 percent of the aggregate expenditure on vehicles and this is claimed to have been consistently applied throughout the history of this account since 1947/48. However, earlier records published in *Farming in South Africa* (DOA, 1960:112) state that only 50 percent were pro-rated for investment in agriculture for the pre-1960 period. In this study it is argued that the level of pro-rating should differ for cars, pickups and trucks. The procedure followed was to include the full expenditure on trucks as agricultural investment. Passenger vehicles the rate of pro-rating start at 50 percent in 1945/46 (following the earlier rule of thumb of the Department of Agriculture) and was gradually decreased to 10 percent by 2011. Initially passenger vehicles were used equally as farm and family transport, but changing design and the increased availability of pickups influenced the use thereof. Pickups were prorated at 90 percent in 1945/46, declining to 83 percent in 2011. Changing tax policy on depreciation deductions of SUV's and double-cab pickups serve as motivation for the change in pro-rating (Blignaut 2010[6]). In this investment series the change in the rate of prorating was phased in over the years as the detail on the timing of tax changes is not available from the archives of the Department of Agriculture.

Table 4.2: Changes Made to National Capital Formation Series

Variable	Changes made	Method/Motivation
Vehicles	Disaggregated into 3 capital classes, e.g. passenger vehicles, pickups, and trucks.	Prior to 1953/54 used trend in new vehicle registration to backcast expenditure on vehicles. Disaggregate between classes using value of asset ratios up to 1982/83; from 1983/84 used trend in new vehicle registration to separate (relative proportion between trucks and pickups kept constant)
	Different pro-rating levels for each class of vehicle as opposed to Directorate of Agricultural Statistics approach of 70 percent overall on vehicles	Pro-rating for cars; 50 percent declining to 10 percent. Pro-rating for Pickups, start at 100 percent declining to 83 percent. Trucks, no pro-rating.
	Depreciation estimated according to service life.	Directorate of Agricultural Statistics estimate depreciation as 10 percent of the total value of all vehicles. Depreciation should first be calculated by class and then aggregated.
Tractors, Machinery & Implements	Disaggregated into 10 capital classes, e.g. tractors, ploughs, wheat & maize planters, crop sprayers, combines, mowers, balers, pumping equipment, electrical motors.	Prior to 1968; used the relative proportion in estimated asset values by class to allocate expenditure. From 1968 to 1994, used the Survey of Agricultural Mechanization to disaggregate, left out inputs that were only sporadically monitored.
	Since 1997; Used AGFACTS estimation procedures to estimate expenditure by class instead off indexed trend projections.	From 1995 to 1997, retained 1994 ratio's. From 1997 data used the slightly different ratios of AGFACTS, which remained constant from 1997 to date.
	Depreciation according to service life.	Directorate of Agricultural Statistics estimate depreciation as10 percent of total value of all Machinery and equipment. Depreciation should first be calculated by class to account for age and service life and then aggregated.
Fixed Improvements	Used Directorate of Agricultural Statistics data, but maintained a constant rate of depreciation (2 percent) throughout the full period.	Depreciation formulas in the long run data series have been adjusted to "closer reflect" the estimates obtained in certain Census years (e.g. 1983, 1993) The need for this came from a corrupted link to the underlying data on capital investment for the period 1970/71 to 1989/90.

[6] Personal communication

4.2.2 Revised capital investment series

Table 4.3 shows the inflation adjusted ten-year average expenditure on fixed improvements, vehicles and machinery and equipment from 1945 through to the present as reported in the census and the *Abstract of Agricultural Statistics* as well as the revised investment series used in this study. The difference in estimates between the census and the *Abstract of Agricultural Statistics* is again emphasised. Estimates for the years 1918 and 1938 were published at the fifty year commemoration of the establishment of the Union of South Africa in May 1960 (DOA 1960). According to the Department of Agriculture the investment in fixed improvements and machinery increased fourfold in the 30 years from 1918 — the census reports only a twofold increase. The expenditure on fixed improvements during the latest decade is double that of 1937, but only about two thirds the peak level of the 1970s — a third according to the census.

The trends in the sub-categories of fixed improvements have shown distinctly different growth patterns over the past century. The ten-year average spending on residential buildings peaked in the 1970s (R1,689.8 million) and decreased to an average of R637 million during the last two decades; the lowest ever. Spending on non-residential buildings followed a similar pattern, but is still almost double that of the immediate post-war period. Construction works, however, grew until 1960, but decreased thereafter. In contrast, the investment in orchard development increased in each decade and is currently 9.7 times higher than the post-war decade. The highest increase occurred from the 1980s through to the 1990s and appears to match the growth trends of the horticultural sector over the sixty year period.

The Department of Agriculture estimated that investment in machinery and equipment shows an almost nine fold increase from 1918 to the immediate post-war period (from R435.6 million to R3.8 billion). It almost doubled from World War II to reach an average of R7,1 billion in the 1970s. Thereafter it remained relatively high during the 1980s, but decreased to about 60 percent of the 1970s peak level during the last decade which is still 11.7 percent higher than the immediate post-war period. Spending on vehicles, which has been fluctuating above R1.3 billion from the post-war period reached a peak of R1.8 million during the 1970s, but decreased to slightly less than the immediate post-war years. Investment in tractors and machinery is now fluctuating around the levels shown during the 1950s and 1960s. To a large extent this mimics the trend in area cultivated (section 4.5.2).

Table 4.3: Comparative Summary Statistics on Capital Expenditure in South African Agriculture, Ten Year Averages, 1945 – 2010

Item	Period								
	1918	1937	1946 – 1950	1950 – 1960	1960 – 1970	1970 – 1980	1980 – 1990	1990 – 2000	2000 – 2010
Census									
Fixed Improvemments	636.6	1,318.2	1,344.2	2,136.9	3,672.2	3,309.7	3,164.6	2,966.1	1,082.6
Residential					1,157.2	1,248.8	964.2	953.1	442.6
Non-Residential			906.9	1,257.6	1,107.6	720.3	799.2	509.7	194.8
Construction Works			437.3	736.5	1,194.9	973.5	878.5	721.7	445.1
Orchard Development				142.8	212.5	367.1	522.7	781.6	
Machinery	435.6	1,531.9	837.1	4,750.2	4,099.3	6,099.6	3,695.1	1,751.5	1,477.2
Cars & Trucks		698.3	283.7	1,885.8	1,607.5	2,217.2	1,190.3	653.5	492.3
Tractors & Machinery		855.0	553.3	2,864.4	2,491.9	3,882.4	2,504.8	1,098.0	984.9
Abstract									
Fixed Improvemments	636.6	1,318.2	2,567.3	3,656.8	3,504.2	4,249.2	3,245.1	2,573.2	2,901.6
Residential			1,094.3	1,544.7	1,261.2	1,689.8	1,128.4	632.6	641.4
Non-Residential			372.8	540.8	622.6	1,069.6	855.6	583.4	622.5
Construction Works			1,022.2	1,450.1	1,460.4	1,202.7	911.0	779.2	880.1
Orchard Development			78.1	121.1	160.0	287.1	350.1	578.0	757.5
Machinery	435.6	1,531.9	3,810.9	4,577.0	4,712.2	7,101.0	6,371.8	3,482.8	4,258.1
Cars & Trucks		698.3	1,342.4	1,409.3	1,447.0	1,769.3	1,220.4	896.8	993.9
Tractors & Machinery		855.0	2,468.5	3,167.7	3,265.3	5,331.6	5,151.4	2,586.0	3,264.2
Revised Series									
Fixed Improvemments			2,550.4	3,656.1	3,504.2	4,249.2	3,245.1	2,573.2	2,901.6
Residential			1,090.6	1,544.7	1,261.2	1,689.8	1,128.4	632.6	641.4
Non-Residential			369.2	540.1	622.6	1,069.6	855.6	583.4	622.5
Construction Works			1,013.0	1,450.1	1,460.4	1,202.7	911.0	779.2	880.1
Orchard Development			77.7	121.1	160.0	287.1	350.1	578.0	757.5
Machinery			3,676.8	4,921.7	4,810.8	6,107.7	5,082.5	3,132.5	3,627.4
Cars & Trucks			1,119.5	1,622.2	1,483.2	1,751.0	1,256.0	840.6	1,025.8
Tractors & Machinery			2,557.3	3,299.4	3,327.6	4,356.6	3,826.4	2,291.9	2,601.6
Difference between Abstract and Revised Series									
Fixed Improvemments			-16.9	-0.8	0.0	0.0	0.0	0.0	0.0
Residential			-3.7	0.0	0.0	0.0	0.0	0.0	0.0
Non-Residential			-3.6	-0.8	0.0	0.0	0.0	0.0	0.0
Construction Works			-9.2	0.0	0.0	0.0	0.0	0.0	0.0
Orchard Development			-0.4	0.0	0.0	0.0	0.0	0.0	0.0
Machinery			-134.2	344.6	98.6	-993.3	-1,289.4	-350.3	-630.6
Cars & Trucks			-223.0	212.9	36.2	-18.3	35.6	-56.2	31.9
Tractors & Machinery			88.8	131.7	62.4	-975.0	-1,325.0	-294.1	-662.6

Sources: Own calculations and OCS (1919 to 1949); BCS (1950 to 1968); DOS (1971 to 1980); CSS (1982 to 1998) and Stats SA (1999 to 2011)

The difference between the revised capital investment series and the estimates of the Department of Agriculture reported in the *Abstract of Agricultural Statistics* appear at the bottom of Table 4.3. The effect of different prorating rates on vehicles had a relative larger effect during the first two decades, initially lower and then higher by about R200 million. From the 1960s it nearly matches the estimates of the Department of Agriculture. Figure 4.2 plots the different estimates of expenditure on vehicles and shows that from 1954 to 1996 both the estimates by the Department of Agriculture and the revised series are slightly lower than the census estimates. The same situation occurred with the census and surveys of the early 2000s as a result of the sub-sampling problem of the census office. The revised vehicle investment series is similar to the estimates of the Department of Agriculture, except for the 1970s and 1980s. The large deviation in 1979 is the result of a double count on trucks in the estimates of the Department of Agriculture. The subsequent dip in the data of the Department of Agriculture up to 1990 is the result of indexed adjustments in estimates, before the estimates were again adjusted to reflect census estimates.

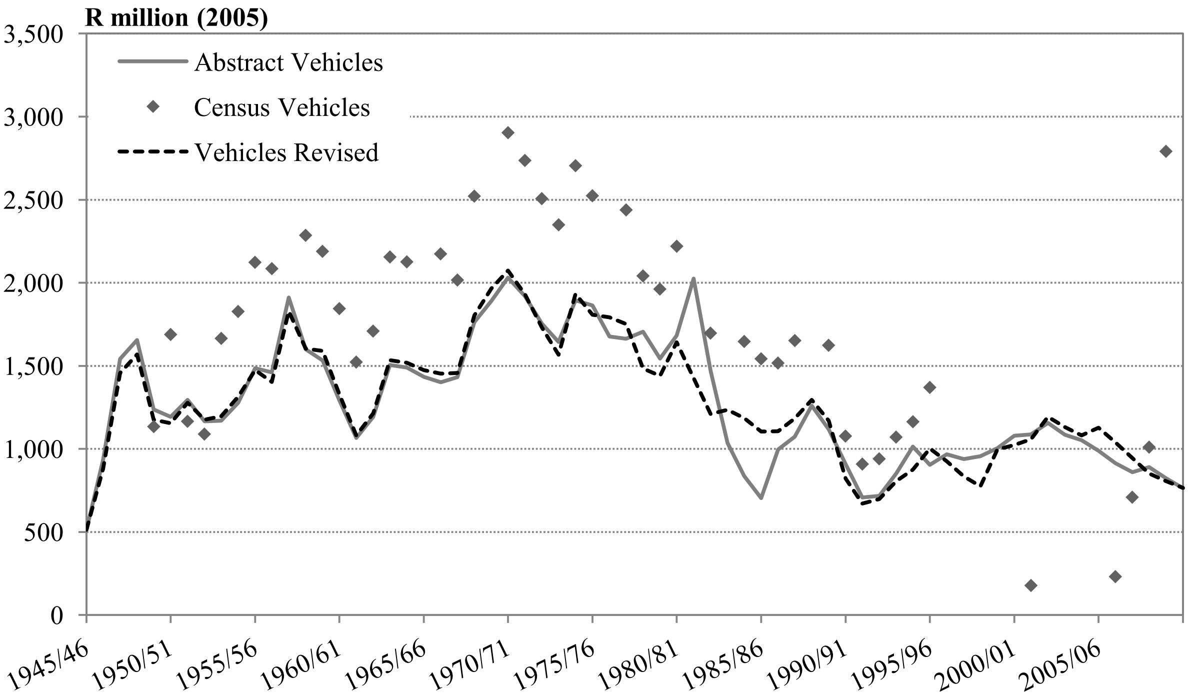

Figure 4.2: Expenditure on Vehicles, Census Versus Abstract and Revised Series, 1945 — 2010

Sources: Stats SA (2011); DAFF (2012); Own calculations

Notes: Abstract (Abstract of Agricultural Statistics)

The revised investment in the tractors and machinery series was slightly higher during the first three decades, but followed a different trend to estimates by the Department of Agriculture for the 1970s and early 1980s where the estimated expenditure is up to R1,325.0 million lower in the 1970s alone — R2,300 in total for the two decades. The effect of using trend projected estimates on expenditure on tractors and machinery based on the sales data of the *Survey of Agricultural Mechanization Sales* from 1975 to 1983 is evident in Figure 4.3. The approach was followed by the Department of Agriculture through to the 1993 census. Thereafter the difference between the revised series and the estimates reported in the *Abstract of Agricultural Statistics* result from the use of the technical ratios followed by AGFACTS in estimating the overall sales machinery and implement sales.

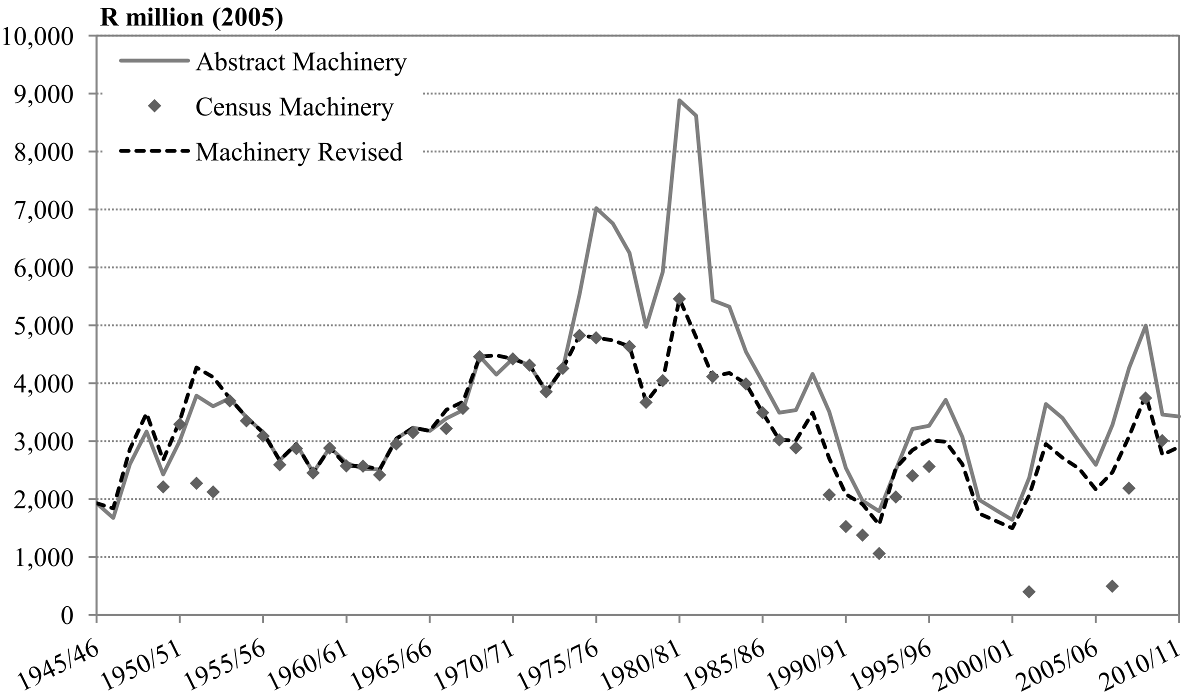

Figure 4.3: Expenditure on Machinery, Census Versus Abstract and Revised Series, 1945 — 2010

Sources: Stats SA (2011); DAFF (2012); Own calculations

Notes: Abstract (Abstract of Agricultural Statistics)

Figure 4.4 shows the trend in investment in fixed improvements of the revised series that matches that of the Department of Agriculture, except for marginal changes to the data for the earlier years as a result of correcting corrupted formulas in the first two decades which has a marginal effect on the end result.

For reason of comparison with earlier studies the revised capital investment series is used to form the Fisher ideal quantity of services used and the data reported in *Abstract of Agricultural Statistics* is used to represent the Thirtle indexes.

4.3 Some Specific Measurement Issues

As capital assets are used over an extended period of time the service flow from the available capital inputs is the appropriate measure of capital use (Anderson et al. 2011; Fuglie et al. 2012; OECD 2001). The first, and critical step, is to estimate a time series of relevant capital quantity and price estimates with sufficient granularity that important compositional changes are reflected in the data. To this end, disaggregated price and quantity information were compiled for 23 classes and 4 types of capital (Table 4.4). Like the InSTePP series (Alston et al. 2010:p.35) different classes of capital differ in their service lives (and by implication, their rates of depreciation) while different types of capital within each class differ in terms of their productive attributes (which are revealed by way of differences in their per unit rental rates). The rationale for disaggregating the data series is to avoid aggregation bias and improve the service flow estimates when forming indexes of capital use.

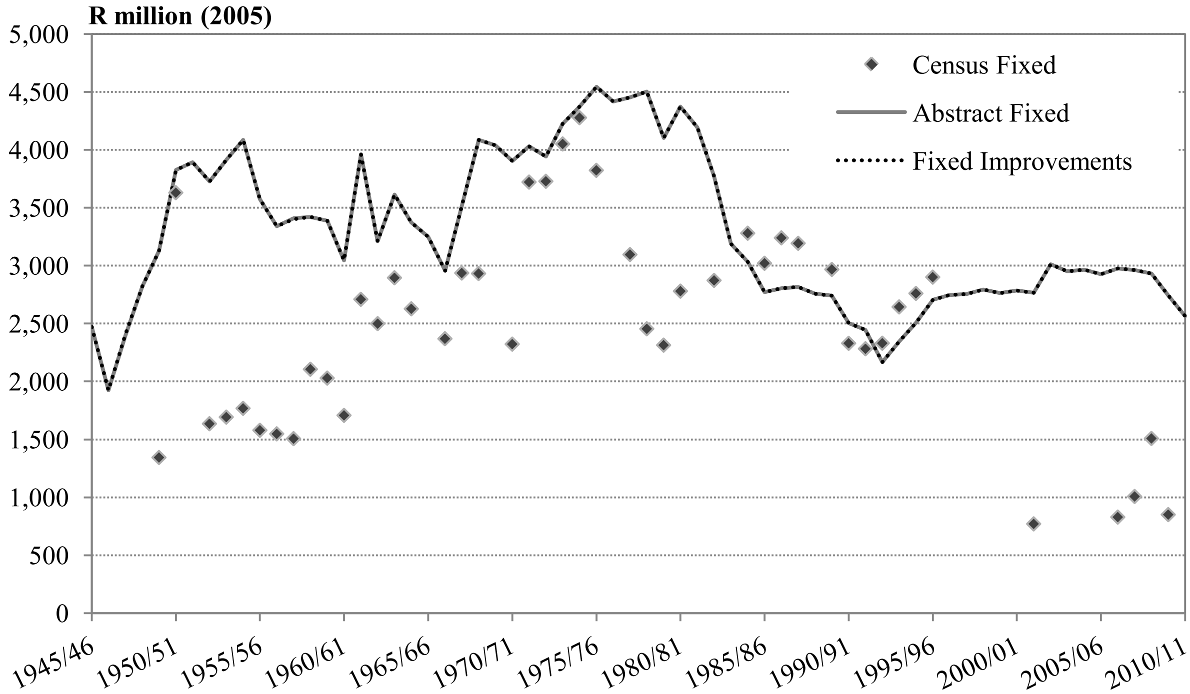

Figure 4.4: Expenditure on Fixed Improvements, Census Versus Abstract and Revised, 1945 — 2010

Sources: Stats SA (2011); DAFF (2012); Own calculations

Notes: Abstract (*Abstract of Agricultural Statistics*)

Earlier studies used information on the operating costs (i.e., expenditures on maintenance and repairs), interest on investment and reported depreciation on capital assets obtained from the aggregate agricultural statistics to estimate the service flow from capital assets. The spliced price indexes for fixed improvements, maintenance and repairs, machinery cost and slaughtered livestock were used to impute the quantity series upon which the Thirtle index is based. In so doing, information on expenditure incurred in the year of purchase is not used (Thirtle et al. 1993). The interest component of all three capital categories was included to reflect the opportunity cost of holding farm capital and was calculated at an arbitrary (and low) fixed rate of two percent on the value of capital assets in each year to reflect the considerable credit subsidies that were available to commercial farmers (Wiebe et al. 2001).

The first aspect in which the earlier estimates of service flows differ from the method introduced in this study is the manner by which depreciation is included in the analysis. The Department of Agriculture estimate depreciation using the declining balance method in which a constant percentage representing the annual rate of depreciation of each category of capital is applied to its estimated value at the beginning of each year. The percentages used are ten percent for the aggregate of vehicles and machinery and two percent for fixed improvements. This method implicitly assumes a homogenous age distribution of the pool of assets over the years. In this study, annual purchases, differing service lives of each class of capital and depreciation are calculated using a geometric rate of decay. According to Anderson et al. (2011) a constant geometric rate of depreciation, δ, is widely used in capital measurement because it is simple to apply and provides a good approximation to physical deterioration when working with measures of the aggregate stock of assets. It also provides an internal consistency between estimates of the productive stocks of assets and their rental rates, as the same δ is used in the calculation of each.

The second area in which earlier studies differ from this study is in its treatment of livestock capital. The depreciation of livestock capital stock was included in the sense that the animals were depreciated 100 percent in the year of slaughter and expenditure on feed was included in the livestock capital series (change in livestock inventory) to prevent this from turning negative in bad years when large numbers of animals were slaughtered (Wiebe et al. 2001). The change in livestock inventory, as estimated by the Department of Agriculture, is based on the value of the total national herd and not the breeding stock alone, as is done in this study. In this study the service flow from biological stock is based on the breeding stock component of the national herd.

4.3.1 Market valuation and the rental rate of capital

Assuming competitive capital markets and following the nomenclature of Anderson et al. (2011) the rental rate for each class of asset is a function of the price of a new unit, ρ_i, its assumed constant rate of depreciation, δ, and the real interest rate, r_t. The simplest form for rental rate calculation assumes a constant interest rate and a constant geometric rate of depreciation:

$$\rho t = Pt(rt+\delta) \tag{4.1}$$

The opportunity cost of the funds invested is represented by the term $P_t r$ and the cost of physical wear and tear and other sources of economic depreciation of the assets as it ages is represented by $P_t\delta$.

4.3.2 Inferring capital stocks and service flows

Since one cannot observe the actual flow of services from an asset over its lifetime it must be inferred using information on the composition of the stock of capital, based on the value of capital purchases or physical counts of assets. Inferring service flows from the market value of a single unit of capital is possible once the service flow profile has been parameterized.

Following the method proposed by Anderson 2010 (Personal communication) I estimate the stock of assets on farms for each asset class, adjusted for the physical deterioration associated with the average age, *k*, of the cohort. The average age could be half of the assumed service life, *L*, of the asset. Ideally, some estimate of the number of assets on farms is available. For example, if there are two tractor classes, big and small, one could collect data on the number of big and small tractors on farms, then convert the data to small tractor equivalents (i.e. each big tractor is equal to two small ones). The raw counts of tractors (gross stock) would then be adjusted for the average age of tractors to form the net stock count of assets by using the assumed constant rate of depreciation to get a net stock. Anderson et al. (2011) define the current (gross) stock of capital through the following capital accumulation equation:

$$K_t = I_t + (1-\delta)I_{t-1} + (1-\delta)^2 I_{t-2} + \ldots + (1-\delta)^L I_{t-L} \tag{4.2}$$

Equation 4.2 yields the moving sum of the depreciated value of current and past investments adjusted for the assumed service life of the asset and assists in developing the annual estimates of the stock of capital for each class.

and the equation to estimate the net stock as:

$$\text{Net Stock} = \text{Gross Stock x } (1 - \delta)\text{^}(k) \tag{4.3}$$

where δ is the rate of depreciation associated with the assumed service life = L of the asset.

The equation for δ is:

$$\delta = 1 - 0.1\text{\textasciicircum}(1/L), \tag{4.4}$$

δ also includes the assumption that the asset is retired when 10% of the original asset remains.

In the case of tractors we begin by estimating the total horsepower of all tractors on farms, and then divide the total by the numeraire tractor (say 55 hp) to get an estimate of numeraire equivalents as an estimate of the gross stock which can be converted to a net stock. Once the net stock is estimated, the assumption is made that the service flow is some fixed proportion of the net stock. Under the proportionality assumption, we substitute the net stocks for the (unobservable) service flows when constructing the aggregate index of capital services (Fisher Index) because the service flows and stocks are assumed to grow at the same rate over time.

Following Anderson et al. (2011): "Assuming $i = 1,2,...,N$ capital classes, annual time series of the rental rate can be combined with annual time series of the stock for each class of capital (which serves as a proxy for the latent annual service flows under the assumption of proportional service flows) to form an index of the quantity of capital services." Using the discrete approximation of a Divisia index, such as a Fisher Ideal index, the quantity of capital services in year t, q_t for $i = 1,,...,N$ classes of capital is computed using:

$$\frac{qk_t}{qk_{t-1}} = \left(\frac{\sum_{i=1}^{N} \rho_{i,t-1} K_{i,t}}{\sum_{i=1}^{N} \rho_{i,t-1} K_{i,t-1}} \right)^{\frac{1}{2}} \left(\frac{\sum_{i=1}^{N} \rho_{i,t} K_{i,t}}{\sum_{i=1}^{N} \rho_{i,t} K_{i,t-1}} \right)^{\frac{1}{2}} \tag{4.5}$$

According to Anderson et al. (2011) the aggregate rental rate is then calculated as an implicit (nominal) price index, by dividing the total rental value in each period by the quantity index of service flows for that period.

4.3.3 Estimates of cost of capital services

The multi-product output of the agricultural sector means that many types of capital are in use at any point in time, and the coincidence of planting and harvesting across farms results in the fact that the ownership of capital assets is more common than the rental of capital services. This means that the flow of services from capital must be inferred from information on the aggregate stock of capital on farms. Furthermore, the measurement of the flow of capital services typically involves assumptions about the time path of the marginal physical product of capital, the relationship between the physical product and its market valuation, and the age and quality composition of the existing capital stock. In what follows, the methods described in the previous sections are used to develop national level indexes of the price and quantity of capital services for RSA agriculture. The 23 different classes of capital include cars, buildings, tractors combines, mowers, balers, ploughs, planters, crop sprayers, wagons and trailers, pumps, electrical motors, pickups, trucks, eight classes of biological capital (breeding cows, chickens, ewes, milking cows, and sows mares) and three classes of Service Structures (buildings, construction and orchards).[7]

The main data sources include the various Agricultural Censuses and Surveys published by the Stats SA and its predecessor services and unpublished data on machinery sales from the Directorate of Agricultural Mechanization Services (DAMS) and later AGFACTS. The rental rates for all of the classes of machinery were calculated using national-level prices and price indexes from the Directorate of Agricultural Statistics (DAS). The unpublished machinery sales data from the Directorate of Agricultural Mechanization Services and AGFACTS allowed the incorporation of vintage effects in the stock and service flow estimates. (The disaggregated counts of tractors and combines of different sizes and types to explicitly address changes in the quality of these machines over time were not used at this stage. Consequently, the data were not used to assist in reducing potential errors related to aggregating tractors and combines of different types and vintages.[8]) Finally, data on physical inventories and physical counts of different assets to construct national estimates of stocks and services flows, resulting in a panel data set with 23 classes of capital over 65 years, 1945-2010.

The rates at which different types of physical capital are assumed to deteriorate, δ, are based on market transaction data for tractors sourced from AGFACTS as of 1983 and the average of this was calculated as 9.13 years. The same ratio of average age to service life was used in deriving the average age for the other capital classes. The service life, *L*, as used in the Guide to Machinery Cost, was used as presented in Table 4.4; the corresponding values for the assumed rate of deterioration are also presented. For biological capital and service structures the InSTePP estimates on service life and

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7 For the purpose of productivity analysis buildings' will include only service structures on farms (excludes residential housing of the owner).

8 Lack of quality adjustment for machinery input can lead to significant undercounting, (Griliches 1960). Even though the statistics are available to do so, very little of the historical data are electronically available and it would have added a considerable amount of time and effort capture this. This and reservations regarding the accuracy of price data for capital equipment obtainable from the directorate for the past 15 years left me with no choice but to limit the analysis to the capital class level and obviously is a caveat in the current analysis that should be rectified in future analysis.

average per livestock category were used, with the exception of ostriches where own estimates was made (Alston et al. 2010).

A further refinement to the biological capital series is that the analysis is based on the estimated number of breeding stock on the national herd. Two census nodes provided sufficiently detailed data to estimate this (BCS 1953; 1961).

Table 4.4: Parameter Values for Calculating Stocks and Service Flows

Category and Class	Depreciation (δ)	Service Life (L)	Age (k)
Machinery			
Tractors	0.17	12	9.1
Combines: Trailed	0.15	14	10.5
Combines Self Propelled	0.15	14	10.5
Mowers	0.15	14	10.5
Balers	0.21	10	7.5
Ploughs	0.21	10	7.5
Planters: Maize	0.21	10	7.5
Planters: Wheat	0.21	10	7.5
Crop Sprayers	0.21	10	7.5
Wagons/Trailers	0.11	20	15.0
Pumps (proxy on Irrigation Equipment)	0.25	8	6.0
Electrical Motors (proxy on generators)	0.25	8	6.0
Vehicles			
Cars	0.25	8	6.0
Pickups	0.25	8	6.0
Trucks 1	0.21	10	7.5
Trucks 2	0.21	10	7.5
Biological Capital			
Cattle	0	5	2
Sheep	0	6	3
Goats	0	6	3
Sows	0	3	1.5
Poultry (chickens)	0	1	0.5
Ostriches	0	3	1.5
Horses	0	25	5
Donkeys	0	25	5
Service Structures			
Buildings	0.05	45	22.5
Construction	0.05	45	35
Orchards	0.09	25	18.75

Sources: See text
Notes: Biological capital refers to only the breeding stock and not the total herd size.

When constructing measures of asset rental rates it is assumed that the appropriate discount rate is identical across all classes of capital. The value chosen for the discount rate will affect the measurement of capital services. A higher discount rate implies that the purchase price must be recovered more quickly in terms of the quantity of services the asset provides each period. If the rate chosen is too high, the real service flow from a unit of capital will be overstated in the early years of service and understated in later ones. Consequently, the real discount rate was taken to be a constant four percent as opposed to the two percent used in earlier studies.

It is deemed appropriate to use a constant real discount rate in the calculation of asset rental rates as the primary data is the physical counts of assets. Also, Anderson et al. (2011) presented evidence that the use of a real market interest rate in the calculation of capital services introduces volatility that is not likely to be consistent with the actual services that flow from the stock of capital on farms. These empirical realities, combined with conceptual arguments in favour of using a fixed rate of interest, lead them to conclude in favour of a fixed rate of interest when calculating capital use in U.S. agriculture.

For the purpose of comparison the earlier approach followed by Thirtle et al. (1993) and others where the aggregate agricultural accounts were used to derive the capital index is replicated here. This approach approximates the service flow from capital inputs based on the expenditure trends on capital inputs as reflected in the national capital formation account, which has been shown to be of dubious quality in section 4.3. The treatment of the change in livestock inventory in the analysis is based on a revised series on the value of the national herd as the long run data series available from the Department of Agriculture suffers from trend breaks that arise from changing methods in estimating the value of a unit of livestock (Liebenberg 2012). Thus, using the change in livestock inventory reported in the capital information account would yield a livestock capital index that is much more erratic than shown here.

4.3.4 Indexes of capital input use

To simplify the analysis of capital service flows, the 23 classes of capital are grouped into three main categories, biological capital, fixed improvements (more appropriately termed service structures), and machinery. The real value of capital services is presented in Figure 4.5 for each of these categories for the years 1945 to 2010.[9]

In the 1950s, the cost of services from service structures and machinery was on average R500.3 million ($US146.5 million) and R925.3 million ($US238.9 million) annually, while biological capital on farms represented a significantly larger share, at an average of R2,001.3 million ($US516.8 million) annually. By the year 2000 they converged to represented roughly equal shares of the total cost of capital services, each at approximately R1,500 million to R2,000 million ($US390 to $US515

[9] Nominal values were deflated using the implicit price deflator for Gross Domestic Product (GDP) (base year 2005).

million) annually. A substantial change occurred from the 1950s through 1980s in the mix of assets that comprise the capital aggregate. The growth in machinery services was largely driven by the industrialization of agriculture after World War II and the expansion of the area under field crop production (Payne, et al. 1990). Since the early 1990s the growth in area under orchards has increased the relative importance of the value of services from fixed improvements to equal that of machinery by the early 2000s.

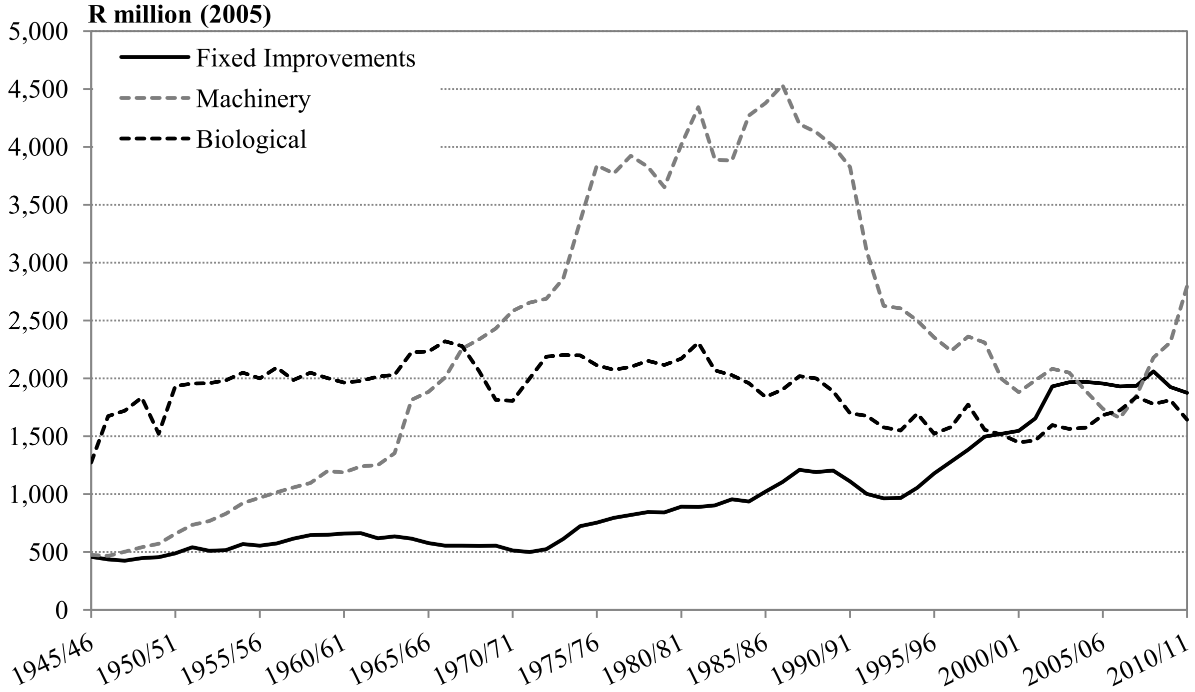


Figure 4.5: Annual Estimates of the Real Value of Capital Services in South African Agriculture, 1945 — 2010 (base year 2005)

Sources: Own Calculations

Notes: See text for description of the various indexes. Annual imputed rental value of capital deflated using the GDP implicit price deflator with base year 2005 (SARB 2011).

The trend in service structures was initially driven by the construction of soil conservation structures in the first two decades, but thereafter orchard development began to dominate. This occurred in two phases, the first starting in the early 1970s, followed in 1993 by a period of even stronger growth following the scrapping of trade sanctions against South Africa. The growth in the services of biological capital was driven by the growth of the red meat and dairy industries up to the mid-1960s, thereafter the expansion in the broiler industry has seen a growth in the share of biological services up to 1981. From this point the decline in the real prices of biological capital placed downward pressure on the share of biological capital services until the year 2000 when the livestock industries experienced a growth in output prices.

As shown in Figure 4.6, the price index of capital services peaked in the years 1951 at 127.1 percent and fluctuated at levels above 118 percent until 1964, declined until 1973, whereafter it stagnated until 1983. From 1983 it increased to 1986, remained stable until 1989 before it dropped to 94.8 percent in 1992. The causal factors driving these fluctuations were first the huge increase in real interest rates, followed by inflationary pressure and general economic turbulence. Prices of machinery and service structures were the most affected by these conditions and increased by 4.6 percent per annum over the seven year period after 1986. The cost of biological capital decreased by 2,20 percent annually from 1966 to 2000, but began to increase by 1.37 percent annually over the past decade. The 1974 and 1980 peaks in the cost of capital services were at least partially influenced by energy price shocks and had the strongest influence on the cost of machinery services.

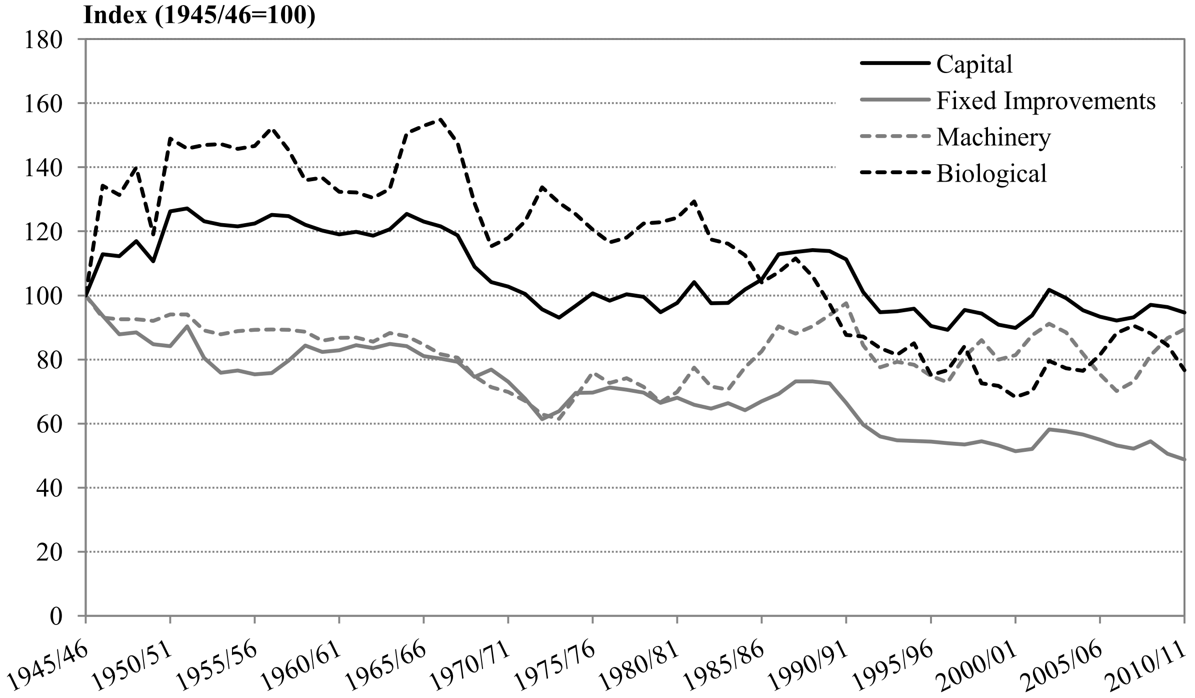


Figure 4.6: Fisher Price Index of Capital Services in South African Agriculture, 1945 — 2010 (base year 2005)

Sources: Own Calculations

Notes: See text for description of the various indexes.

In Figure 4.7 the Fisher quantity and real price indexes are shown along with the Thirtle index formed following the methods applied in earlier studies. Four distinct growth phases can be observed in the Fisher aggregate quantity index of capital used. During the first almost two decades after World War II the quantity of capital used in agriculture increased by 2.74 percent per annum until 1963, then the rate of growth increased to 3.69 percent lasting until 1980. The deregulation of agricultural support and control policies amidst the turbulent economic conditions that prevailed over the subsequent decade then saw a decline in capital input use of 2.49 percent over the little more than a decade until 1993, whereafter it begun to grow at 1.20 percent per year until 2010. The trend in the Thirtle quantity of capital used index is much more erratic and difficult to interpret. Showing a decline in capital used initially until 1950 it yields a period of high growth until 1970 — the drop from 1964 to 1967 reflects the direct impact of the drought of the time on investment in capital. From 1970 to 1986 it plots a decrease in capital use before it resume to grow until 1999 from where it stagnated until 2008, ending with another decline in capital use. In comparison to the Fisher index the Thirtle index appears to predict turning points five to ten years earlier.

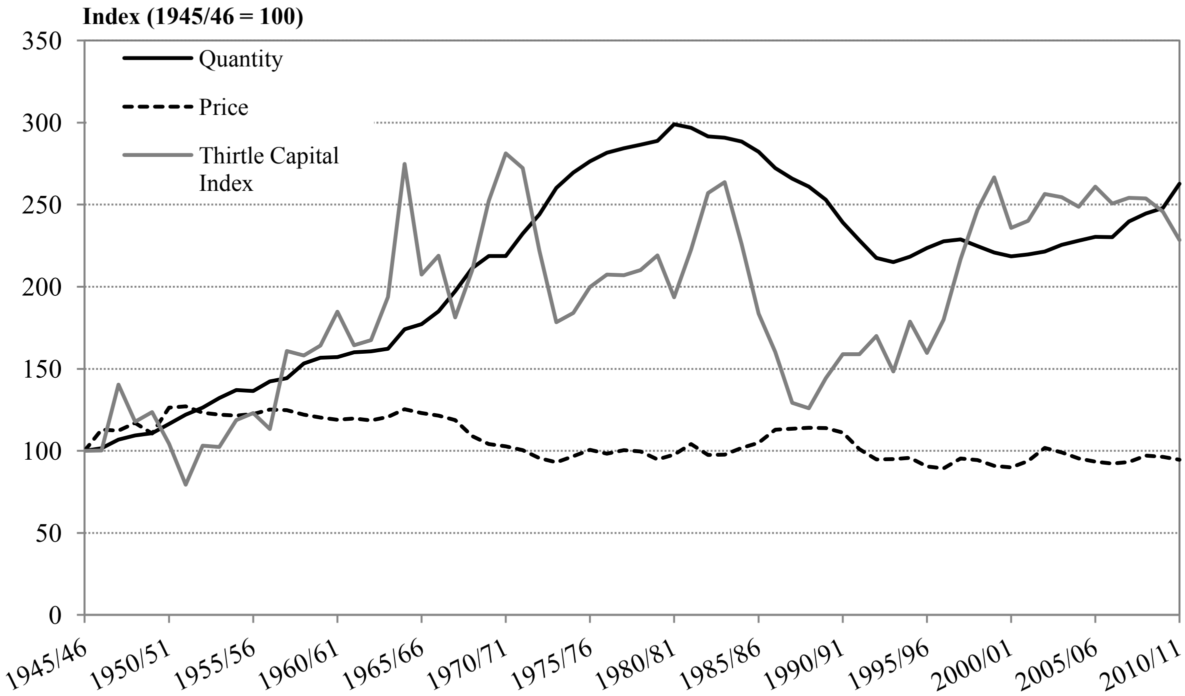


Figure 4.7: Quantity and Real Price Indexes of Capital Services in RSA Agriculture, 1945 — 2010

Sources: Own Calculations

Notes: Annual imputed rental rate of capital deflated using the GDP implicit price deflator with base year 2005 (SARB 2011).

Summary statistics describing the characteristics of the different index methods are shown in Table 4.5. In almost all the methods of measurement the results for the Fisher indexes are higher than that calculated for the corresponding Thirtle indexes. It does, however exhibit the same symmetry between the relevant indexes — i.e. the range of the machinery indexes are higher than that of biological capital and fixed improvements in both the Fisher and Thirtle derived indexes. The confidence levels are also shown to be higher for the Fisher than the Thirtle indexes. The year-on-year fluctuation in the Fisher index appears to be more stable than that of the Thirtle indexes as observed from Figure 4.7.

Table 4.5: Descriptive Statistics of Different Quantity Indexes of Capital Service Used

Statistic	Machinery	Biological	Service Structures	Thirtle Indexes		
				Machinery	Animals	Fixed Improve-ments
Mean	616.6	134.7	338.4	401.3	107.2	92.2
Standard Error	42.0	2.7	28.2	13.2	2.3	3.7
Median	564.4	137.5	259.5	399.4	102.9	85.1
Standard Deviation	341.1	21.6	229.5	106.9	18.4	29.8
Sample Variance	116,322.8	468.4	52,657.6	11,430.3	339.6	888.9
Coefficient of variation	55.3	16.1	67.8	26.6	17.2	32.3
Kurtosis	-1.1	-1.3	-0.3	0.4	0.9	-1.1
Skewness	0.2	-0.1	1.0	-0.6	0.9	0.5
Range	1,110.0	70.7	740.2	491.9	92.1	102.9
Minimum	100.0	97.9	100.0	100.0	79.4	48.6
Maximum	1,210.0	168.6	840.2	591.9	171.6	151.5
Count	66.0	66.0	66.0	66.0	66.0	66.0
Confidence Level(95.0%)	83.8	5.3	56.4	26.3	4.5	7.3

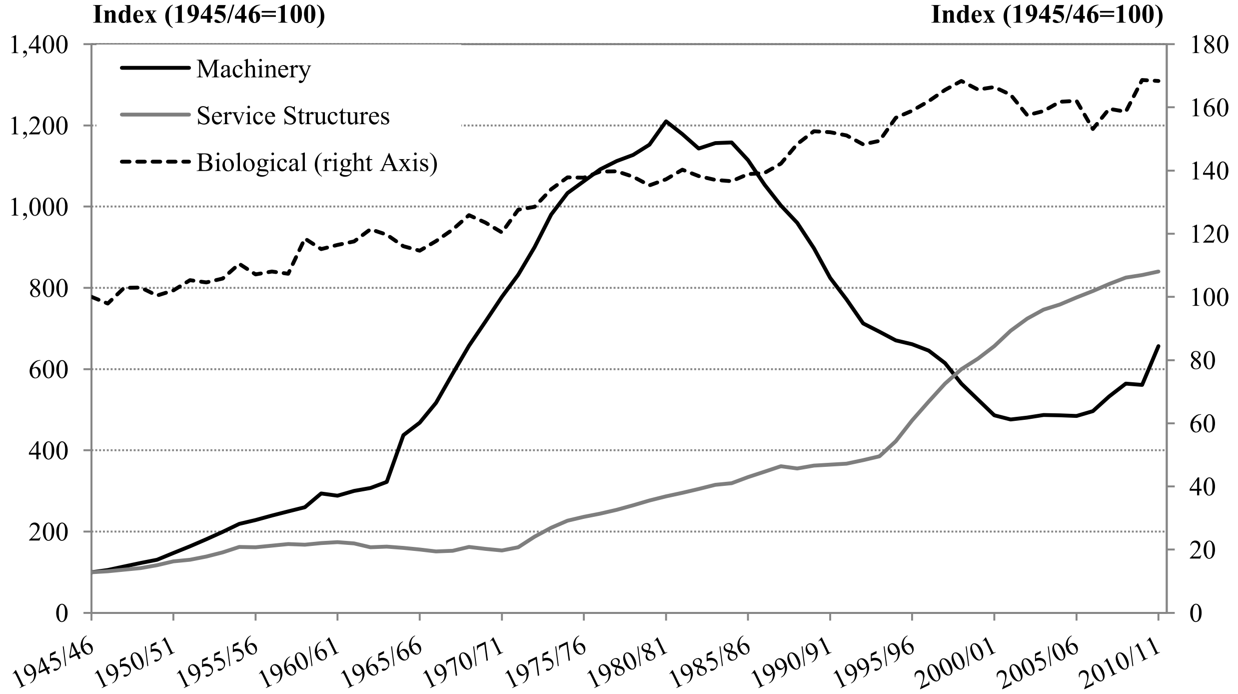
Sources: Own calculations

The Fisher output quantity indexes of the underlying three categories of the aggregate index are shown in Figure 4.8, Panel a, with the Thirtle equivalent in Panel b. What is immediately apparent is that the Thirtle quantity indexes again follow trend patterns that differ significantly from the Fisher quantity indexes. Whereas the Fisher machinery index predicts an annual growth rate of 6.78 percent from 1945 until 1963 followed by a higher annual rate of growth of 8.34 percent until 1980, the Thirtle machinery index starts with an annual growth rate of 14.04 percent until 1959, whereafter it decreases by 3.98 percent per year until the end of the drought in 1963 before resuming to grow to a peak in 1970 — 5.43 percent per annum for the latter period. Over the remainder of the period the Thirtle machinery index exhibit an equally poor match with the trend in the Fisher machinery index. In this respect the Fisher index appears to reflect the policy phases of the time in terms of support to farmers better than the Thirtle index.

With respect to the indexes on the quantity used of service structures the two methods yield distinctly different results. The Fisher quantity index for the service flow from service structures clearly reflects the growth in investment in farm buildings (as a result of the growth in the poultry industry) and orchard development from 1966 through to 1993, whereafter the orchard development increased markedly as international markets for wine and fresh fruit improved after the sanctions years. None of these events and the effect it had on capital investment in fixed improvements are reflected in the Thirtle index for fixed improvements.

The Fisher quantity index of biological capital is generally much more stable and shows decreases for the drought periods of the mid- 1960s, early 1980s and 1990s and 2001. In contrast, the Thirtle

Panel a: Fisher quantity indexes of sub-categories of capital services



Panel b: Thirtle quantity indexes of sub-categories of capital services

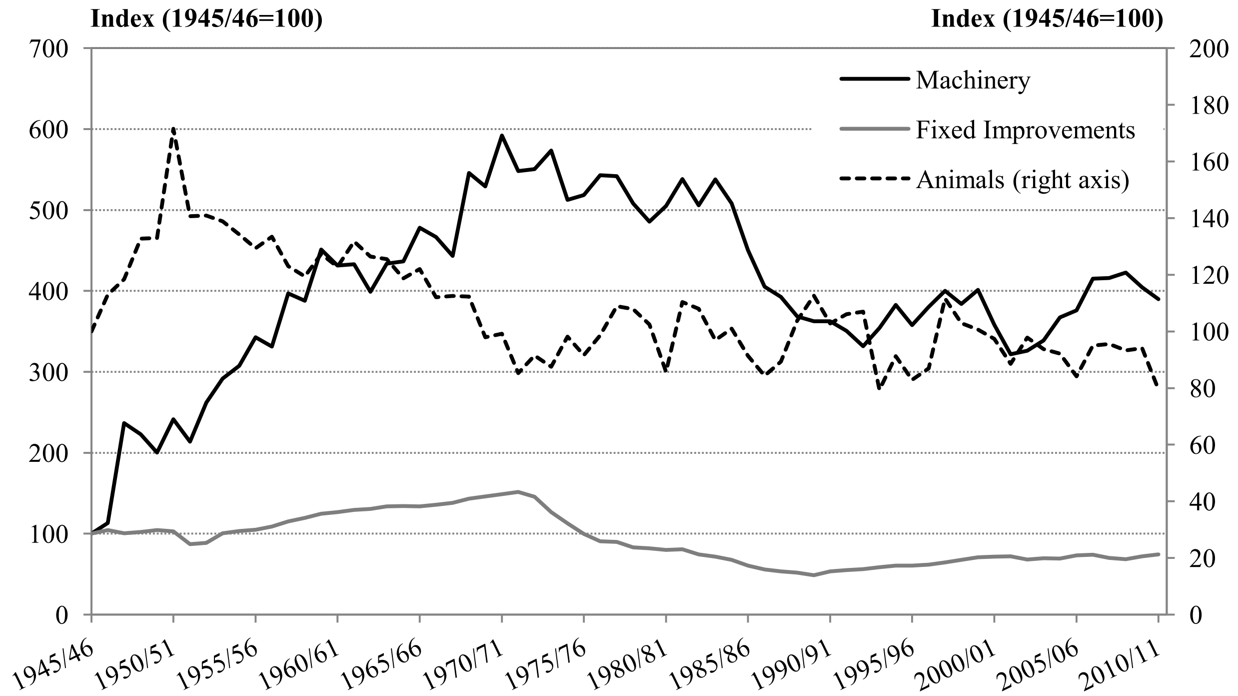


Figure 4.8: Quantity Indexes of Sub-Categories of Capital Services, 1945 — 2010

Sources: Own Calculations

quantity index on animal capital appear to reflect market trends, discussed in chapter 3. For example, the boom in the wool industry 1950/51 clearly shows up as a spike in the Thirtle index, which would be unrealistic for it to be of such a short duration. Another interesting feature is the contrasting trends between the Thirtle animal capital index (formed from the change in livestock inventory and expenditure on feeds) and the Fisher biological capital index (based on breeding stock). The Fisher index reach a peak in 1998 and fluctuated below that level until 2009 when it again reached the 1998 level of 168 percent. The Thirtle index, however, peaked in 1951 at the time of the wool boom, whereafter it decreased until 1970. From 1975 it has fluctuated between 90 and 110 percent, but has declined since 2000. This is in contrast to the headcount of the national herd, which has been estimated to be higher in more recent decades as opposed to earlier decades, except in the case of sheep and horses (DAFF 2012). It is thus doubtful that the Thirtle index measures the actual flow of services from biological capital adequately.

4.4 LAND USE IN AGRICULTURE

4.4.1 Data sources

Since the 1958 edition of the *Abstract of Agricultural Statistics* the Statistical services of the Department of Agriculture reported data on land utilization as periodically reported in the census. No adjustments were made for changes in definition of land use categories, nor were all the usage categories enumerated in the census reported. For example, categories of land use reported included; area under field crops, fallow land, sugar cane plantations, pineapple plantations, banana plantations, fruit orchards, and vineyards, whilst leaving out timber and wattle plantations, indigenous forests, and area irrigated. Areas under timber and forests were not considered an agricultural activity according to the mandate of the Department of Agriculture.

In 1954 the basis of categorization changed to cultivated land, permanent crops, wood or forest land, artificial permanent pastures, natural permanent pastures and other land use. Detail on this varied for the subsequent census years and in 1981 the definitions again changed to reporting on land under perennial planting (orchards, plantations and vineyards, fodder crops, and timber and wattle plantations), and other land use (annual plantings, fallow, natural veld, indigenous forests, and all other land) (CSS 1987). Details were given on area under irrigated and rainfed plantings where applicable. In 1988 land use patterns were enumerated according to the dominant branches of farming, i.e. field crops, horticulture, forestry, animal production, and mixed farming (CSS 1993). Reporting on land use patterns ceased to be done with the 1993 Census (CSS 1998).

Productivity analyses done by the United States Department of Agriculture (USDA) and others categorize land utilization according to area under rainfed agriculture (dryland crop production), irrigated cropland, and area under planted pastures and rangeland (natural grazing). The changing basis upon which land utilization has been enumerated or reported in the South African agricultural census and survey reports over the years clearly limits the ability to structure the South African analysis in a similar manner.

An effort was made to construct a long-run series on land utilization in South African agriculture on a basis that matches that of the USDA. In this study the area under field crops is based on the area planted to the various crops as reported in the census to arrive at an aggregate estimate of area cultivated. The difference between area planted and area harvested of crops such as maize, wheat, grain sorghum and other minor crops were allocated to fodder crops (planted pastures). Lucerne, teff and other grasses was also allocated to planted pastures. To avoid double counting the area under irrigation was subtracted from the total area cultivated to form the series for irrigated cropland. The area under natural veld was added to planted pastures to form the pastures and rangeland category. In the case of potatoes data on the area planted under rainfed and irrigated systems were obtained from Potatoes South Africa (2010).

Area planted to orchards and vineyards presented a special challenge since census reports only reported on the number of trees and vines planted, with no spatial indication. Estimates for the pre-1952 years on plant spacing and estimated area planted were obtained from the April 1952 edition of *Farming in South Africa* and used as a guide to derive area planted to these crops (DOA 1952). For the inter-census years observations were augmented, where available, with data from the *Abstract of Agricultural Statistics* and more recently from the Tree Census Surveys of the producer/commodity organizations (DFPT 2000-2010; AVCASA 2000-2010; SAWIS 2000-2010).

A complicating factor in the analysis was the area cultivated by black farmers. Prior to World War II the census only reported data on area cultivated for farms owned by whites, with area planted by squatters (white, coloured, Indian) either mentioned separately, or included in the area reported for white owned land. Area planted by black farmers was never enumerated until the 1954/55 census. At this point it was the practice to include the area farmed by black squatter farmers with that of black farmers in the Homelands. In this analysis an effort was made to estimate the area planted by black farmers on white owned farms based on the relative differences in yield between white farmers and black farmers and to include that in the estimate of total area cultivated. This replicates the practice followed by the Department of Agriculture citing the Tomlinson Commission and the Development Bank of Southern Africa (and its predecessor BENBO). These estimates were done for the eight dominant crops that black farmers were involved in, i.e. maize, grain sorghum, millet, oats, groundnuts, cow peas and to a lesser extent wheat.

4.4.2 Land in farming, crop- and irrigated land and planted pastures

Earlier studies on agricultural productivity in South Africa used the total area in farming in calculating an index of land use. Coverage on this in the *Abstract of Agricultural Statistics* is limited to Census years with no inter-census extrapolation and the most recently published data available are for 1996 (DAFF 2012; Stats SA 1999). The *Abstract of Agricultural Statistics* report this according to the financial year end specified in the census — a practice which is rarely highlighted in the *Abstract of Agricultural Statistics* and could easily lead to misinterpretation. The Schimmelpfennig et al. and earlier studies by Thirtle et al. (1993) appear to have suffered from this. This study deviates from earlier studies by using the aggregated cultivated area from the underlying data on area planted as reported in the censuses and survey reports to interpolate the inter-census year observations and observing the date at which the land use pattern was enumerated.

The results differ slightly from that of the earlier studies, as shown in Figure 4.9 for the period 1945/46 to 2010/11. Prior to 1976 the trends is largely the same, but it follows a different allocation of the data by one year. Since 1976 the trend is the same until 1986. The deviation since 1986 arises from a change in the structure of reporting on land use with land under forestry being included in the *Abstract of Agricultural Statistics*, but excluded here since forestry production is excluded from the definition of agricultural output applied by the Department of Agriculture prior to 2011.

Figure 4.10 plots the trends in rainfed cropland, irrigated cropland and planted pastures and rangeland based on the revised aggregate land in farming series (net of forestry and indigenous forests). This reveals very different trends in each of these over time. The area under rainfed cropland peaked at 10.21 million hectares in 1963 and hovered at a slightly lower level until 1975 whereafter it decreased by 0.94 percent per annum to 8.51 million hectare in 1980. Thereafter, it increased at 1.95 percent per annum until 1988 and decreased annually thereafter by 2.63 percent to 6.17 million hectare in 2009; 4.27 million hectare less than its 1987 level and 77.69 percent of the cultivated rainfed area in 1947/48.

The cultivated area under irrigation (largely horticultural production) nearly doubled from its 1947 level of 0.49 million hectare to reach 0.87 million in 1963. In contrast to the area under rainfed cropland it thereafter grew by 2.01 percent per annum until 1976, then increased by 8.12 percent annually over the next five years to peak at 1.67 million hectare in 1980. Over the seven years from 1980 it declined by 4.41 percent per year before it increased at a moderate 1.27 percent per year to reach 1.49 million hectare in 2001, or 18.8 percent of the land area under crop production. The area under planted pastures has increased throughout the whole period, growing at 1.63 percent per annum over the three decades since 1945 to reach 0.81 million hectares in 1975. In response to the subsidized program to convert marginal cropland to planted pastures, the area under planted pastures nearly doubled over the next decade to reach 1.29 million hectare in 1987 and continued to expand until 1992 to level off at about 2.61 million hectares.

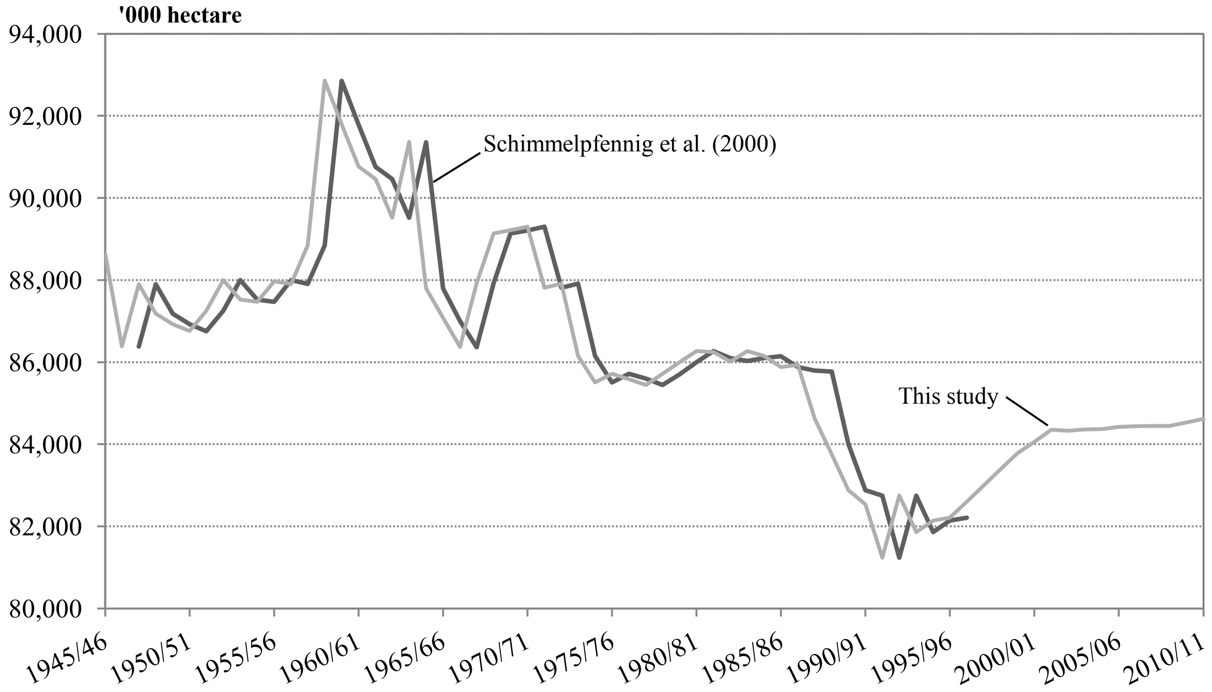


Figure 4.9: Land in Farming (White Commercial Farms Only), 1945 — 2010

Sources: Own Calculations

The widely fluctuating trends shown in Figure 4.10 emphasizes the point made that market forces and policy incentives faced by farmers involved in the different agricultural industries force different trends in the use of cultivated land. This would result in differing rental values in the use of such land as opposed to the approach followed before of using the imputed average rent based on the total area in farming.

In Figure 4.11 the trend in area planted in homelands (estimated as discussed in Section 3.4.2) is shown against that of commercial farmers since 1910/11. Surprisingly, the area planted by black farmers increased to 2.53 million hectares in 1923/24 in spite of the promulgation of the Natives Land Act of 1913. Even though the Land Act began to be implemented by the mid-1930, the area planted by black farmers still remained above 2 million hectares until after World War II. It then began to decline steadily by 1.75 percent until 1960. Over the subsequent 14 years it dropped to 19.03 percent of its level in 1960 — 13.56 percent of the maximum planted by black farmers in 1923. Over the three decades after 1945 the area planted by black farmers declined by 6.80 percent per annum. Even though yields obtained by black farmers were reported to be typically much lower than that of

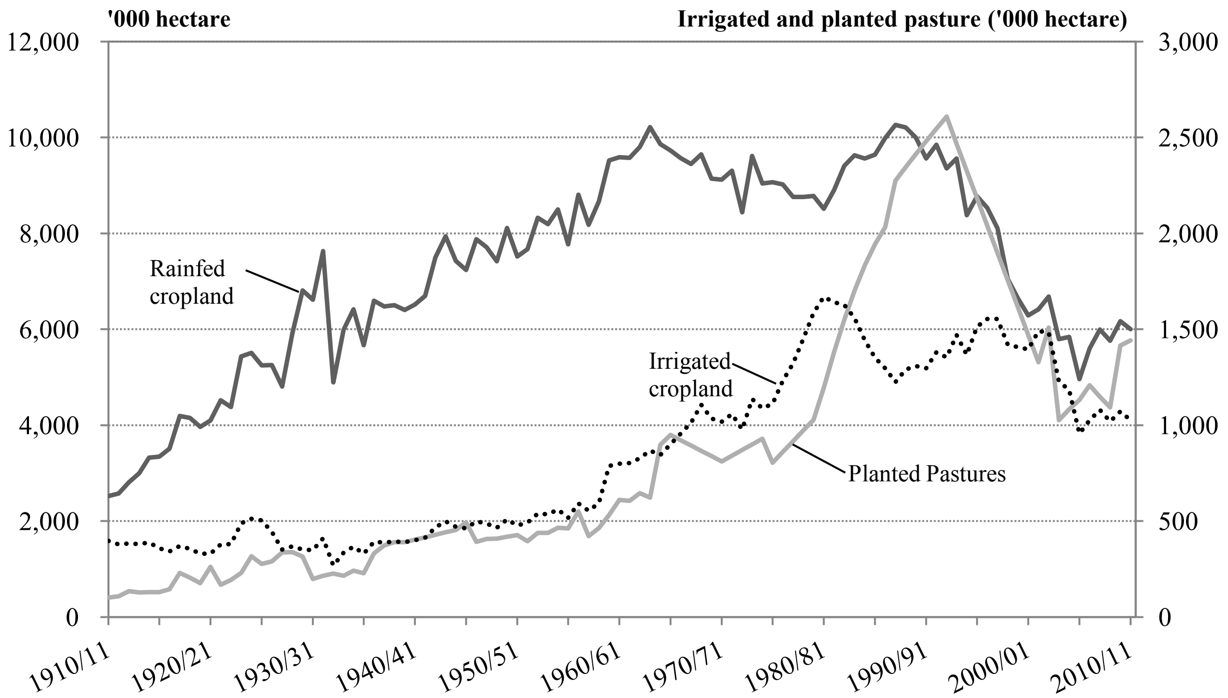


Figure 4.10: Trends in Rainfed, Irrigated and Pastures, 1910 — 2010

Sources: Own Calculations

commercial farmers the suppressing effect that the discriminatory policies increasingly had on the contribution of this section of the farming community is significant enough to explain the low estimates of productivity growth of the RSA agricultural sector measured in past studies for the period 1947 to 1968.

4.4.3 Land rental rates

Thirtle et al. (1993) and by convention Liebenberg and Pardey 2010) imputed rental rates for land from the entire land area under farming based on the estimates of rent paid done by the Department of Agriculture and the share of land rented (Wiebe et al.2001). As observed by Thirtle et al. this may not be accurate since the owner occupied land may differ from rented land in quality and value. However, the estimates of the Department of Agriculture of rent paid is inconsistent in its inclusion of rent paid to farmers and non-farmers and since 1981 shows little to no correlation with rental payments reported in agricultural census reports.

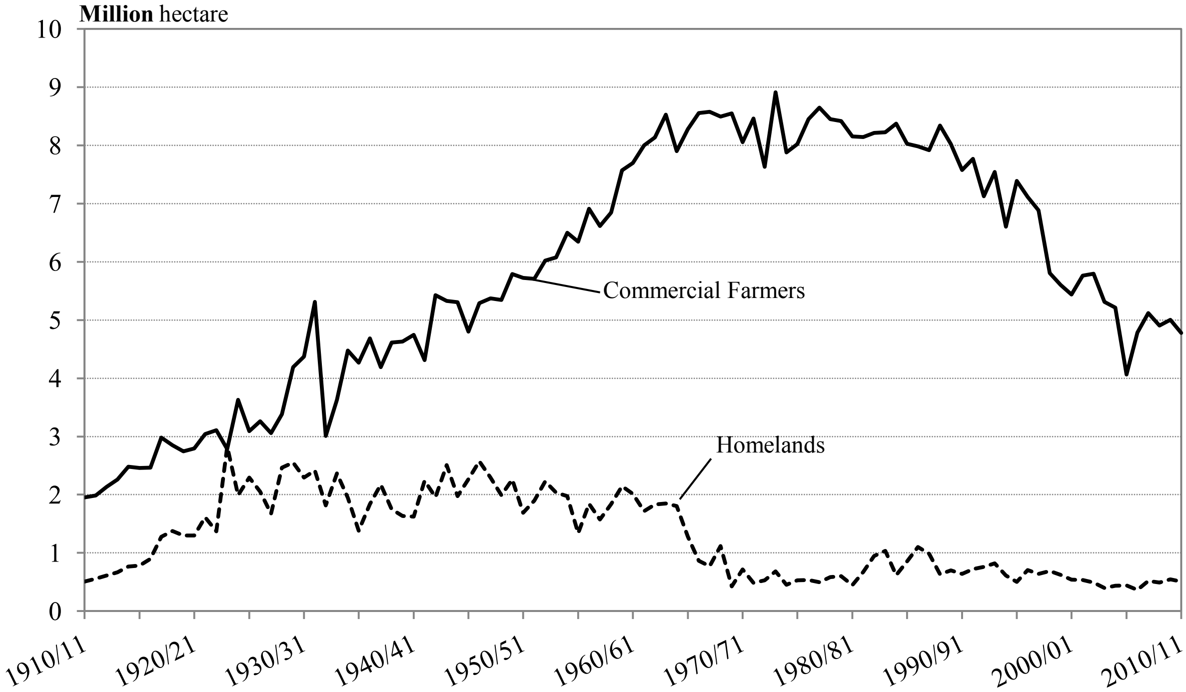


Figure 4.11: Trends in Area Cultivated by White Owned and Black Farms 1910 — 2010

Sources: Own Calculations

The alternative approach followed here was to construct an imputed rental rate per hectare based on the value of production per hectare by land type. Unfortunately, no records could be sourced from the Department of Agriculture that would enable such a construct. As an alternative, the rental rates by type of land use were derived using the following approach. For range and pasture land, the value of cattle, sheep (wool & non-woollen sheep), and goats were converted to a value per Livestock Unit (LSU) using the same approach followed by the Directorate of Agricultural Statistics to estimate the value of the livestock inventory in the country. With an average carrying capacity of about 12 hectares per LSU taking 4 percent of the value of a LSU as the rental rate of a hectare of range and pasture land yielded a rental rate of R96.61/ha in 2004. For rainfed and irrigated land the rental rates were based on 4 percent of the gross production value per hectare for field crops and horticultural land (horticultural production assumed to be representative of production on irrigated land).

After adjusting for inflation, using the GDP implicit price deflator (SARB 2011), the trends in rent rates since 1910 are shown in Figure 4.12. For range and pasture land the rental rate peaked in 1950 in inflation adjusted values at R418.04/ha (influenced by the wool price boom of the time), whereafter it declined to R86.11/ha in 2000 recovering to about R105.53/ha in recent years. Land under rainfed production decreased from the R80.20/ha in 1910 to a low of R29.10/ha in the drought years of the early 1930s increasing from there to peak at R217.20 in 1980, just prior to the 1982 to 1983 drought years. Thereafter it declined to R70.27 during the drought of 1991 and has since erratically increased.

Land under irrigation shows a consistent increase in rental values from the 1930s through to the mid-1960s, when the settlement of farmers on new irrigation schemes was largely completed. It decreased since then to the early 1980s when the area under irrigation again started to expand and with the growth in the horticultural sector it has increase markedly. After an initial drop of 24.3 percent from its peak value of 524.13/ha in 1974 to R329.69/ha in 1980, it increased from 1993 as international markets again became accessible to South African agricultural exports and is now estimated to fluctuate at about three times the 1993 levels.

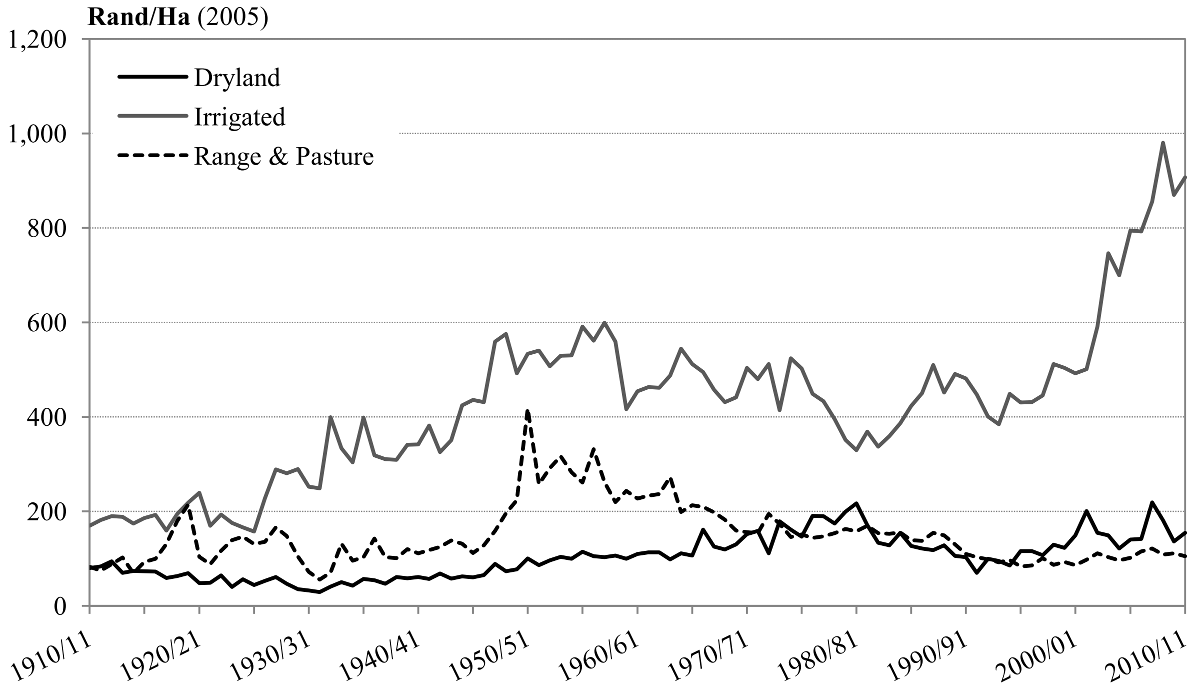


Figure 4.12: Real Land Rental Rates; Rainfed and Irrigated Cropland and Range and Planted Pastures, 1911 — 2010

Sources: Own Calculations

One possible criticism against this method of estimating lands rental rates is that rental values are influenced more by trends in current commodity price trends than what farmers may expect to achieve from the use of the land, which is a function of the performance of the previous year(s) and their expectations of market trends for the year(s) ahead. Another concern is the arbitrary rate of 4 percent of production value per hectare and more pertinently the carrying capacity of 12 hectares/LSU. These may vary significantly between the various production regions in terms of carrying capacity and in terms of proximity to towns and cities, and alternative investment opportunities, which influences the opportunity cost of the land in terms of alternative use and sources of income available to the owner[10].

4.4.4 Indexes of the quantity and rental rate of land

The Fisher quantity and rent indexes of land in aggregate are shown in Figure 4.13 together with the Thirtle quantity index for the past century. Both the Fisher and Thirtle quantity indexes is shown to peak in 1958 with a minimum in 1918 (Thirtle and others found the peak to be in 1959, but here the revised land in farming data series is used). The rate of growth over the respective periods, however, differs significantly. The estimated annual rate of growth found in this study and using the Fisher quantity of land used index for the period 1918 to 1958 is 0.40 percent, with a rate of decrease since 1958 of 0.25 percent. The Thirtle land quantity index indicate the respective growth rates as 0.48 percent per annum up to 1958 with a decrease of 0.18 percent per annum since 1958.

The terminal index values reached in 2010 for the Fisher and Thirtle indexes are 101.0 and 109.0 respectively, which is explained by the aggregation bias and lack of quality adjustment inherent in the methodology applied in forming the Thirtle index. Another observation from Figure 4.13 is that the Fisher index exhibits a greater degree of sensitivity to land use changes —compare the greater degree of variation since 1990 between the two indexes.

4.5 LABOUR USE IN AGRICULTURE

The statistics on employment published in the *Abstract of Agricultural Statistics* do not provide a detailed description of the composition of the reported numbers on employment beyond whether seasonal and casual labour were included or not. A comparison with census reports reveals that prior to 1965, seasonal labour was generally not included in the *Abstract of Agricultural Statistics*. It was sporadically reported in the census reports, but not explicitly itemized in the *Abstract of Agricultural Statistics* as a separate item.

[10] Lacking spatially disaggregated data from the census, which would enable the estimation of land rental rates according to representative land types, the approach followed was selected as a next best option. Obviously a more representative methodology should be developed for estimating land rental values.

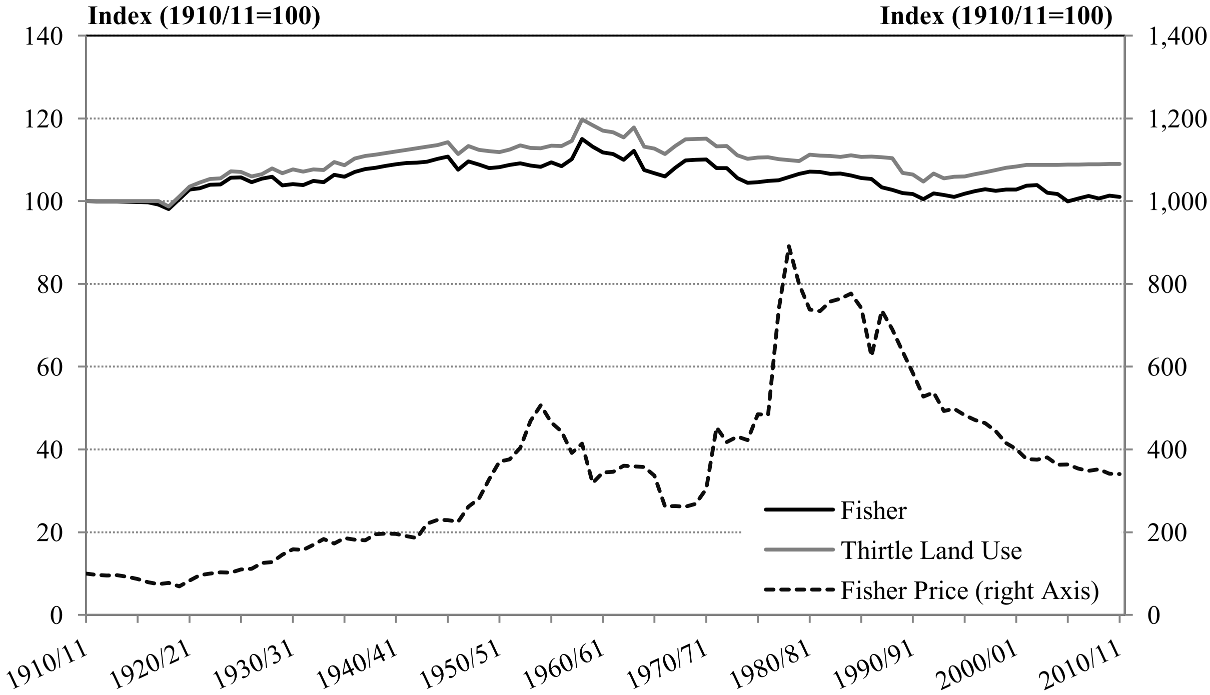


Figure 4.13: Fisher Versus Thirtle Quantity Index of Land Used, 1910 — 2010

Sources: Own Calculations

Generally, domestic servants working for households on farms are included in the *Abstract of Agricultural Statistics* employment series on regular employment, although it is not uniformly the case for all census years prior to 1947. Since 1947 it is reported as a separate category of labour in the census reports, but reported in the *Abstract of Agricultural Statistics* as part of the regular employment statistics in agriculture. The *Abstract of Agricultural Statistics* also never specified whether proprietor and family labour were enumerated; introducing another source of inconsistency, or lack of clarity, in the measurement of the farm labour force. In the following section these inconsistencies are addressed by carefully tracking the descriptive notes on employment enumeration as stated in the agricultural census and survey reports and revising the data series accordingly.

4.5.1 Data: Its sources and treatment

The domestic servants category is excluded from agricultural productivity analysis as they do not contribute to agricultural output. In the construction of the labour series a dedicated effort was made to ensure that it was separately identified and subsequently excluded from regular labour[11]. The number of domestic servants employed on farms was first reported in 1918 as 82,431 (16.9 percent of regular labour). By 1947 this has risen to 134,298, or 17.1 percent of the combined total of regular

[11] Estimates on domestic servants were only done for 1949/50 in order to deduct them from the total employment in agriculture. For all years since 1947 where they were included estimates on their numbers were published separately.

and domestic servants. They peaked at 164,058 (17.3 percent) in 1955, but then declined to 63,819 (8.9 percent) of the aggregate of regular and domestic servants in 1990, or 97.0 percent of the owner and family labour in that year. The significant size of the domestic servant labour force in both absolute and relative terms and its changing share of the regular labour category warrants care to ensure they are systematically omitted from the labour data series in this analysis.

Earlier, Vink & Kirsten (2001) constructed a data series on agricultural employment by making use of trend projections based on regression models of the agricultural employment data. Thirtle et al. (1993), and Schimmelpfennig et al. (2000) used linear projections for inter-census nodes and imputed the seasonal and casual labour force as a proportion of the regular labour force. Liebenberg and Pardey (2010) adapted the labour series of Schimmelpfennig by deducting domestic servants prior to estimating the size of the seasonal and casual labour force. None of these studies, however, included owner and family labour in their estimates of the aggregate labour force working on farms in South Africa.

In this study the regular employees were first adjusted for inconsistency arising from the sporadic inclusion of proprietor and family labour, seasonal labour, and domestic servants. The number of proprietors involved in farming was estimated for the inter-census nodes through trend projections of the ratio of the number of owner-operators to farms not rented (or share cropped) as a share of the total number of farming units. Estimates of family labour are based on the linear projections between census nodes of the ratio of family labour to working proprietors — wherever relevant proprietor and family labour were then deducted from the series on regular employees. Finally, the number of seasonal workers was estimated using 1) the trend in salaries paid to regular casual and seasonal workers where available; and, 2) the trend in the volume of production in the absence of salary data.

Figure 4.14 plots the trend in relative shares of the categories of labour as estimated and the average number of farm workers per category for each decade since 1910 is shown in Table 4.6. The Agricultural Census for 1946/47 was the first that identified family labour (relatives of the owner or occupier) as a separate category of labour, reported as 50,996. Due to the influence World War II this can be regarded as abnormally low. Using the approach described above the number of proprietors involved in actual farming activities in 1946 is estimate to have been 98,503 bringing the total number of whites involved in farming in 1946 to 164,959, with proprietor and family labour then representing 69.2 percent of total white labour employed.

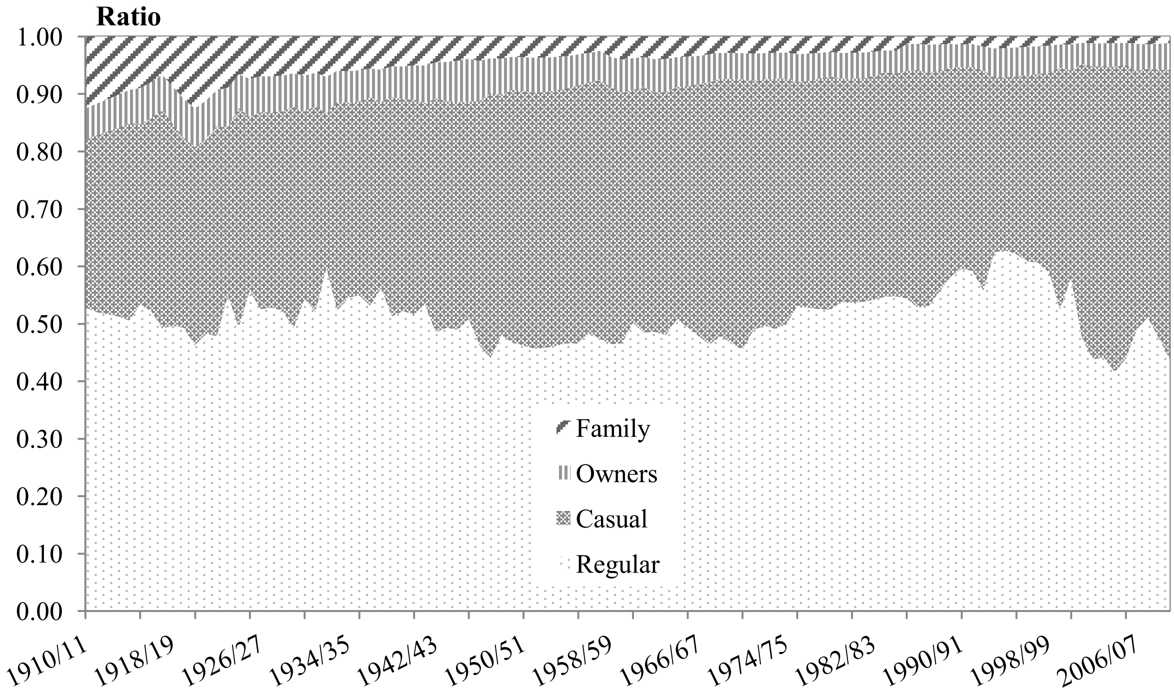


Figure 4.14: Trend in Relative Shares of Labour 1910 — 2010

Sources: Own Calculations

Table 4.6: Number of Farm Workers 1910s to 2000s

	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
	Decade Averages (thousands)									
Family	78	83	80	61	56	57	40	24	17	11
Regular	411	523	730	699	773	806	704	677	603	411
Casual	265	354	467	583	738	716	584	485	349	417
Domestic	8	0	0	28	137	123	94	61	20	0
Owners	48	65	76	94	93	86	64	54	46	37
Total (excl. Domestic)	802	1,025	1,354	1,438	1,661	1,665	1,392	1,241	1,014	896

Sources: As adapted from OCS (1919 to 1949); BCS (1950 to 1968); DOS (1971 to 1980); CSS (1982 to 1998) and Stats SA (1999 to 2011)

Notes: For the inter census nodes from 1993 to 2007 and from 2007 to date the Labour Force Survey was used to project the trend in the regular labour force (Stats SA 1996-2012).

Ten years earlier in 1937 whites employed as regular farm labour amounted to 205,261 with proprietor and family labour representing about 160,183 (78.1 percent of the regular white labour) and the non-white labour force totalling 764,945. From 1958 occupier and family labour was enumerated for 3 consecutive years. From 132,560 in 1958 it increased to 158,475 by 1960 — 93.2 percent of regular white labour in 1958, increasing to 98.3 in 1960. It re-appeared in the 1985/86 Agricultural Survey as 82,861 consisting of 64,042 proprietor labour and 17,473 family workers out of a total of 100,200 white labourers working regularly on farms. The Agricultural Census for 2006/07 showed that owner and family labour has declined to 47,570. As a proportion of the regular labour force proprietor and family labourers varied between 41.6 percent in 1921 and 15.99 percent in 1958 and today fluctuates around 18.62 percent.[12]

Figure 4.15 compares the agricultural employment data of productivity studies done since 2000 with the agricultural employment statistics published in the *Abstract of Agricultural Statistics*. My estimates differ from the earlier estimates reported by Liebenberg and Pardey (2010) and earlier studies in a number of ways. In Liebenberg & Pardey (2010) projections in seasonal and casual labour between census years were based on trends in the regular labour force (adjusted to exclude domestic servants) using a more detailed set of census statistics than that used by Schimmelpfennig et al. (2000). In my analysis I used the trend in salaries, and when not available, the trend in the quantity of production and owner and family labour was included in the estimates of the aggregate number of farm workers. This approach is justified as a different set of factors such as area planted, prevailing production conditions and the nature of mechanization (Van Zyl et al. 1987) determine the size of the seasonal labour force and should be improved upon.

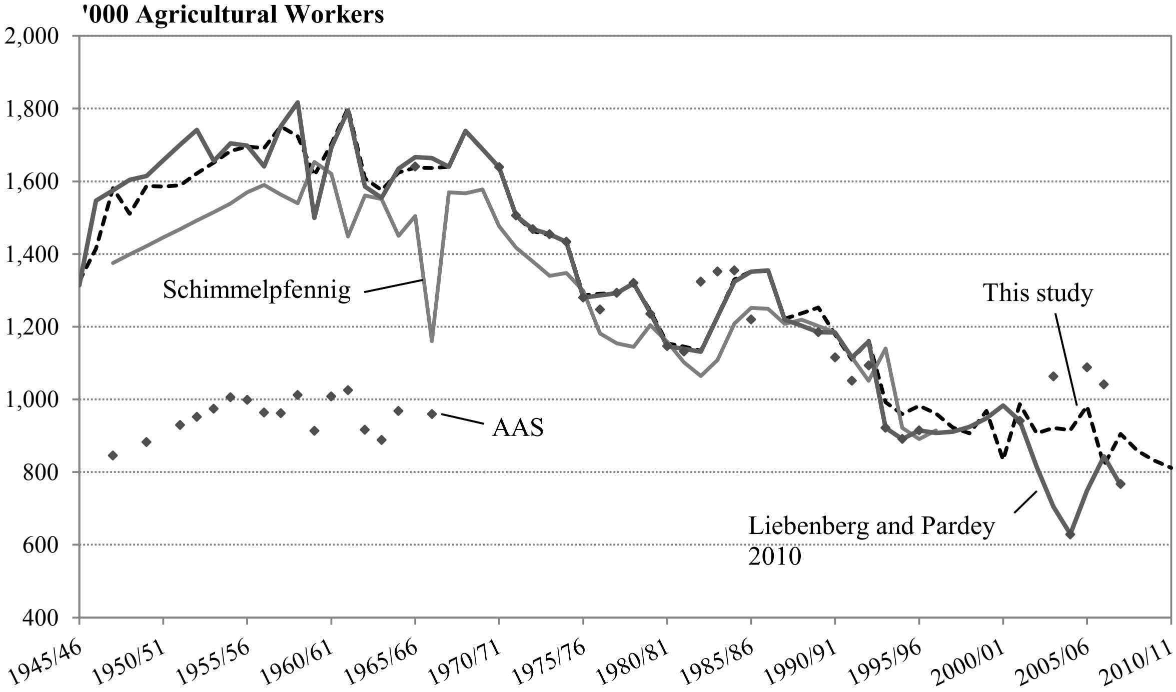


Figure 4.15: Different Estimates of Agricultural Employment Trends 1945 — 2010

Sources: Own Calculations

[12] These estimates may be an underestimate in view of the recent results of the Population Census for 2011 (Stats SA 2012). Due to the sampling methods used for the Agricultural Census small holdings and smaller commercial farms is excluded from the analysis done here.

By accounting for the inconsistent inclusion of domestic servants — and by excluding it from the data — and adding estimates for owner and family labour, Figure 4.15 shows that these adjustments in aggregate have a significant effect on the labour force estimates for the years prior to 1954 and smaller but still visible effect for the period 1991 to 2000. On the whole the revised employment series appears to follow a more stable pattern throughout the period.

4.5.2 Quantity and cost of labour indexes

The Fisher and Thirtle quantity indexes presented in Figure 4.16 were formed based on the revised employment series. Employment in agriculture reached a peak in 1961 with 1,802 million (excluding domestic workers), which is 67 percent higher than the 0.781 million at the start of the century. The Thirtle index yields a growth rate of 75.9 percent over the same period. During World War II agricultural employment dropped by 14.3 percent (15.2 according to the Thirtle index) whereafter it grew by 30.6 percent to 1961 in line with the expansion of the area under cultivation. Since 1961 it decreased by 46.3 percent until 1982 as a result of the mechanization of harvesting. From here it briefly increased by 17.6 to 1986 in response to increased interest rates during this period, but from 1986 employment continued to decrease by 51.1 percent to 2010.

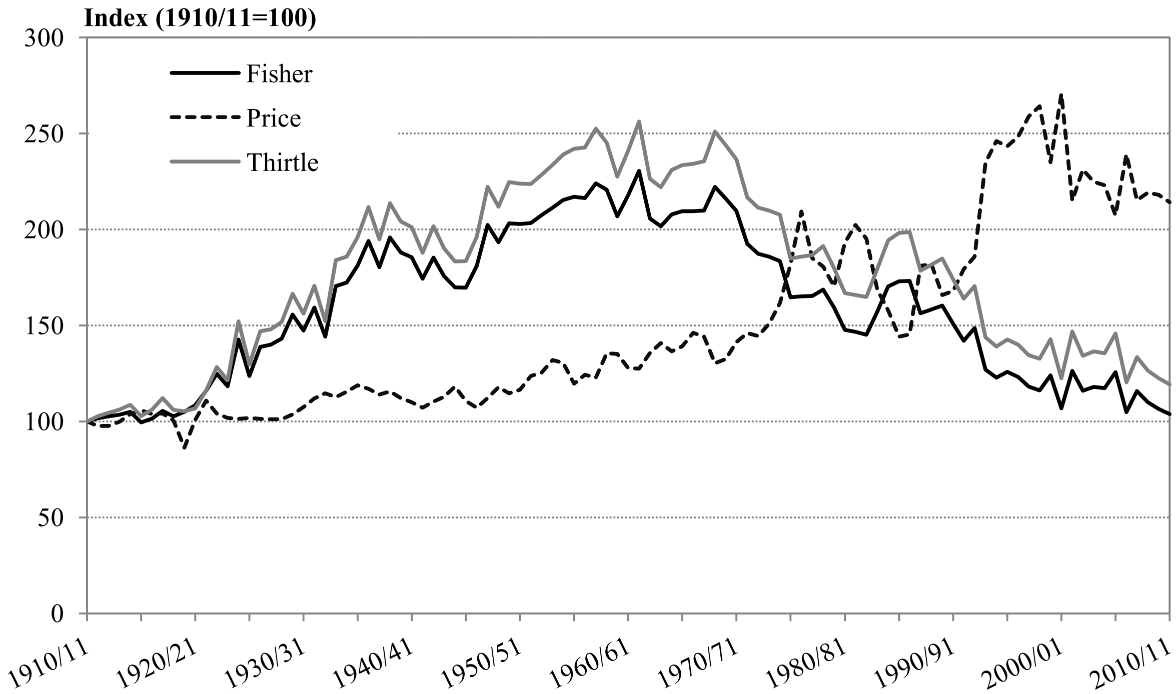


Figure 4.16: Labour Quantity and Price Indexes, 1910 — 2010

Sources: Own Calculations

The introduction of the Agricultural Labour Act (Act147 of 1993) resulted in a wage rate increase in the agricultural sector in 1992/93 of 26.4 percent. This is less than the wage increase experienced from 1972 through to 1976 of 39.19 percent, but the highest increase the sector faced in a single year. This resulted in a decrease in labour use of 14.58 percent from 1992 to 1993, about 3 percent less than the annual decrease in labour over the four year period from 1972.

4.6 THE COMPOSITION OF PURCHASED INPUTS

Expenditure data on the individual categories of materials inputs (interchangeably referred to in the literature as purchased inputs, intermediate inputs, or farming requisites) are collected annually by the Department of Agriculture. Crop year estimates are imputed from the annual observations using quarterly weights. The categories for which the prices (and expenditure) are monitored are: farm services; building and fencing material; fuel; dips and sprays; electricity; maintenance and repairs of machinery and implements; fertilisers; packaging material; seed and plants; and feeds. Also included in the materials inputs account under the category *other*, but for which prices are not monitored are: licences; insurance; land tax; third party; water tax; and expenditure on items such as magazines, stationary, banking costs, consultants, and auditing fees. The detailed panel data set dates back to 1947. Before that the aggregate of materials inputs, as well as seed and animal feeds produced by the agricultural sector is available with estimates dating back to 1910.

4.6.1 Data limitations

Estimates of the expenditure on materials input are claimed to be validated against the estimates of the agricultural census. Observations for the inter-census nodes are obtained from manufacturers and suppliers or their affiliated associations, weight adjusted according to the observed deviation of the latest census and then re-calibrated once the next census becomes available (Blignaut, Chief Statistician, Directorate of Agricultural Statistics, personal communication, 2010). Cross-referencing between the results reported in the *Abstract of Agricultural* Statistics with the census data reveal that the validation done by the Department of Agriculture is consistently done. The worst example was found with fertilizer expenditure where the estimates of the Department of Agriculture since 1981 were based solely on the information supplied by the Fertilizer Association of South Africa — membership of the association is estimated to represent roughly 60 percent of the fertilizer sold in the country (Dr G van der Linde, CEO of FSSA, Personal communication, 2 June 2011). Since 1981 the estimated expenditure on fertilizers reported by the Department varies between 7 and 44 percent below the expenditure reported in the census. Data on fertilizer expenditure used in this study has been readjusted to census statistics. With feeds and fuels the same lack of validation was found to exist, but lacking sufficient information to correct for these errors no adjustments have been made.

In earlier studies the price indexes reported for the sub-categories of the Farming Requisites Index were used to form the Thirtle quantity divisia index. The Farming Requisites indexes of various base periods were spliced to form the long-run price series from 1947. The same approach is replicated here for the period dating back to 1945 for comparative purposes.

Table 4.7 summarises the method followed to form the long run price series for each of the 8 subcategories of materials inputs included in this analysis. With the exception of building materials, quarterly prices of a number of suppliers are available from the ledger files of the Department of Agriculture dating back to October 1958. These prices were captured and the average price by crop year calculated. From the series thus formed chained price indexes were constructed by category — base year weights were linearly extrapolated between base years. Insufficient information to accurately track the source of prices and changing measurement units pre-empted the formation of a chained price index for the pesticides and seed categories. In the case of building materials only the Laspeyres price index reported by Stats SA is available. In total this constitutes more than 262 sets of quarterly price variables dating back to from 1958.

In the construction of the panel dataset for prices two important observations were made that need to be borne in mind in terms of the quality of the data underlying the Farming Requisites Price Index (FRPI) constructed by the Department of Agriculture — especially so since the late 1990s. The first is that weights currently used for particular brands, or specific suppliers, in the FRPI mostly reflect the weights established in the 1985 base year. With each subsequent re-basing of the Farming Requisites Price Index since 1985 only the weights for the product category where changed. Another cause for concern is that the price data files obtained in electronic format from the Department of Agriculture for the years since 2000 show that a significant proportion of the product prices were calculated and do not constitute captured data. This would be acceptable if respondents provided data in a format that require adjustments for changing units of measurement, or pro-rating if Value Added Tax were included in the prices received. However, a simple test on the rates of change in the prices of consecutive quarters revealed that in many cases prices were derived by adjusting an earlier observation with a growth factor and that the growth rates showed a remarkable degree of consistency across the different sources — leading one to conclude that the data were updated using a suitable price index. At best one can hope that the index used for this adjustment would be representative with the specific product category in question, but as the Department of Agriculture is the only agency monitoring these prices this is highly unlikely.

Table 4.7: Numeraire Prices for Each Sub-category of Material Inputs

Category/Input	Prices used	Treatment	Source
Farm Services	Quarterly Service Tariffs of 5 cooperatives since 1958/59	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Maintenance			
Building repairs	Long run Building Materials Index	Spliced index as no underlying data could be obtained that span the period	Stats SA
Machinery	Quarterly prices of 7 items from 4 suppliers	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Implements	Quarterly prices of 6 items from 5 suppliers	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Tyres	Quarterly prices for 9 different tyre sizes from 3 suppliers	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Services	Hourly service tariffs of 19 service providers	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Energy			
Fuel	Quarterly diesel prices	Average by crop year calculated	DAFF
Electricity	Quarterly electricity tariffs	Average by crop year calculated	DAFF
Pesticides	Spliced Laspeyres price index	Could not construct a robust price series that span the period	DAFF
Fertilizer			
N	Quarterly price of a ton of Urea from 3 suppliers	Weighted average price by crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
P	Quarterly price of a ton of MAP from 3 suppliers	Weighted average by price crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
K	Quarterly price of a ton of KCl from 3 suppliers	Weighted average by price crop year from 1958, backcast with FRPI (1936/37 - 1938/39 base)	DAFF
Packaging			
Wool Bags	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Potato Bags	Quarterly prices of 4 suppliers	Weighted average price	DAFF
Cabbage Bags	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Onion Bags	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Citrus Bags	Quarterly prices of 1 suppliers	Weighted average price	DAFF
Grain bags	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Carton	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Box-Wood	Quarterly prices of 1 suppliers	Weighted average price	DAFF
Seed	Spliced index	Spliced index as no underlying data could be obtained that span the period	DAFF
Feeds			
Dairy Product	Quarterly prices of 6 suppliers	Weighted average price	DAFF
Finish	Quarterly prices of 5 suppliers	Weighted average price	DAFF
Laying-Meal	Quarterly prices of 7 suppliers	Weighted average price	DAFF
Poultry Growing	Quarterly prices of 5 suppliers	Weighted average price	DAFF
Pig Growth	Quarterly prices of 7 suppliers	Weighted average price	DAFF
Cattle Block	Quarterly prices of 5 suppliers	Weighted average price	DAFF
Bone-Meal	Quarterly prices of 2 suppliers	Weighted average price	DAFF
Grain	Quarterly prices of 1 suppliers	Crop year price	DAFF
Hay	Quarterly prices of 1 suppliers	Crop year price	DAFF
Salt	Quarterly prices of 1 suppliers	Crop year price	DAFF

Sources: Own calculations from historic records of Department of Agriculture

To test the extent to which this problem exists in the data obtained from the Department of Agriculture a series of correlation test were done. Table 4.8 shows the results of the correlation tests for five categories of the materials inputs account based on the 268 price variables underlying the five more important materials expenditure categories, i.e. feeds, fertilizer, dips and sprays, machinery maintenance and packaging. Of the 268 products that were monitored in the 1995 basket of inputs for the five categories only 239 are still monitored in the 2005 basket. This decrease originates primarily from a reduction of the number of fertilizer products monitored, down from 47 to only 12 from 2005. The reduction in the number of fertilizer products is primarily fertilizer compound mixtures, which is strange as this ignores the growth in product specialization in this industry —prices of liquid fertilizer are not monitored either, even though this is an increasingly common method of fertilization accompanying the switch to precision farming technologies. The count of cross-correlation coefficients below the diagonal higher than 0.95 and 0.985 is expressed as a percentage of the sum of entries below the diagonal in the correlation matrix for each category. A score of 100 percent mean that the trend in prices for all the products is perfectly correlated. In all three categories there has been a significant increase in the degree of correlation over the three five year periods since 1995 — all show a marked increase from the five year period from 2000 to 2005 to the five year period from 2005 to 2010. A line plot of the sub-categories within each category shows that for many of the variables there appears to be a linear relationship between the price series (Figure 4.17).

Table 4.8: Correlation Test Results for Five Input Categories, 1995 - 2011

Period	1995 - 2000	2000 - 2005	2005 - 2010
	Number of products monitored		
Feeds	40	40	40
Fertilizer	47	47	19
Dips & Sprays	56	55	55
Maintenance	114	114	114
Packaging	11	11	11
Total	268	267	239
	Percentage showing cross-correlation factors higher than 0.95		
Feeds	5.94	34.65	59.41
Fertilizer	20.77	30.35	12.82
Dips & Sprays	5.23	5.49	66.46
Maintenance	6.98	12.62	50.17
Packaging	6.67	-	40.00
	Percentage showing cross-correlation factors higher than 0.985		
Feeds	-	2.97	51.49
Fertilizer	9.90	7.99	5.13
Dips & Sprays	1.74	4.27	53.05
Maintenance	4.32	4.32	33.22
Packaging	6.67	-	26.67

Sources: Own calculations

Notes: Percentages reflect the number of observations below the diagonal in the cross-correlation matrix that is equal or higher than 0.95, or 0.985.

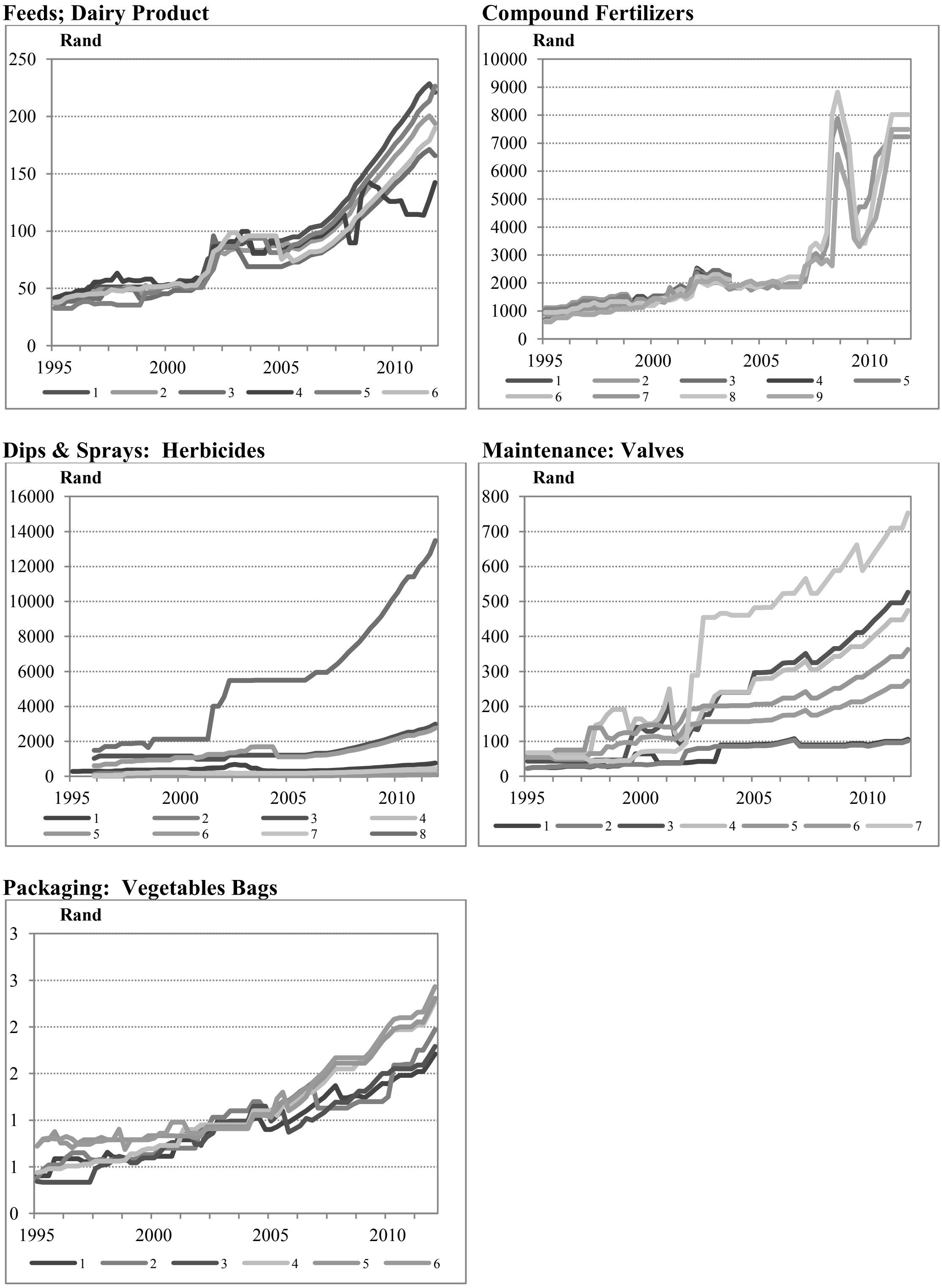


Figure 4.17: Trend in Prices of Selected Product Categories of Purchased Inputs, 1995 — 2011

Sources: Own Calculations

Finally an analysis of the price adjustment formula, in the few instances where it was left 'alive' in the data file, revealed that the quarterly adjustment was based on the previous quarter and not the same quarter a year ago. Failing to adjust the growth rate to reflect correct quarter-on-quarter growth rates, would explain the exceptionally high growth trends in the farming requisites indices of the Department of Agriculture when compared to the trends in the producer price indices of comparable sectors compiled by Stats SA (2012). From 2005 to 2011 general prices in the economy, as indexed by the GDP deflator, increased by 44.71 percent. Over the same period the producer price index for the mechanical engineering sector increased by 32.46 percent compared to the 62.65 percent increase measured by the farming requisites price index for machinery parts.

Other examples where the price increases estimated by the Department of Agriculture is much higher than price trends reported by Stats SA for comparable products is cardboard box products. Stats SA reported a 29.9 percent increase in cardboard box products from 2005 to 2011 compared to the 42,9 percent increase in prices of cardboard boxes reported by the Department of Agriculture. The same situation exists for wood products (excluding minewood) for which Stats SA report an increase of 35.9 percent from 2005 to 2011 compared to the 56.2 percent for boxwood reported by the Department of Agriculture.[13]

Taken together, one is understandably highly suspicious of the quality of the input price data obtainable from the Department of Agriculture for the recent decade or so. If the price trend has been overstated it is of particular concern for this analysis, as this would result in understating the imputed quantities of materials input use and consequently result in overstating the productivity growth estimates. As a result, the price information for the product categories mentioned here was substituted with the appropriate price index from Stats SA for the last decade.

4.6.2 Trends in composition of purchased inputs

The composition of purchased input use has changed remarkably over the past six and a half decades. To illustrate this, the cost shares of the various purchased input categories expressed as three-year averages centred around 1946, 1967, 1988 and 2009 are presented in Table 4.9. According to the estimates of the Department of Agriculture the share of farm services of the total expenditure on purchased inputs has more than doubled from 4.1 percent in 1988 to 11.8 percent in 2009. This reflects a similar trend experienced in the USA — the items included under the services category in

[13] Even though there has been a shift to synthetic packaging materials, i.e. plastic, fomolite, over the past two decades the Department of Agriculture has not yet included any of these products in its basket of packaging materials monitored. The increase in the producer price index for plastic products since 2005 was only 30.7 percent compared to the 54.3 percent reported for packing material reported by the Department of Agriculture. As rational economic agents farmers would most certainly have switched to using the synthetic alternatives instead of using the increasingly expensive products monitored by the Department of Agriculture.

South Africa are included along with a number of other inputs under the heading Miscellaneous in the USA — where the share of this item increased from 9 percent in 1950 to 23 percent by 2000 (Alston, 2010: 48). Contrary to the USA, where it was found that the expenditure on energy decreased from 1950 to 2000, South African farmers halved their expenditure on energy from 1946 to 1967; from where the share of energy expenditures increased to become the second highest expenditure item (17.5 percent). This was aided by the relative decrease in the cost of fuels which today fluctuate at about half the rates of the immediate post-war years (See next section). Expenditure on feeds increased from 16.4 percent to 22.2 percent in 2009 aided by the growing dominance of the poultry industry.

Table 4.9: Cost Shares of Materials Inputs; Three year Averages Centred on 1946, 1967, 1988 and 2009

Category	1946		1967		1988		2009	
	Rank	Percentage	Rank	Percentage	Rank	Percentage	Rank	Percentage
Services	8	2.3	10	3.2	9	4.1	3	11.8
Building Material	7	4.6	6	5.6	8	4.8	9	3.7
Fuel	1	23.6	4	13.1	4	13.1	2	15.8
Dips & Sprays	8	2.3	9	4.2	5	9.8	7	7.2
Electricity	11	-	11	1.5	11	2.5	11	1.7
Taxes	6	8.7	8	4.3	10	3.2	10	3.2
Maintenance	4	11.7	3	14.6	3	13.2	5	9.8
Fertilisers	2	16.6	2	18.0	2	15.4	4	10.6
Packing	5	11.4	5	8.9	7	5.5	8	6.2
Seeds	8	2.3	7	5.2	6	5.7	6	7.8
Feeds	3	16.4	1	21.5	1	22.7	1	22.2

Sources: Own calculations

Expenditure on seeds as a proportion of total expenditure on purchased inputs has increased from 2.3 percent in 1946 to 7.8 percent in 2009 reflecting the increased use of improved varieties by farmers over time.

For productivity analysis it is the trend in the quantities used that is of interest, which is discussed in the next section.

4.6.3 Quantity indexes of purchased inputs

Figure 4.18, Panels a through c, plot the trends in the quantity indexes of materials inputs used for selected categories. Fertilizer use increased by 5.9 percent annually from 1945 to 1983, with slight decreases during the droughts of 1961 and 1982. From 1983 the quantity of fertilizer used decreased

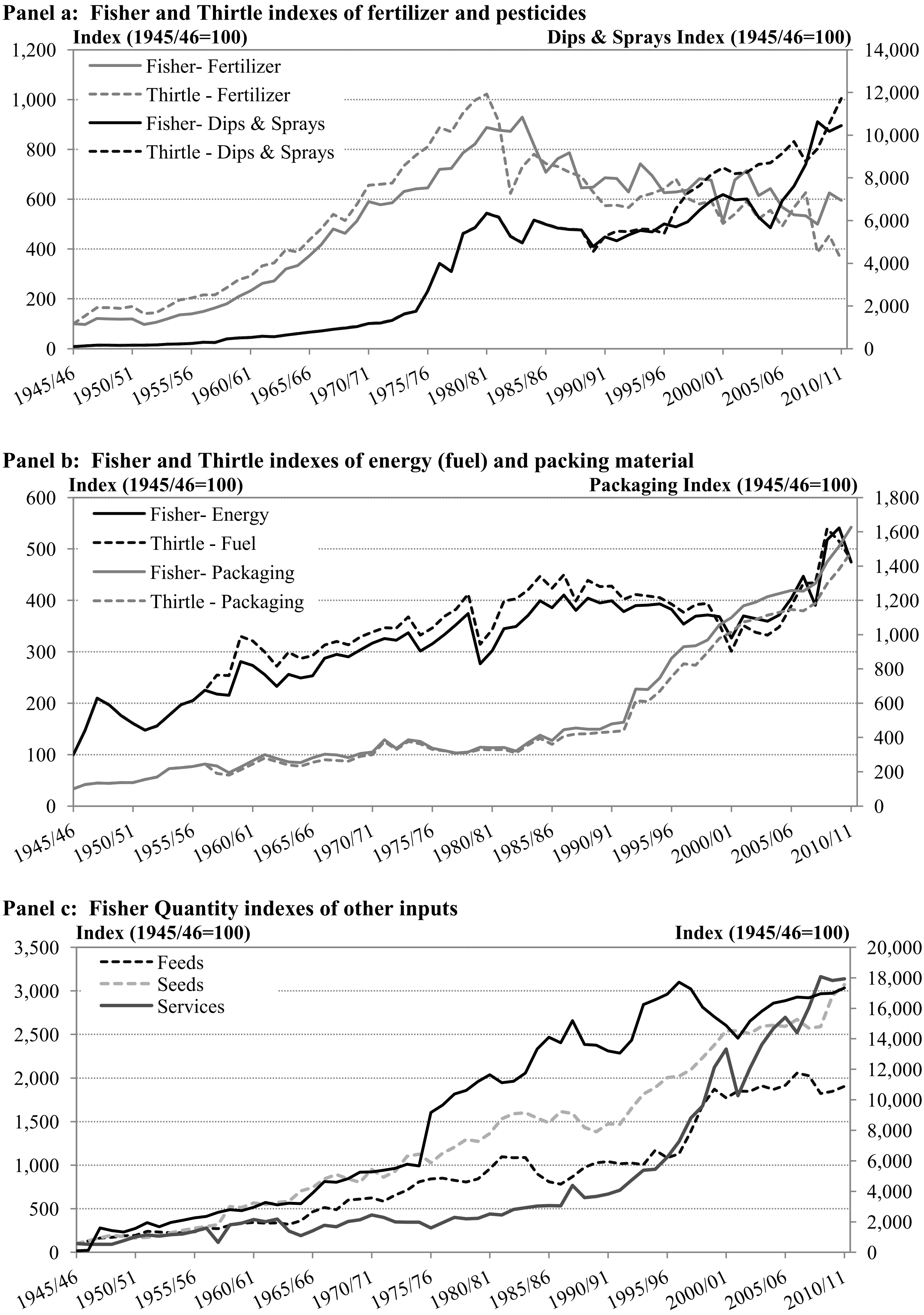


Figure 4.18: Quantity Indexes of Purchased Input Use, 1945 — 2010

Sources: Own Calculations

by 1.4 percent per year until 2008 in line with the decreasing area planted for this period. From 2008 it decreased by 19.7 percent in response to the 37.7 percent increase in the price of fertilizers. The equivalent Thirtle quantity index for fertilizer use shows largely the same trend up to 1981, albeit at a higher rate of growth. From here it dropped to below the Fisher index, a result of the underestimate of expenditure on fertilizer by the Department of Agriculture. The quantity indexes of pesticides follow exactly the same trend until 1990 as both methods of indexing used the spliced pesticides price index of the Department of Agriculture to form the respective indexes. The Fisher index deviates from the Thirtle index for pesticides from 1990 since the producer price index for chemical compounds published by Stats SA was used to project the trend in the price index series from this point. As a result the growth patterns between the two indexes differ significantly. The Thirtle quantity index for pesticides began to increase significantly as of 1995 whereas the Fisher quantity index for pesticides showed a decrease up to 2004 of 1.4 percent per year. From 2004 to 2008 the Fisher quantity index for pesticides use increased to almost equal the Thirtle index by 2009[14].

By using different price data for both energy and packaging material the quantity indexes formed for these categories differ throughout the period under review. The Fisher quantity index for energy use (electricity and fuel) also differs from the Thirtle index for fuel (fuel only) in that electricity use is included in the analysis from 1966. The two indexes follow roughly the same trend, with the same trend breaks in line with energy price shocks, but from 1999 the similarity is less obvious. Whereas the Thirtle index showed a persistent growth in quantity used with a stronger growth as of 2006, the Fisher quantity index for energy use decreased from 2001 until 2006 before it increased by 12.5 percent per year compared to the 4.2 percent increase estimated by the Thirtle index.

The explanation is that for the Fisher Index the price of diesel was indexed against the diesel price index published by Stats SA as of 1999, as the price data of the Department of Agriculture became unreliable (Blignaut, Personal communication 2011).

The trend in the use of packaging materials for both indexing methods is also very similar, but whereas the Fisher quantity index for packaging material stagnated from 1999 to 2006, the Thirtle index showed a persistent growth with a slightly higher rate of growth (5.3 percent) from 2006 onwards. The comparative rate of growth estimated by the Fisher index is 7.9 percent per year as a result of adjustments to the price series for box wood and carton boxes. In both cases the prices monitored by the Department of Agriculture are highly correlated and much higher than the price indexes reported by Stats SA (2012).

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[14] Spliced Laspeyres indexes were used to form the Fisher Index to save time in the construct of the price series. Ideally a divisia index should have been constructed, but changing units of measurement and frequently changing product composition made this data set particularly difficult to process into a coherent Divisia index. Given the experience with the effect of using spliced Laspeyres indexes in Chapter 3 it is advisable that this index should be formed using a Divisia index in future analysis.

In panel c the Fisher quantity indexes for feeds, seeds, services and maintenance are shown, which were not analysed as separate input categories in the earlier studies as a result of the basis upon which these input categories were aggregated. An interesting feature of this graph is the rapid growth shown in the use of maintenance since 1974, services since 1990 and feeds since 1996. In the case of maintenance the increases follow on times of economic downturn, droughts and the change in tax policy on depreciation write-off in 1981 in particular, serving as a substitute for the purchase of new capital items.

Figure 4.19 plots the price indexes for the four most important purchased input categories adjusted for inflation with the GDP implicit price deflator, with base year 2005 (SARB 2011). Over the whole period included in the analysis, the aggregate price of materials inputs decreased by 0.9 percent annually, However for most inputs the decline lasted until 1999, whereafter it begun to increase by 1,7 percent per year. The price spikes observed for fertilizers (1951 and 2008) and energy (1979 and 2002) reflect actual market trends at the time. An interesting feature of fertilizer use during the 1970s is that even though prices were highly unstable the quantity used continued to grow until 1982. This is in contrast to the Thirtle quantity index, which shows a drop in fertilizer use of 38.9 percent from 1980 to 1982. Data on fertilizer demand from the Fertilizer Society of South Africa for this period shows

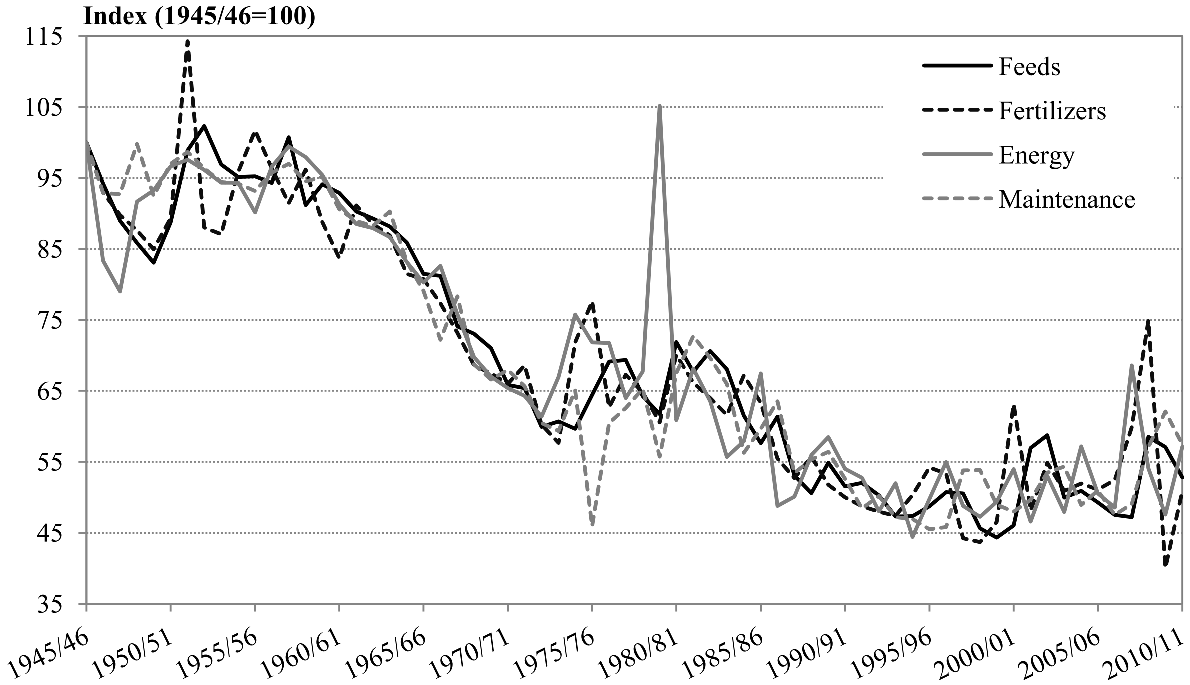


Figure 4.19: Fisher Real Price (2005 base) Indexes of Selected Purchased Inputs, 1945 — 2010

Sources: Own Calculations

only a decrease of 3.5 percent in the physical consumption of fertilizer, or a decrease of 1.4 percent in the aggregate of quantity. The difference is ascribed to the 44 percent underestimation in expenditure by farmers on fertilizer by the Department of Agriculture which are accounted for in the Fisher index. However, the price hikes of 2008 have resulted in a drop in fertilizer use from which one can deduce that the farming industry has become much more responsive to price changes in input markets.

4.7 INDEXES OF THE QUANTITY AND PRICE OF AGGREGATE AGRICULTURAL INPUTS

The aggregate quantity indexes of capital, land, labour, purchased and total input use for South African agriculture is shown in Figure 4.20, Panel a, along with the aggregate price indexes in Panel b. While the quantity used of materials inputs grew faster (4.3 percent per year) than the quantity of all other input classes, the aggregate (inflation adjusted) price of purchased inputs decreased the fastest (by an average of 0.9 percent per year since 1945). Conversely, among all measured inputs, labour use declined fastest (0.8 percent per year) while the aggregate price of labour grew faster than other inputs (1.0 percent per year since 1945).[15]

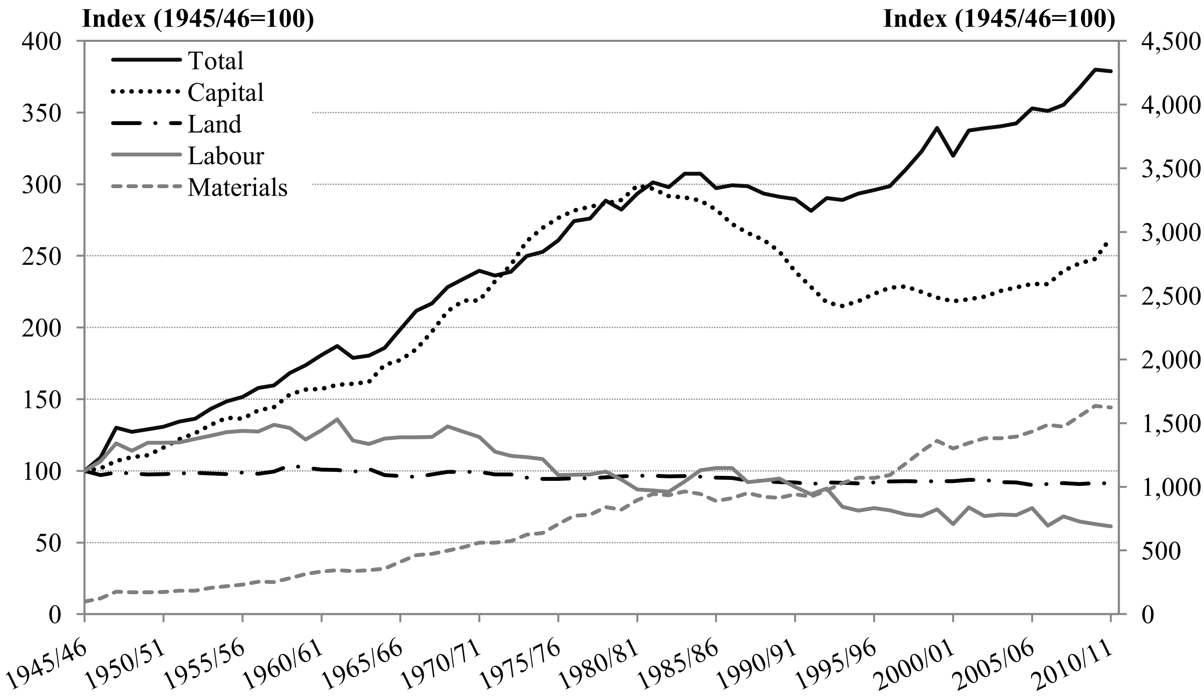
In aggregate the trend in input use reflect times of drought (e.g. 1962, 1982 and 1991), as well as periods of adverse economic conditions, such as the post-1983 drop in the gold price and the sanctions that followed shortly after. Since 2005, and driven by the increase in commodity prices, the expansion in output has seen a resurgence in input use driven largely by an increase in capital and purchased input use.

4.8 CHANGING COMPOSITION OF INPUT USE

Factor proportions in South African agriculture have changed markedly over the past 66 years. Figure 4.21, Panel a, plots the changes in relative factor use for four broad input categories, namely land, labour, capital services, and materials (purchased inputs). Indexes of factor proportions were computed as ratios of the indexes of the quantities of individual inputs, all of which were normalized to a value of 100 in 1945 (i.e., all of the ratios start at 1.0 in 1945). The corresponding growth rates in these ratios are reported in Table 4.10.

[15] The inflation adjusted price index is shown here as the high rates of inflation experienced in this country, especially during the 1970s and 1980s, result trend patterns that are difficult to interpret.

Panel a: Quantities



Panel b: Prices

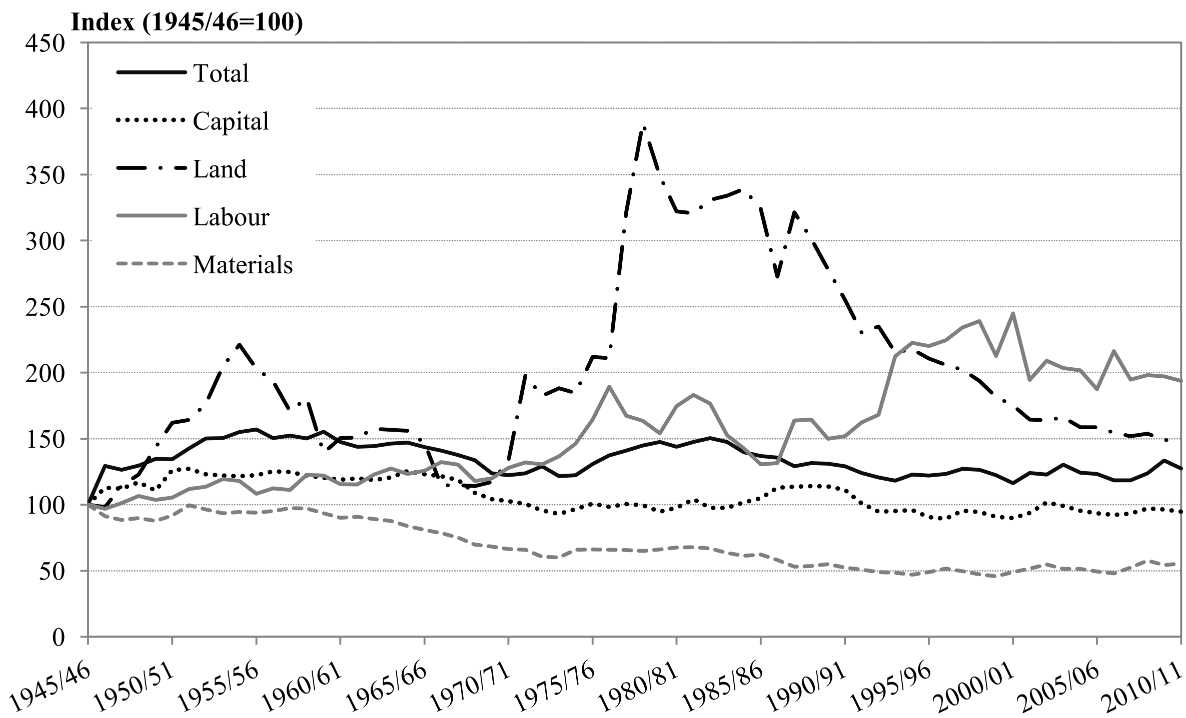


Figure 4.20: Fisher Quantity and Real Price Indexes of Aggregate Inputs Used, 1945 — 2010

Sources: Own Calculations

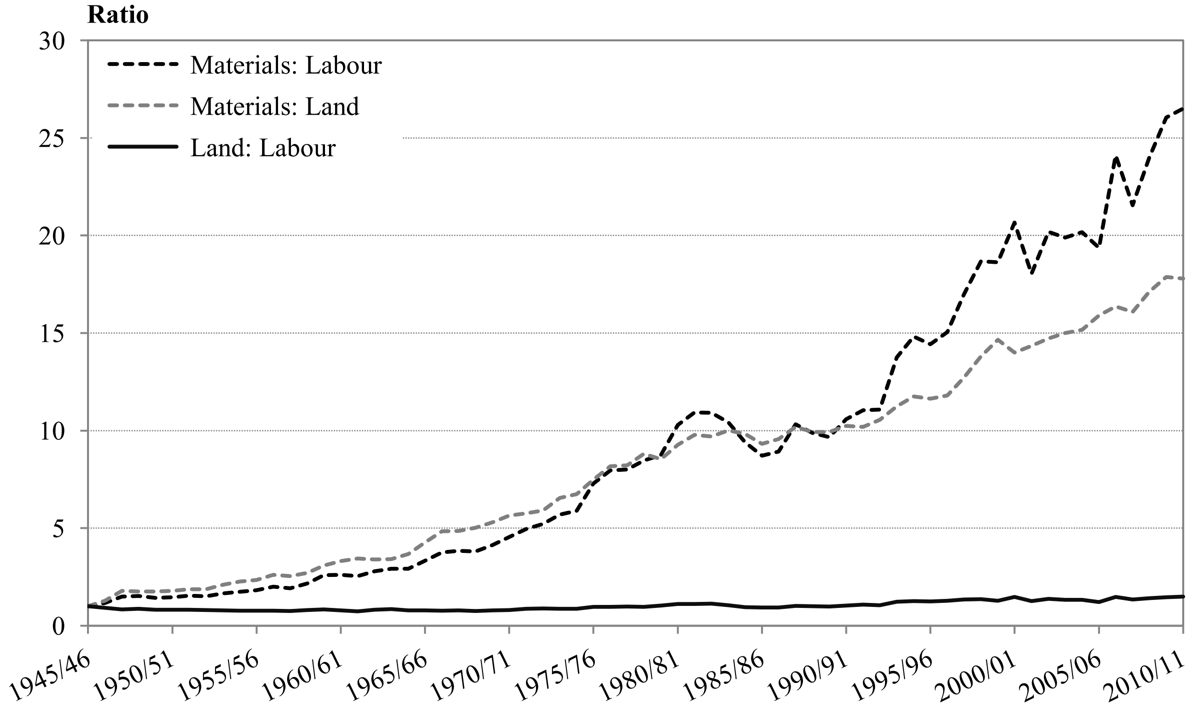
Since 1945, the materials: labour and materials: land ratios on average increased the fastest by 4.92 and 4.32 percent per year respectively. The materials: labour ratio exhibits three distinct phases. At first it grew at 6.64 percent per year until 1981, whereafter it dropped to 1985. From 1985 it grew again by 4.52 percent per year until 2010. This follows the labour and energy price shocks of 1992/93 and 2007/08 respectively.

The land: labour ratios experienced a less dramatic but still measureable increase since 1945. With the exception of the 1981 to 1994 period when the tax policies in support of capital purchases changed followed by the subsequent sanctions period, both the labour: capital and land: capital ratios experienced substantial decreases. Contrary to the 1945 through 1981 period the decrease in the labour: capital ratio (Panel b) was faster than the land: capital ratio in response to changing agricultural labour legislation and the introduction of the Extension of Security of Tenure Act (Act 62 of 1997). Interestingly, if the analysis for this metric is extended to 1910, land: labour ratios experienced during the last decade of the 21st century is similar to what prevailed during the first decade of the previous century (Figure 4.22).

The changing factor proportions also reflect changes in production practices and technologies. The strong decrease in the labour: capital and land: capital ratios until 1981 was mostly aided by the strong mechanization drive in commercial agriculture. Since 1981, the land: capital ratio increased slightly until 1993 before it gradually started to decrease, to hover around the same ratios experienced in the early 1980s. The double digit inflation and interest rates that prevailed up to 1994 no doubt played a significant role in this regard. The labour: capital ratio followed the same pattern, but it decreased at a much more rapid rate to reach levels in recent years that are below that of the early-1980s. Similar metrics for the USA shows that the early 1980s was also a turning point followed by a decrease similar to South Africa (Alston et al.2010)

As a consequence of these offsetting price and quantity effects, the increase in the share of total costs attributable to materials is much more muted than the increase in the quantity of materials inputs used (Figure 4.23). Similarly, the increase in the share of total costs attributable to purchased inputs is much more modest than the increase in the quantity of purchased inputs used found for the U.S. agriculture. Conversely, the decrease in the quantity of land used is much lower than the decrease in the cost share of land in total costs. Capital services used, however, increased whilst its share in total costs has declined over the period since 1945.

Panel a: Land, labour, and materials (purchased) inputs ratios



Panel b: Land, labour, and purchased inputs relative to capital

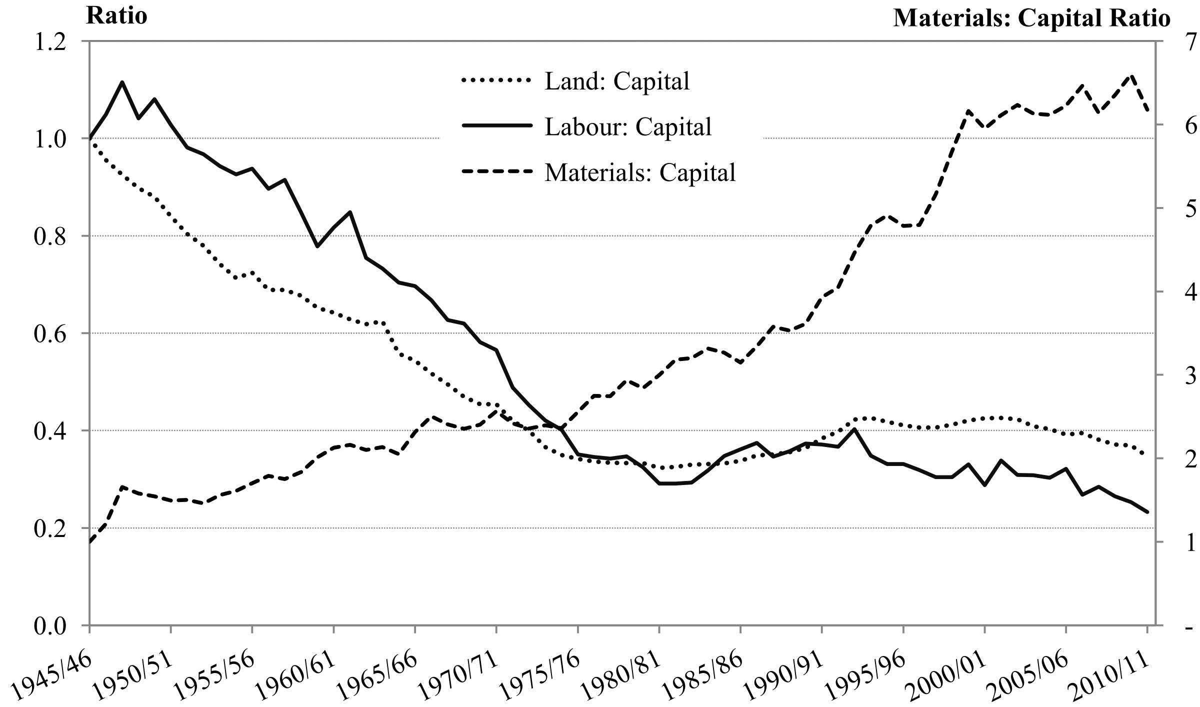


Figure 4.21: Factor Proportions for South African Agriculture, 1945 — 2010

Sources: Own Calculations

Notes: Due to the huge increase in the use of materials (purchased) inputs, all the factor proportions for materials yield ratios higher than one up to about 30.

Table 4.10: Factor Proportions, Average Annual Growth Rates, 1945 to 2010

Period	Materials to			Land to		Labour to Capital
	Labour	Land	Capital	Labour	Capital	
1945 to 1981						
Minimum	1.00	1.00	1.00	0.74	0.32	0.29
Maximum	10.93	9.77	3.18	1.12	1.00	1.12
Average annual percentage change	6.64	6.33	4.37	(1.17)	(2.83)	(1.66)
1981 to 1994						
Minimum	8.71	9.32	3.15	0.93	0.33	0.29
Maximum	14.80	11.74	4.90	1.26	0.43	0.40
Average annual percentage change	2.33	1.41	3.33	0.92	1.92	0.99
1994 to 2010						
Minimum	14.48	11.68	4.80	1.22	0.35	0.23
Maximum	26.94	18.14	6.70	1.49	0.43	0.34
Average annual percentage change	3.74	2.70	1.54	1.04	(1.16)	(2.20)
1945 to 2010						
Minimum	1.00	1.00	1.00	0.74	0.32	0.23
Maximum	26.94	18.14	6.70	1.49	1.00	1.12
Average annual percentage change	5.07	4.45	2.83	0.61	(1.63)	(2.24)
1910 to 1961						
Minimum				1.00		
Maximum				2.07		
Average annual percentage change				1.43		
1961 to 2010						
Minimum				1.03		
Maximum				2.07		
Average annual percentage change				(1.43)		
1910 to 2010						
Minimum				1.00		
Maximum				2.07		
Average annual percentage change				0.03		

Sources: Own calculations

Notes: Growth rates based on the average between period end points.

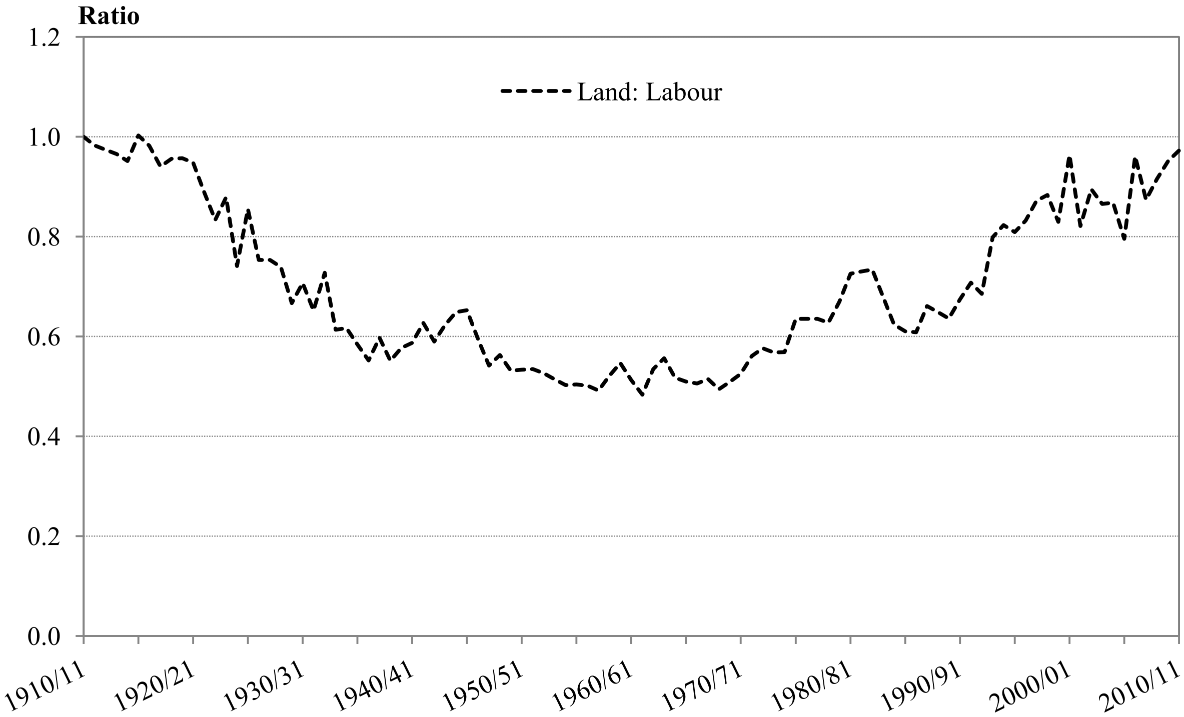


Figure 4.22: Land to Labour Ratio, 1910 — 2010

Sources: Own Calculations

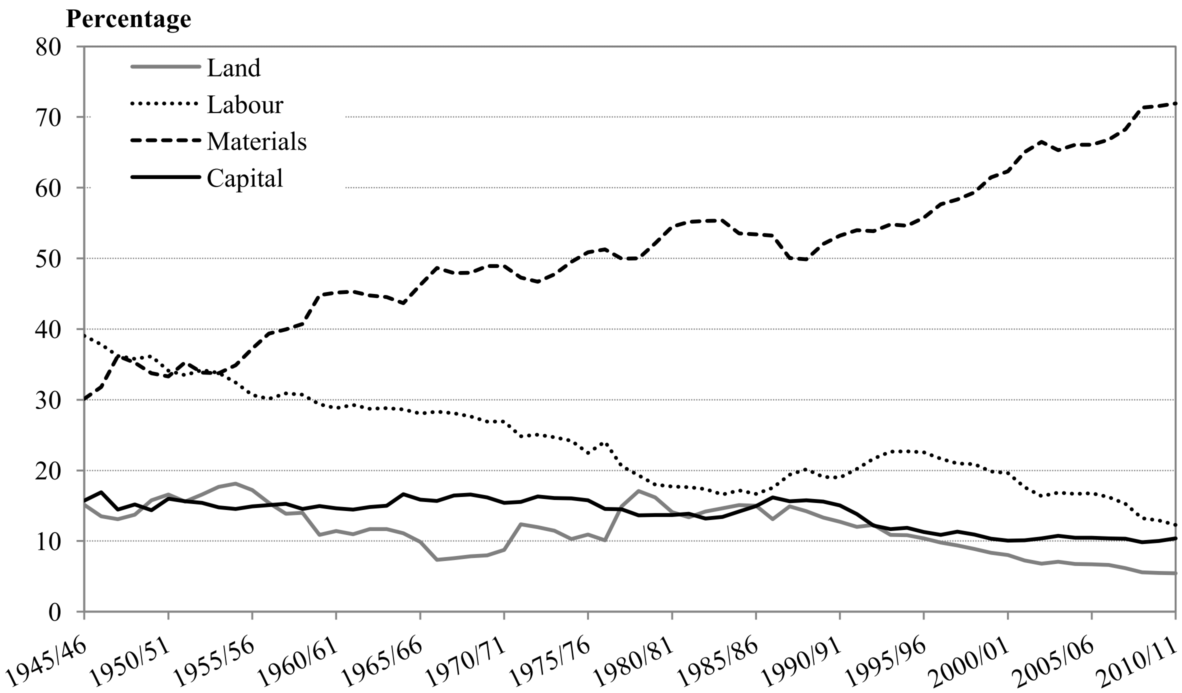


Figure 4.23: Cost Shares of Inputs Used in South African Agriculture, 1945 — 2010

Sources: Own Calculations

4.9 CONCLUSION

Earlier studies on agricultural productivity in South Africa all used the published purchased input and capital formation accounts published in the *Abstract of Agricultural Statistics*, supplemented by unpublished data on wage and rent payments available from the Department of Agriculture. In this study the published data on input expenditure and use was evaluated against the available data from the various agricultural Census and Survey reports and adapted for, 1) changing methodology in the construction of the capital formation and purchased input expenditure accounts of the Department of Agriculture, and 2) in the case of capital inputs disaggregated by class of capital asset.

In so doing, a number of caveats in the data reported by the Department of Agriculture have been revealed. These include:

a) The basis upon which overall sales of agricultural machinery and equipment is estimated since 1994 has become outdated and in effect leads to estimates that may be entirely incorrect. Since 1994, major innovations in farm implements have been introduced and the ratios used to impute the overall sales may no longer hold.

b) The agricultural census as a means of verification to validate the estimates of input use, as done by the Department of Agriculture, has become limited — equally so for research into agricultural productivity. Not only has the scope of the census become merely reflective of the larger commercial farms (thus excluding smaller commercial farming units and more importantly the black farming community almost entirely) its basis of reporting and the variables enumerated has become limited to those aspects required to calibrate the estimates of national income accounting. Its usefulness as an instrument to inform policy decisions has thus become obsolete. The same is true for the scope of inputs monitored, which still reflect the input structure of three decades ago (e.g. packaging, fertilizer compounds and products used).

c) The basis of estimating capital formation, as is done by the Department of Agriculture, is very antiquated and has failed to keep pace with international statistical standards. Improved methods to estimate depreciation and greater detail on the characteristics of inputs, such as labour, capital stocks, etc. are required.

d) In recent years the quality of the purchased input price data collected by the Department of Agriculture (and the subsequent price indexes on farming requisites derived from it) have become suspect. It increasingly exhibits a high degree of almost perfect correlation between the underlying price series and yield growth rates that often exceed the trends observed for similar products monitored by Stats SA.

Taken together these caveats undermine the validity of the estimates made regarding the contribution of the agricultural sector to national income.

Improvements on past studies on agricultural productivity introduced by this study include:

- The more thorough construction of indexes on quantity and price based on estimated service flows from capital inputs. The results obtained differ significantly from past estimates and yield indexes that more visibly reflect the trends in the sector. The indexes obtained are also much more stable in their trajectory
- The disaggregation of land use to better reflect the trends in dryland and irrigated cultivation plus range and pasture land use. In the absence of data on rental rates in the market these were estimated as a function of commodity price trends, which may, however, not be entirely valid.
- On-farm employment data have been revised to include proprietor and family labour and to exclude domestic servants. The basis to estimate the use of casual and seasonal labour has also been revised and ratios interpolated between census years. This yielded a more stable series on labour use.
- Purchased input use has been adjusted to better reflect census observations in the case of fertilizer use as the procedures followed by the Department of Agriculture failed to calibrate these estimates against census data since 1981.

In general, the indexes formed using the revised data and employing the Fisher Ideal approximation of the Divisia index yielded results that are both more stable and less inclined to exaggerate the growth in input use. It also better reflects the known points of when droughts occurred, changing policy regimes and the effects of market price trends.

INTRODUCTION TO PART II

Data collection and entry on government expenditure and researcher staff commenced in December 2003 after the 're-discovery' of the hard copy records on government budgets supplied to the Department of Agricultural Economics, Extension and Rural Development at the University of Pretoria. This material formed the basis of a program of analysis of the aggregate rates of return to agricultural R&D conducted by Colin Thirtle, Johan van Zyl, and Rob Townsend and others in the early to mid-1990s.

Recognizing the complexity and frequency of changes in the institutional structure of the public agricultural Research and Development services over the century and the influence this may have had on budgetary reporting, data was captured at the lowest level of detail available in the government budget reports. Data captured was entered at line item level, inclusive of personnel numbers, position and where available seniority. Institutional expenditure totals and any additional explanatory information contained in footnotes to the budget line entries were also recorded. In this way it was possible to track the allocation of spending throughout the century by function and to a limited degree by institution.

The responsibility for the agricultural sector resided in more than one government department, or was planned for and reported against separate budget votes. The database contains;

detailed public expenditure on agriculturally related services since FY1910/11 of the Departments of Agriculture, Agricultural Technical Services, Agricultural Economics and Marketing as well as Land Affairs (later to become Agricultural Credit and Land Tenure) and the Agricultural Credit Board. As a result of a change from a functional reporting structure to a program based reporting structure in 1975 two sets of files (one for the pre 1975 and another for the post 1975 budget structure) were constructed for each department/portfolio related to agriculture. Budgets of the former homeland administrations for agriculture is not included as the primary aim here was to construct a long-run investment in agricultural technology research and development series, a function or capacity that were not significantly promoted in the homeland administrations (DAWS 1989);

expenditure data of the nine provincial departments of agriculture established in 1995 to replace six of the seven regional Agricultural Development Institutes.;

detailed public expenditure data on support and assistance payments to farmers, industry and consumers since 1910 as a by-product of the construction of the data on agricultural investment in agriculture.. This information did not always form part of the budget report of the Department of

Agriculture — sometimes reported as a separate budget vote — and is incomplete in terms of the history of the Agricultural Credit Board prior to its transfer to the Department of Land Affairs circa 1968. Other subsidies not included are those administered by the Department of Trade and Industry , such as the subsidy on hessian bags and exports as these was not separately specified in the parliamentary budget reports.. An earlier version of this data formed the basis of a study by Johann Kirsten and Nick Vink on support to agriculture in South Africa since 1961 — published in Anderson and Masters (2009).

From the detailed database the following long-run summary data files were constructed:

Allocation of government expenditure on agriculture for 75 different functions.

Government expenditure by department and institution.

Gross expenditure on science research and development in South Africa since 1961 for the aggregates of public sector R&D, public sector agricultural R&D and the private sector R&D investment; and,

National income account data on the RSA economy, the agricultural contribution to the economy, and agricultural trade, used to contextualize the levels of investment over time.

The first analytical report was presented to the staff of the ARC and the (then) National Department of Agriculture (NDA) in August 2006. Thereafter the analysis was completely revised after a further three month revision of the categorization of the functions. A further process followed in which unallocated program overheads were assigned to the relevant functions in order for the expenditure estimates to match the institutional expenditure control totals. This second version of the database formed the basis of a second report on government expenditure trends — presented in summarised form by Prof Phil Pardey at the 2007 AEASA Conference. This version of the long-run data series suffered from trend breaks around FY1975 and FY1994. The first coincided with the change in budget reporting structures and the second with the introduction of the new constitutional dispensation under which agriculture became a shared competence between national and provincial governments. These trend breaks was addressed through the collection of even more detailed data from the appropriation reports of the Department of Agricultural Technical Services and the National Department of Agriculture. The assistance of the staff at the Directorate of Finance of the National Department of Agriculture — especially Koos Geldenhuys and Andries Wessels — who assisted in finding and copying the appropriate sections of the huge volumes of appropriation reports from the archives of the Finance Section is hereby recognized. These documents are only kept for 15 years and were apparently destroyed soon after I collected it.

The third and final version of the long-run data series with all the structural problems addressed was published as an InSTePP Working Paper in January 2010 — six years after the first data entry commenced. Since then the management of the Agricultural Research Council and the Department of Agriculture have on several occasions used this resource to motivate and defend budget applications for research in Parliament. Other outputs that used this long-run database was a presentation at the 2010 AARES Conference in Adelaide and the USDA-ERS Conference in May 2010 on Global Agricultural Productivity Trends. Locally two presentations were made by myself and the material used by others in a number of local policy symposia and workshops. Two journal articles in Agrekon have been published in 2011, the first of which received the SJJ de Swardt Award from AEASA.

All the datasets are updated annually and the process of updating the database takes approximately a month spaced over 6 months as information is released from the various sources.

CHAPTER 5

PUBLIC SECTOR SPENDING AND SUPPORT OF AGRICULTURE

5.1 INTRODUCTION

In tracking the one hundred year history of the agricultural sector in this country the trends in agricultural production and input use are perhaps better understood if placed in the historical context of the policy eras in government policy on agriculture (Chapter 2). The changes in policy are described here through the influence this had on the spending patterns of government on both service delivery and support to farmers and industry organizations. The focus is primarily on the expenditure of the departments of agriculture and other public institutions, such as the Agricultural Research Council, that was established from the institutes of the Department of Agricultural Technical Services. Undoubtedly, other institutions, such as the Land Bank, Organised Agriculture, the Control Boards and the Agricultural Credit Board (to name a few) also played a major role. The primary aim of this study, however, is the role that direct public sector support and policy direction played in the development of the agricultural sector.

Many of the rural development and policy interventions that became well known in later years were already implemented in some form under the earlier colonial governments. Examples of these are the labour colonies of the Dutch Reformed Church that preceded the later farmer settlement on irrigation schemes that enjoyed emphasis between the 1930s and the 1960s; the earlier forms of organised marketing of wool and ostrich feathers; farmer assistance programs and regulatory programs to combat animal diseases. These programs and the acts and policies governing them were incorporated in the administration of the Union of South Africa. A concerted effort was made since the establishment of the Union to consolidate these initiatives. For regulatory services familiar early initiatives were the Agricultural Pests Act (Act 11 of 1911); Diseases of Stock Act (Act 14 of 1911) and the Land Settlement Act (Act 12 of 1912) and for the marketing of agricultural products the Marketing Act (Act 26 of 1937). In the field of financial support to farmers the Land Banks of the Transvaal, Natal and the Orange Free State were closed down in 1912 and there assets and liabilities transferred to the Land and Agricultural Bank established under the Land Bank Act (Act 18 of 1912).

The purpose of the analysis here is to briefly highlight how the policy focus of government with respect to agriculture evolved over time in order to contextualize the trends in the more detailed long run data series on public sector investment in agricultural R&D as analysed in Chapter 6.

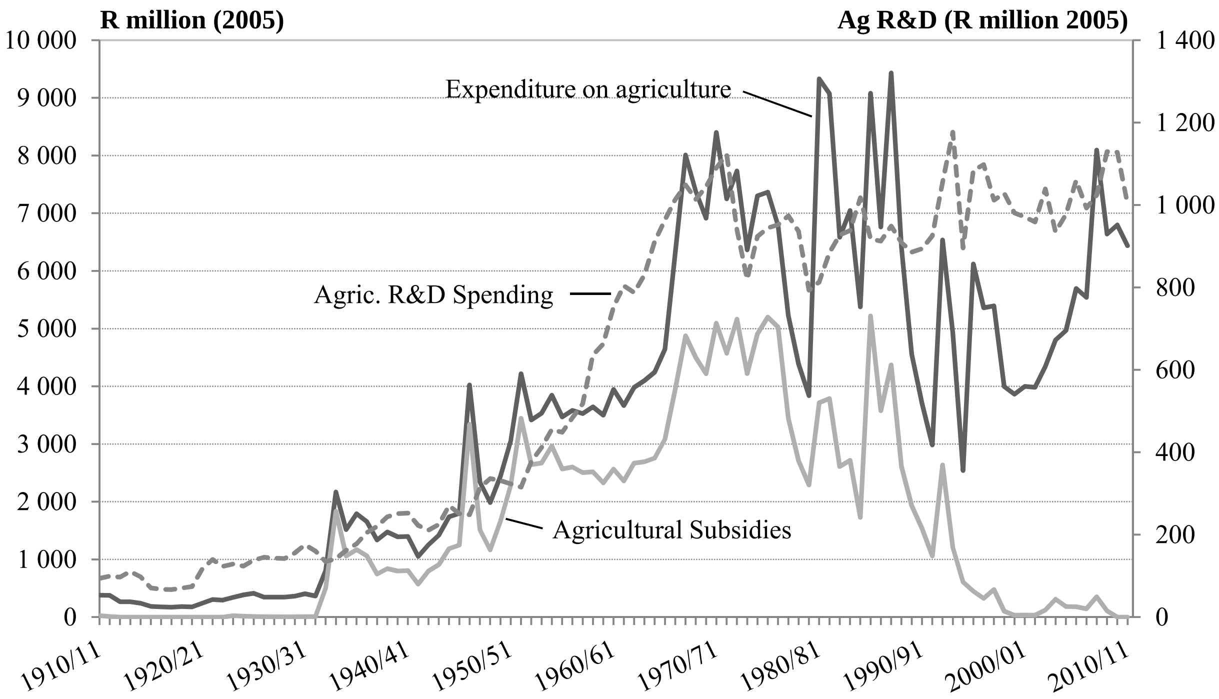
5.2 GOVERNMENT EXPENDITURE ON AGRICULTURE

Government spending on agriculture reflects shifts in priorities since the establishment of the Union government in 1910 (Figure 5.1, Panels a and b). During the first two decades after the establishment of the Union expenditure by the Departments of Agriculture fluctuated at fairly low levels of around 4 to 6 percent (R267 to R340 million in inflation adjusted values) of total government expenditure. This period was characterised by high levels of poverty and recessionary phases in the economy (Lumby, 1990). Spurred by the depression and the subsequent drought and aided by the changing fortunes of the gold mining sector the insights gained from the Carnegie Report provided the stimulus for government to increase its levels of investment in agriculture and rural infrastructure starting in FY 1933 — spending on agriculture increased from 7.7 percent of total government expenditure in FY 1932 to 16.9 percent in FY1933. This largely took the form of subsidies aimed at soil and veld reclamation interventions and subsidies on the transport of livestock and fodder to and from drought stricken areas and marks the earliest steps in policy change to the era of industrialization of farming in South Africa.

With the outbreak of the Second World War spending on agriculture declined slightly, but in FY1942 the share of government spending on agriculture again increased to reach 14.2 percent (R4,024 million) in FY1947 from where it erratically decreased to reach 2.3 percent of total government expenditure in FY1980. The drought relief payments and subsidies paid to assist farmers in marginal crop production areas to switch to livestock farming increased the share of public spending on agriculture to reach 5.07 percent in FY 1981, which mark the shift in policy development to the phase of deregulation aimed at achieving 'optimal production in agriculture' (DAEM 1984). From here the share of government spending on agriculture declined to reach 1.7 percent of total government expenditure in FY 1994. The change to a fully democratic dispensation in 1994 marked the change to a new era in policy development in agriculture. With the closure of the control boards and the scrapping of the Agricultural Credit Board from 1996 to 1997 most of the support programs administrated by them also ceased to exist and spending on agriculture stagnated around 1.4 percent of total government spending during this policy phase.

Agriculturally related spending by other government departments has changed markedly since the early half of the century. In the 1920s, for example, spending by non-agricultural departments added the equivalent of 20 percent to the annual spending by the agricultural departments (Union of South Africa 1922). Currently agricultural related spending by non-agricultural departments amounts to about 5.9 percent of spending by the agricultural departments — inclusive of the provincial Departments of Agriculture and the Agricultural Research Council (Dept of Finance 2009).

Panel a: Public expenditure on agriculture and agricultural R&D



Panel b: Share of total government expenditure

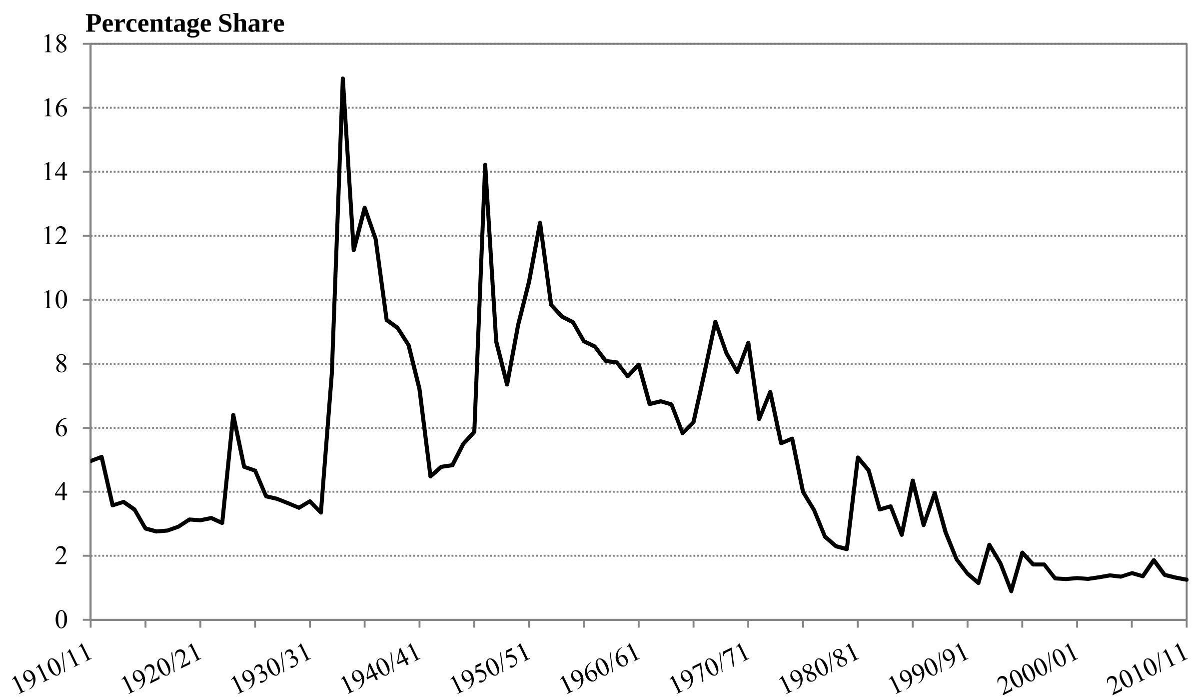


Figure 5.1 Government Spending on Agriculture; 1910 — 2010

Sources: Union of South Africa (1910 - 1959), RSA (1960 - 2009), and ARC (1993 - 2009).

The spending relativities among public agricultural R&D and the supporting technology transfer and regulation cum inspection services has also shifted, in some cases substantially, over the years. Figure 5.2 shows that R&D accounted for a fluctuating but generally slowly growing share of agricultural spending from FY1911 (28.8 percent) until 1998 (74 percent). Thereafter it declined precipitously to a 46.5 spending share by FY2011 occasioned by a dramatic decline in both the nominal and inflation-adjusted commitment to agricultural research during this period as well as an increase in spending on administrative and regulatory services.[1] Up to the 1930s the primary focus was on the delivery of regulatory services in response to pest and disease outbreaks (1910 through 1930) and the emphasis on soil conservation works in the aftermath of the drought of the early 1930s. From FY 1934 through to FY 1945 the share of research increased markedly as the emphasis in public spending shifted to address rural poverty problems through promoting the 'industrialization of farming' and in response to the growing demand for the technical services of the Department of Agriculture (Du Toit 1954). This shift in public spending emphasis from FY1934 marks the onset of a new phase in policy and lasted until about 1980, but in terms of the relative position of agricultural R&D the change came in FY1972 with the transfer of the faculties of agriculture to the responsibility of the Department of National Education (Chapter 6)

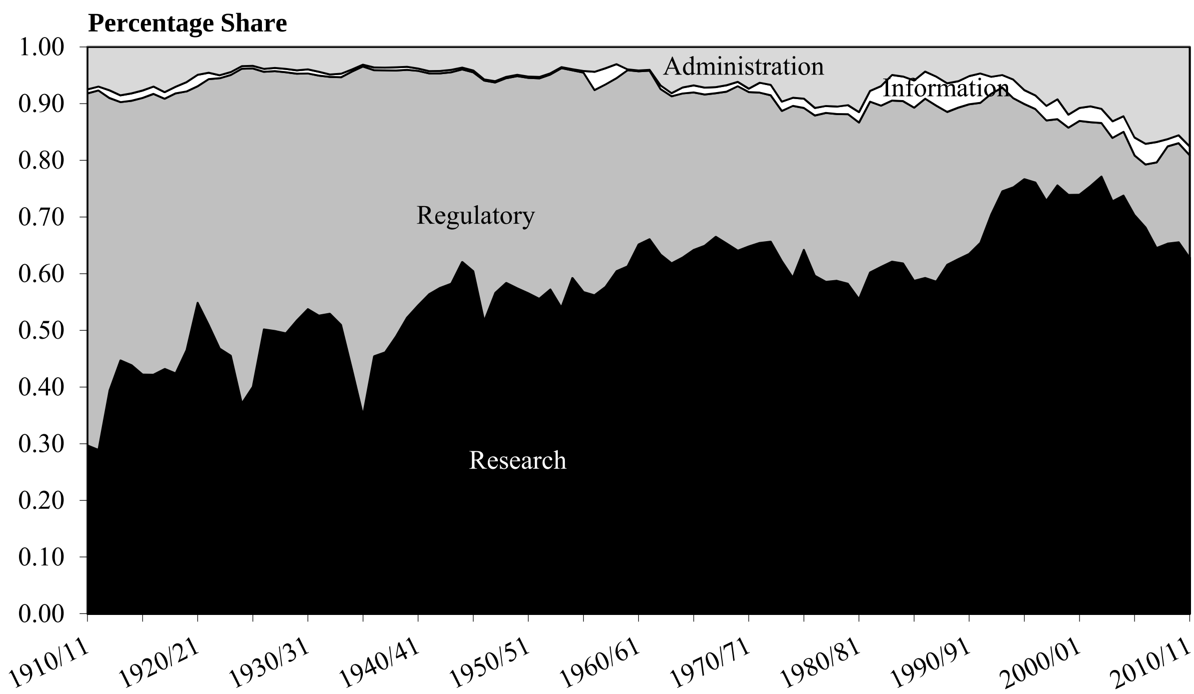


Figure 5.2 Public Spending on Agriculture by Service Category, 1910 — 2010

Sources: Union of South Africa (1910 - 1959), RSA (1960 - 2009), and ARC (1993 - 2009).

[1] The reported increase in the share of administrative costs may in part reflect changed accounting practices, wherein some costs previously charged directly to R&D programs are now treated as a central overhead cost.

Not shown in this graph are the farmer support subsidies and general assistance payments to agriculture that (as will be shown in the next section) for many decades were orders of magnitude larger than the funds directed to research and technically related services. These support payments were reported as a separate budget vote in government budgets and some elements (such as interest subsidies and soil conservation) were included in the budget votes of non-agricultural departments responsible for the administration of these programs.

5.3 SUPPORT PROGRAMMES

In FY1911 support to agricultural development took the form of subsidized imports of breeding stock, steam ploughs and a strong focus on the training of students both locally and abroad (Table 5.1). The level of spending on agriculture grew rapidly during the drought that followed on the depression of the early 1930s. Drought relief programs were introduced and a strong drive to curb soil and veld erosion were introduced, whilst a program to 'Train Rural Unemployed People' began to take shape in 1925 as an initiative of the Department of Labour (Union of South Africa 1926). This program was transferred to the Department of Agriculture in 1930 and a decade later to the Department of Land Affairs (Union of South Africa 1941) to become the main farmer settlement drive of government for the next three decades. Credit support by means of subsidized loans through the State Advances and Recoveries Office governed by the Farmers Assistance Board — later to become the Agricultural Credit Board — also became the responsibility of the Department of Land Affairs.

Starting in the 1930s support to farmers was aimed at purchases of land, infrastructure development in a broad sense, production credit and subsidized soil conservation works. Beginning in the late 1950s and continuing through to the 1980s industry support subsidies were introduced, examples of which were the stockpiling of butter and public funding of export losses which together with support provided through the Credit Board dominated public spending on agriculture from the 1970s through to the late 1980s. Substantially increased public investment in agricultural research and development preceded industry support and continued to grow until the mid-1970s whereafter it stagnated.

The ability to maintain high levels of support payments to farmers came under pressure in the mid-1970s as a result of domestic security considerations and the tough international economic conditions at the time. The drought of the early 1980s, forced another increase in support to farmers soon to be followed by the introduction of a 'land use conversion' initiative to shift cropland in marginal production areas out of crop production into livestock farming on planted pastures. By the early 1990s

Table 5.1 Agricultural Subsidy Payments in South Africa; Ten-Year Averages from 1910 to 2010

Type	Notes	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
		Rand million (2005)									
Export Subsidy	Administrated by DoA	-	-	3,371	-	-	-	-	-	-	-
General Assistance	Unspecified	-	-	-	12	14	5	-	161	429	526
Crop Insurance		-	-	-	-	-	-	75	374	-	-
Fencing		0	-	-	-	-	-	-	-	-	-
Fertilizer		-	-	-	625	2,193	5,816	5,012	578	-	-
Food Price	Mostly to cover losses on trade	-	-	243	7,331	19,859	22,251	27,697	19,674	1,458	-
Housing	Incomplete history; first introduced in 1929	-	-	-	-	-	-	24	17	101	-
Mechanization	Importation of Steam Ploughs in Natal	18	-	-	-	-	-	-	-	-	-
Inputs	Seed purchase	-	2	-	-	-	-	1	72	12	-
Settlement in Designated Areas	Encourage settlement in border regions affected by terrorist attacks	-	-	-	-	-	-	-	295	49	-
Silo Construction	Part of Soil conservation and veld improvements initiatives	-	-	32	32	7	0	-	-	-	-
Storage	Construction of bulk storage facilities	-	-	-	-	-	-	16	57	-	-
Transport	Railway subsidy on transport of Fruit, Wool & Mohair, and Wattle Bark	-	-	153	-	-	-	-	-	-	-
Drought Relief	Mainly railway subsidies on transport of livestock and fodder	-	34	700	2,862	991	967	722	2,816	518	620
Flood Relief		-	-	-	-	-	30	64	-	-	-
Debt Relief		-	-	2,232	1,116	9	99	2,155	5,718	5,386	10
Conservation	Subsidies on conservation works	4	0	106	132	96	300	340	350	3	0
Co-operatives		-	-	-	-	-	-	46	42	35	-

Table continue...

Table 5.1: (Continued)

Type	Notes	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
		Rand million (2005)									
Industry Assistance											
Citrus		-	-	-	37	3	100	30	0	-	-
Cotton		-	-	-	-	-	13	3	50	-	-
Dairy	Subsidy on butter	2	-	424	620	1,942	2,763	2,406	126	-	-
Egg		-	-	-	-	-	23	11	-	-	-
Fruit		0	-	126	122	-	-	-	160	-	-
Industry		-	-	-	-	-	-	-	-	31	3
Livestock	Subsidies to Farmers for Purchase of Bulls in Cattle Improvement Areas	9	1	108	105	-	-	-	27	-	-
Maize		-	-	439	138	395	6	4	651	3	-
Meat		-	40	53	14	0	-	266	176	-	15
Mohair		-	-	-	-	-	-	11	-	-	-
Oilseeds	Subsidy to promote the planting of oilseed crops following WWII	-	-	-	-	131	-	-	-	-	-
Rooibos		-	-	-	-	-	-	-	17	-	-
Sorghum		-	-	-	-	-	150	233	11	-	-
Sugar		-	-	-	4	-	-	-	76	-	-
Tobacco		-	-	-	-	-	-	-	-	-	-
Vegetables		-	-	-	-	-	88	80	346	2	-
Wheat		-	-	-	46	-	-	-	5	-	-
Wine		3	-	-	6	-	-	-	-	-	-
Wool		-	-	-	-	875	134	896	83	113	-
Field crops	Support of experiments	1	-	-	-	-	-	-	-	-	-
Total		37	77	7,988	13,201	26,516	32,745	40,089	31,882	8,142	1,174

Sources: Union of South Africa (1910 - 1959), RSA (1960 - 2009), and ARC (1993 - 2009).

all subsidy support to farmers was phased out. The increased public support payments to farmers since 2000 came as a result of the Land Reform and Restitution initiatives implemented beginning in the late 1990s.

From Figure 5.3 it is clear that support payments differed markedly between industries and that the consistent emphasis was on (what is classified here as) general subsidies — soil conservation works, and drought and credit subsidies. The field crop industries, in particular staples such as maize and wheat, benefited the most from the subsidy programs, followed by livestock. The horticultural industries first saw the introduction of subsidy payments during the Second World War in aid of assisting farm incomes when exports of fresh fruits were impossible. The latter were considered an embarrassment by fruit producers at the time (Black, 1952).

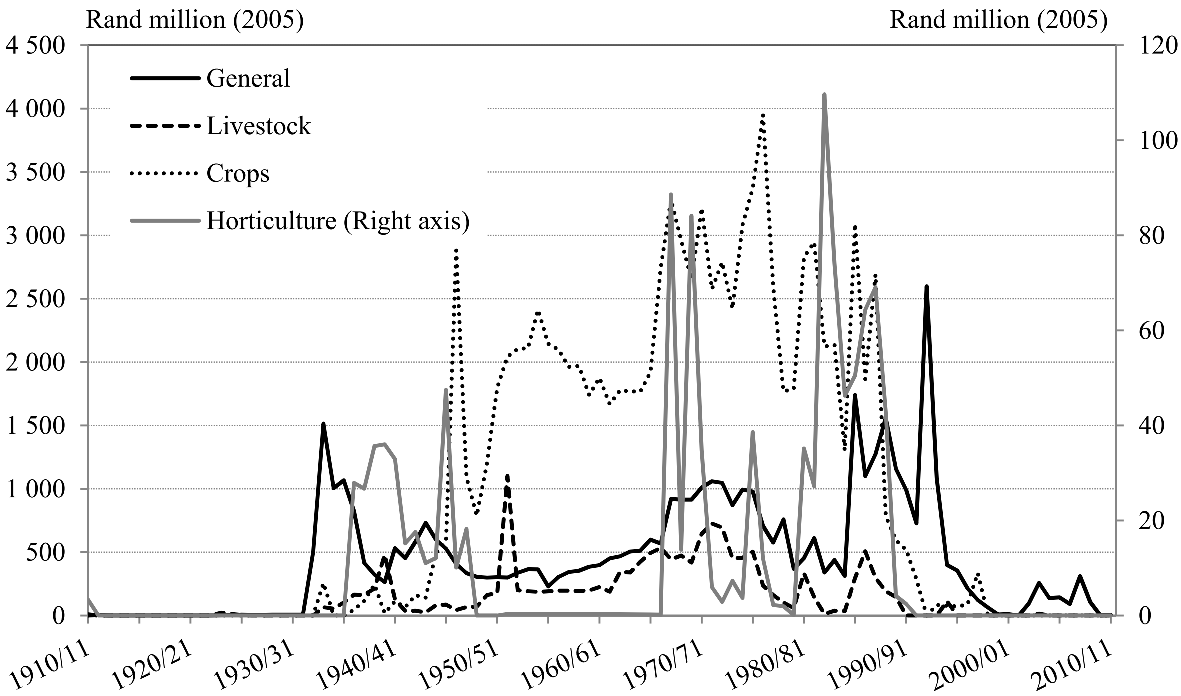


Figure 5.3 Industry Support versus General Support Payments, 1910 — 2010

Sources: Own Calculations from Union of South Africa (1910 - 1959), RSA (1960 - 2009), and ARC (1993 - 2009).

5.4 FARMER SETTLEMENT AND ASSISTANCE SCHEMES

The picture that emerges from the spending relativities described above fails to fully capture the support given to farmers under the farmer settlement programs, especially for the earlier half of the century. This took the form of subsidized loan schemes to farmers, the subsidy equivalent of which is not included in the expenditure estimates reported above. In this section the history of the earlier state sponsored farmer settlement is briefly discussed as this undoubtedly impacted on productivity trends in the sector.

During the two Anglo-Boer Wars the Colonial Government of the day created the Cattle Preservation Department, which did not, however, function efficiently — this was in addition to initiatives such as the labour colonies established by the Dutch Reformed Church. In December 1901 the first Land Board was appointed which took over the assets and functions of the Cattle Preservation Department to establish the Squatter's settlements at Pietersburg, Zeerust, Potchefstroom and Ventersdorp. These settlements, however, did not serve the purpose for which they had been created. Two pieces of legislation were required to aid in farmer settlement. The first was the Settlers Ordinance of 1902, in terms of which the Lieutenant - Governor was authorized to divide Crown lands into farms and allocate them. The next was the Crown Lands Disposal Ordinance of 1903 which made more liberal provision for the allocation of Crown land and the granting of advances to provide for farming requirements.

5.4.1 Schemes introduced from 1956

A brief summary of the history of the main schemes that served to support farmer settlement and the nature thereof as summarised in the *Farming in South Africa* (DOA 1960) is reported here to illustrate the nature of past farmer settlement initiatives.

The Department of Lands came into existence when the Union was established on the 31st of May, 1910. Its functions included the administration of all matters relating to Crown lands, irrigation, land settlement, land boards and surveying. On 16 October, 1912, the Land Settlement Act (Act 12 of 1912) came into force. This act originally was a rehabilitation measure since it aimed at rehabilitation: placing suitable people on Crown lands so that they could contribute to the progress and prosperity of the country in the agricultural field, and above all making independent citizens of those to whom Crown land had been granted. The amended Land Settlement Act (Act 21 of 1956) introduced three important schemes in terms of which Crown land was granted to suitable applicants:

Scheme 1: Section 20 of the Land Settlement Act of 1956. as amended (also known as the one-tenth contribution acquisition system).

In this case the applicant chose the land for which he[2] intends to apply and obtained an option to purchase from the owner at a reasonable price. If the applicant satisfied the prescribed requirements and the acquisition was approved he had to pay at least one-tenth of the approved

[2] Applicants were restricted to men only.

price, subject to the provision that the State's maximum contribution amounted to R10,300 at the time.

During the first two years the settler made no payments, but the interest for this period — 4⅞ per cent — as well as transfer costs, were capitalized in the price of the land. The annual payment was calculated over a 63 year period. If the settler satisfied all the prescribed conditions after 5 years, he was entitled to the title deed, after which he could make use of the land at his own discretion (implying that prior to this point he had to heed the advice of extension officers).

Scheme 2: Granting of land in terms of Section 23 of the Land Settlement Act of 1956.

Vacant Crown land or land that was reverted to the state was divided into economic farming units, was offered for allotment in the Government Gazette and press in terms of this scheme. The land was rented to the successful applicant for five years. This period could be extended to a maximum of 10 years, but it was a condition that the option of purchase be exercised within the second period. When the option to purchase was exercised, the price with interest was redeemed over a period of 65 years.

The successful settler paid no interest for the first two years in this case, but as with Scheme 1, the interest for the first two years was capitalized in the purchase price. The settler paid 2 per cent rent calculated on the sale price of the holding during the third year, and from the fourth year the rate of interest was 4⅞ per cent per annum.

In the case of grants made in terms of Section 23, settlers were entitled to conveyance 10 years after the commencement of the lease on condition that they satisfied all the conditions laid down by the Act.

Scheme 3: The allotment of land in terms of section 29 of the Land Settlement Act of 1956 (i.e. allotment of farming units to successful applicants as probationary lessees in closer settlement areas).

Under this scheme, which was limited mainly to irrigation areas, the size of the incorporated irrigable land varied from 15 to 30 morgen (approximately 12 to 25 hectares) per holding. Initially a temporary occupation right of a maximum of 5 years was approved and the probationer lessee regarded as a trainee. He usually had little or no expense in the cultivation of his holding at the beginning, except for labour costs which he had to pay himself. Probationary lessees were under the supervision of trained agriculturists during the probationary period. The time taken to complete the training course satisfactorily depended entirely on the efforts and initiative of the trainee. After expiry of the probationary lease — usually from 18 months to 2 years — the holding was granted on the same provisions as described in Scheme 2.

Provision was also made for the payment of subsistence allowances and the provision of medical services to probationer lessees. These costs were recovered from crops and any other income which may have accrued to the probationary lessee from time-to-time. During the probationary period the State took a quarter of all crops sold to cover the cost of feed, fertiliser, etc. with which the probationer lessee was provided. A third of the balance was kept in trust for the probationary lessee and the balance was paid to him after any recoverable debts, such as the medical services mentioned above, had been deducted.

In 1960 the activities of the Department of Agriculture in terms of the above-mentioned three schemes were summarised as follows (DOA 1960):

Section 20 (i.e. the one-tenth contribution acquisition system): Between 1912 and 1959, 8,261 holdings were purchased on behalf of successful applicants. These holdings covered an area of 4.17 million hectares and were granted at the probationary value of R38,435 million (nominal values). A large number of these settlers had taken transfer while others had ceded their interest in the leases to other non-landowners.

Section 23: The allotment of vacant Crown land: Between 1912 and 1959, 12,648 allotments, covering a total area of 10.34 million hectares valued at R27.96 million (nominal values) were granted to successful applicants. As in the case of acquisition in terms of Section 20, there were a large number who had taken transfer, while some settlers had ceded their leases to approved non-landowners.

Section 29: The allotting of farming units in more densely settled settlement areas: The planning of settlements in farming units was a very important aspect and done in conjunction with the Departments of Water Affairs and Agricultural Technical Services. In denser settlement areas a house and out- buildings were erected on each holding which was fenced, partly cleared and levelled. These expenses were included in the purchase price.

Grants to settlers: Between 1912 and 1960 it is estimated that R5.00 million (nominal values) were granted to settlers as advances in terms of the various sections of the Land Settlement Act. These advances included the acquisition of cattle and fixed improvements.

From information available on income generated by the few *Section 29*irrigation schemes settled by 1960 indicates that they already began to make a contribution to the national income of agriculture around the second half of the 1950s.

5.4.2 Contemporary support initiatives

The contemporary farmer settlement initiatives under the Land Reform and farmer settlement initiatives (chapter 2) implemented since 1994 were discussed in Chapter 2. Three salient features of the earlier, pre-1975, schemes that contrast with current land reform and farmer settlement initiatives are, 1) that probationary farmers had access to a comprehensive package of support measures ranging from access to credit and technical support through to social support initiatives such as medical services and education; 2) the cost of which were expected to be repaid to some extent — forcing a degree of accountability and re-capitalization of the program; and, 3) they were aimed at creating owner operated farming enterprises — through the policy that hired labour had to be paid for by the probationary farmer. Current initiatives meet none of these criteria. The purchase of land is funded through grants to individual applicants, groups of prospective farmers and, more often, communities. Little or few restrictions are placed on the subsequent management of the farm. The new entrants receive little or no training and have access to an extension service that has been strained since the late 1970s (see chapter 6). This is fundamentally different from the comprehensive, dedicated and integrated education and support programs that evolved from the *Training of the Rural Unemployed* of the late 1920s through to the 1960s. Finally, the credit facilities provided by, primarily, the Agricultural Credit Board were administrated by former extension staff of the Department of Agricultural Services and were designed to serve a measure of rural cum social development interests. The current approach of providing credit to newly settled farmers through the Land Bank stands in contrast to this as the Land Bank has always had a financing mandate with no social development objectives.

5.5 CONCLUSION

The growth in agricultural production in South Africa was backed by a strong growth in the level and scope of policy incentives to develop the sector. Direct subsidy support to farmers only really started to come into effect in the 1930s with the main emphasis being placed on drought relief, credit support and soil conservation works. These subsidy and support programs remained in place until the 1980s whereafter it was phased out and eventually terminated in 1997. Whereas the initial focus of government spending was primarily on the provision of regulatory services, the focus shifted toward the provision of research and development services — which remain the biggest emphasis to date, albeit within a relative decline in the proportion of government spending assigned to agriculture. A key feature of the settlement schemes of the day was that beneficiaries had to repay the benefits received albeit at subsidized rates and the education and support initiatives had a focus that addressed rural needs in general.

CHAPTER 6

SOUTH AFRICAN AGRICULTURAL RESEARCH AND DEVELOPMENT

6.1 INTRODUCTION

It is generally accepted that the agricultural sector is an important source of long-term economic growth for the South African economy, as it is for many other economies around the world (Van Zyl et al. 1988). In turn agricultural R&D is seen as a significant source of growth for the sector (Thirtle and Van Zyl 1994). Hence, science and technology policies are inextricably intertwined with the country's long-run economic growth and development performance. Science and technology policies are also interconnected with trade policies — as exemplified by numerous biosafety, phytosanitary, intellectual property and other regulatory aspects that directly affect the cross-border flows of new knowledge and new technologies. They also play a role in foreign policy more broadly, not least as a source of knowledge and technology spillovers to other parts of Africa. In addition, one of South Africa's overarching policy goals is to redress the inequities of the apartheid era and help families rise above and move beyond the restraints of that regime. Thus, not only the economic efficiency but also the income distribution implications of (agricultural) R&D have a bearing on overall science policy objectives, along with the details by which those policies are implemented.

As with the rest of the economy, the South African agricultural sector (especially the fruit, wine, and sugar industries) have long been dependent on exports, increasingly so since democratization in 1994.[1] Thus the technical changes that (agricultural) R&D bring about are critical for maintaining competitive advantages in international markets, especially in relation to the cost and quality of South African agricultural produce.

[1] For the century since 1910 the agricultural sector in South Africa has almost always maintained a positive trade balance. The ratio of agricultural exports to agricultural outputs (AgGDP) was typically in excess of 31 percent (except for the World War II years when it dropped to 18 percent) and reached an all time high of 70 percent in 2005 (DAS 2009). After a downturn that bottomed out at R9.37 billion (constant 2005 prices) in 1993, at the end of the sanctions years, agricultural exports grew thereafter by 5.6 percent per annum to total R18.21 billion in 2006. After the abolition of the controlled marketing era in 1997, the composition of export commodities changed markedly, with fruit (35 percent of agricultural exports), wine (13 percent), and sugar (13 percent) now being the most valuable export commodities, replacing commodities such as wool and maize that were dominant agricultural exports as recently as the 1980s.

All of these aspects give rise to a myriad of financial and policy pressures on the South African science and technology sector (including agriculture), not all necessarily steering these R&D-oriented sectors in the same direction. To disentangle and properly assess the near- and longer-term implications of these numerous policy perceptions requires an understanding of some empirical benchmarks about the evolution of the R&D sector and its current status. Taking a long-run view is paramount. Alston et al. (2008 and 2010) show that the productivity payoffs to agricultural R&D spending in the United States peak after a lag of 24 years and persist for upwards of 50 years; a result that is likely to apply with equal force to other countries, including South Africa. To make meaningful agricultural science policy choices requires that decision makers be cognizant of these long lags, while also adjusting to new and emerging economic realities.

In this chapter an entirely new set of long-run, in-depth indicators of South African agricultural R&D are presented and briefly interpreted.[2] These indicators are also placed in a more comprehensive science policy context. Not only are the technical boundaries between the agricultural and broader bio-sciences blurring, but the policy realities bearing upon agricultural R&D in South Africa are increasingly affected by policy pressures arising elsewhere in the economy. Juxtaposing general science developments against corresponding agricultural R&D trends informs, and thereby, hopefully, will improve these inter-related policy processes. It also helps shape private (including pre-, on-, and post-farm) decisions as well; an important consideration given the private sector's increasingly important role in South Africa as both a funder and performer of R&D, in conjunction with its longstanding role as a user of the results of research.

Technical change requires much more than the new ideas and new technologies that flow from R&D. It also requires supporting regulatory and technical services to facilitate the transfer, uptake, and efficient use of these technologies. Some elements of these policy measures are discussed in greater detail in Chapter 5. Here, some attention is given to the broader technology support services and public spending developments as it impacted on agricultural R&D.

Finally, the increasing international interconnectedness of science and technology demands that domestic policy formulation processes be fully cognizant of rest-of-world developments. To this end some of the South African science spending indicators are compared with the international setting. In particular selected comparative R&D indicators for the United States and Australia are presented.

The structural changes discussed in chapter 2 point to a long period of both physical and economic expansion in agriculture stretching from 1910 through to the 1950-1970 period. The 1950s and 1960s

[2] Parts of this chapter draw- and build on and extend earlier work by Liebenberg and Kirsten (2006), Liebenberg et al. (2004) and Roseboom et al. (1995).

were a period of transition (at least for commercial agriculture), characterized by continued economic growth of agriculture, but growth that took place in the context of farm consolidation, a continued, and perhaps even accelerating change in the composition of farm output, and a movement of labour out of agriculture as opportunities in other sectors of the economy competed for labour used within agriculture. These sizable structural shifts have important implications for — and in turn have no doubt been affected by — the amount and nature of R&D and the accompanying technical and institutional changes striving to sustain economic development and productivity growth in agriculture going forward. It is to these developments in science and technology that I now turn.

6.2 General Science and Technology Developments

The beginnings of organized scholarly and scientific endeavours in South Africa trace back to at least the formation of local professional societies. Marais (2000, pp. 176-178) reports that the South African Institution and the South African Literary Society, both established in 1829, were amalgamated three years later to form the South African Literary and Scientific Institution. The South African Philosophical Society, forerunner to the Royal Society of South Africa, was established in 1877. Almost 30 years later, in 1903, the South African Association for the Advancement of Science was formed and began publishing the *South African Journal of Science*, probably the best known scientific journal in South Africa.

Citing Kingwell (1990, pp. 4-5) and Smit (1984, p. 6), Marais (2000) noted that the Industries Advisory Board (IAB) formed in 1916 "… was the first attempt in South Africa at public support for academic and industrial research…(p.177)." However, public support for agricultural R&D in South Africa (and its precursor republics and colonies) preceded the activities of the IAB by several decades. In fact, the kudos for the earliest organized and publicly supported R&D in South Africa likely rests with a range of research activities funded by and largely carried out within the Departments of Agriculture of the former Boer Republics and Colonial government[3]. *The Cape Agricultural Journal* published by the Department of Agriculture of the Cape Colony first appeared in 1889 and reported on the results of research carried out by the Department plus other scientists working in other institutions. For example, research into rinderpest — a highly contagious viral disease, often fatal for domesticated cattle — was undertaken during the 1890s by Professor Theiler, the veterinarian for the Transvaal

3 Several examples exist of agricultural R&D activities that pre-dates the examples mentioned here. Sim (1952: 115) mentions that since the Elsenburg School of Agriculture was opened in 1898 "a considerable amount of research on grain growing was conducted". In fact, and if selection trials can be regarded as agricultural research, the May 1952 edition of *Farming in South Africa* frequently refer to the initial trials of Jan van Riebeeck to test and select suitably adapted cultivars of vegetables, grains and fruits to produce in the colony.

Republic (Diesel and Fourie 1952). The Transvaal Department of Agriculture established a Veterinary Bacteriology Laboratory in 1897 followed by a Division of Chemistry in 1902 that surveyed, classified and systematically studied the soils supporting South African agriculture (De Villiers 2002).

Notably, harnessing research done elsewhere to address the production problems of South African farmers (R&D spillovers in contemporary economic parlance) was a feature of publicly supported agricultural research since its inception. Union of South Africa expenditure reports show that Professor Nuttall of Cambridge University was commissioned in 1911 to investigate the causes and control remedies of East Coast Fever. [4]

In common with many Commonwealth States, it took until the period immediately following World War II before government ramped up its policy attention to science and technology and public support of R&D (Pardey, Roseboom and Anderson 1991). The Council for Scientific and Industrial Research (CSIR) was established in Pretoria in 1945 under the leadership of Basil Schonland who had been a scientific adviser to Field Marshal Montgomery. CSIR is now the dominant, and in many cases, the only publicly funded agency undertaking a range of industrial R&D.[5] It also does some research related to forestry and agriculture, including agricultural chemicals, biotechnology, food processing and the environment.

Initially, much of the country's agricultural R&D was decentralized and performed in a set of department-based research institutes (distributed across the country according to climatic zones and the pattern of agricultural production). At least in earlier times, these Departmental based Research Institutes had comparatively close links to publicly supported extension agents and university researchers, with a legal framework to foster further physical and institutional integration by way of the Stellenbosch-Elsenburg College of Agriculture Act of 1926 (Act 45 of 1926). Public medical research was also based in a range of Departmental based Research Institutes.

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4 In fact the Estimates of Expenditure of the Union of South Africa for the fiscal year 1910-11 reports that the Department of Agriculture obligated Grants-in-Aid to the amount of £18,000 to various agricultural societies and provided funding for bacteriologists, veterinary laboratories and various other research-related activities or divisions, such as Botany and Agronomy, Tobacco and Cotton, Horticulture, Viticulture, Entomology. These funds also helped underwrite the cost of maintaining government run agricultural and experimental farms. These agencies and activities constituted the research and extension capacity of the Agricultural Department of the Boer Republics and colonies that formed the Union of South Africa in the early part of the 20th Century. Additional allocations of a research nature were made under Vote 21 for Agricultural Education, which included support for the agricultural colleges and the experimental farms attached to them. Research infrastructure support also received significant allocations from the Public Works Department, and the Buildings, Furniture and Fittings Vote. On average additional expenditure from other government departments to the agricultural portfolio amounted to roughly 20 percent of the total budget allocation for agriculture (including research) and agricultural education during the formative years of the Union of South Africa.

5 CSIR's industrial R&D agenda included research in radar, nuclear physics, nuclear weapons, aeronautics, operation research, and command and control technologies, and over time has expanded to include research on mining, transport, construction, testing and standards and environmental studies.

In the late 1980s the state science system was re-organized into a set of Science Councils organized around scientific disciplines or fields of science (for example, the Council for Geosciences and the South African Bureau of Standards) as well as the Foundation for Research Development (FRD) that was spun out of CSIR as a funding agency. The present nine statutory Science Councils are each constituted through their own act of parliament and report to different ministers. The Agriculture Research Council (1992) was the last of the Councils to come into being, literally on the eve of democracy.

A White Paper on Science and Technology (DACST 1996) introduced an "innovation system" approach to science and technology policy formulation in South Africa. The public policy instruments to finance R&D also drew attention in the White Paper. Prior to 1996, public-sector support for R&D was channeled through two Parliamentary Votes. An Education Vote involved a block grant approach to funding R&D conducted by the universities. The Science Vote had three lines of funding for R&D. One involved block funding earmarked for research carried out by the universities and managed on an agency basis by the Foundation for Research and Development and the Medical Research Council (MRC). Another involved a line of base funding for each of the statutory Science Councils. A third line of funding was a competitive funding mechanism for research conducted by private institutions. Provision was also made in the White Paper related to tracking and evaluating science. This led to the introduction of a Performance Measurement System for the Science Councils and the re-vitalization of the then moribund series of R&D Surveys. It was hoped that the new funding mechanisms would steer the Science Councils to realign their activities to the goals of the government's Reconstruction and Development Program, which happened to some extent, but by and large the Science Councils carried on with their core business with little substantive changes.

Over the past decade and a half there were a series of measures to promote innovation including direct financial support for research by way of the Support Program for Industrial Innovation (1993), the Technological Human Resources for Industry Program (1993), the Innovation Fund (1997), the South African Research Chairs Initiative (2005), as well as indirect support by way of the enhanced tax allowance for industrial R&D (RSA 2007). Higher education has also been restructured, largely with the intent of undoing the divisions of apartheid, promoting redress through laws on employment, procurement and asset equity, and facilitating foreign students or foreign trained professionals to study or work in South African universities and Science Councils. Notably, in 2004 a journal subsidy scheme administered by the Department of Education saw a dramatic increase in the grant paid per publication authored by university academics.[6]

6.3 Performance of Public Agricultural R&D

6.3.1 Institutional history

Formal agricultural research in South Africa pre-dates the establishment of the Union of South Africa, with some research institutes, for example Onderstepoort, established in the Zuid Afrikaanze Republiek in 1897. The evolution of the research service largely parallels that of the Department of Agriculture until the early 1990s, as described by Roseboom et al. (1995).[7] The Department of Agriculture was formed in 1910 from 18 divisions that existed under the former British colonies of Natal and the Cape and the two Boer Republics. At that time, the research services were housed almost without exception as subdivisions of the Department of Agriculture's inspection and regulatory services divisions, with the same being true of extension. Certain other research undertakings that today form part of agricultural research were located in various other government departments. An example is irrigation research, which initially resided in the then Department of Irrigation of the Free State republic. Only later did it join and has subsequently remained with the Department of Agriculture. The Chemistry Services Division of the Department of Agriculture, formed in 1910, was the sole public provider of scientific support to the country's regulatory capacity through its analytical chemistry laboratories. It took until 1960 for the Division to be relieved of all its chemical analysis responsibilities for sectors other than agriculture (De Villiers 2002).

[6] The journal subsidy scheme dates back to the mid-1980s. In its current configuration, the scheme retroactively pays South African higher-education institutions for each publication affiliated to an institution that appears in journal titles abstracted by the Expanded Science Citation Index, the Arts and Humanities Citation Index, and the International Bibliography of the Social Sciences, as well as those peer reviewed journals on a supplementary list recognized by the Department of Higher Education and Training (DHET). In 2004 the funding formula was revised and the unit value of each publication increased substantially from around R25,000 per publication to (currently) R105,000. These publication payments now represent an important source of university income. Around 11 percent of the university funding distributed by the DHET is tied to measurable "research outputs," including recognized professional publications and the number of masters and doctoral students who successfully complete a degree. In some instances, a portion of the grant is credited to the academic's research account; in other instances all the funds are retained in a central university account. Each university sets its own policy regarding what proportion of the grant, if any, is passed on to the author(s) of the publication. Notably, the parliamentary allocation to higher education (including payments for research and teaching outputs) is set to rise from R15.3 billion in FY2008/09 to R19.0 billion in FY2011/12 (RSA 2009).

[7] See Roseboom, Pardey and Beintema (1998), Roseboom et al. (2000) and Beintema, Pardey and Roseboom (2004) for earlier perspectives on agricultural R&D developments within South Africa. Beintema and Stads (2004) help quantitatively place South African agricultural R&D within a regional context.

Identifying salient eras in the historical evolution of South African agricultural research is complicated by the numerous structural changes that the Department of Agriculture has undergone in its various guises since its establishment. These institutional changes were ostensibly driven by the changing political and economic developments facing the agricultural sector, which according to Vink (1993) involved three distinct phases of structural change. The first phase (1910-1940s) involved the initial efforts to segregate white and black farmers, in terms of their participation in the economy and their ownership of land. This phase lasted until after World War II.

The second phase (1940s-1980s) encouraged the commercialization of white farming through the adoption of modern mechanical and biological technologies, within a policy environment that favoured expanding the production of large-scale, owner-operated farms. In this period of 'grand apartheid' the balkanization of the country was completed, with the establishment of four 'independent' countries: Transkei, Bophuthastwana, Venda, and Ciskei (TBVC), and another six 'self-governing territories' (SGTs) into which the majority of Africans were corralled on a tribal basis. During this phase, the 'homelands' of the TBVC and SGT statelets operated within a policy environment that emphasized large-scale development projects under expatriate management aimed at cash crop production, such as tea plantations. This strategy came at the expense of efforts to promote staple food production. Politically sanctioned racial discrimination and policy-induced agricultural price distortions proved unsustainable.[8] The pressures to redress these polices began to intensify during the 1980s.

This heralded a third period of structural change, beginning in the early 1980s and still on-going. This phase is largely characterized by a reversal of the policies of the previous two periods; notably removal of the racial barriers between black and white agriculture, and increased liberalization and democratization of the agricultural sector. Other significant drivers of change in the large-scale farming sector include legislation on the security of land tenure of labour tenants working on large farms as well as the stipulation of minimum wages (Deininger and May 2000; Hall 2004). Both of these legislative initiatives are deemed to have reduced the amount of hired labour on farms, although their effect on the use of labour-saving technologies is uncertain. However, other factors were in play. For example, Van Zyl et al. (1995) inferred that the decline in farm employment can be ascribed to distortionary policy measures (tax incentives on depreciation) in the market for capital equipment

[8] Virtually all the major agricultural livestock and grain commodities were marketed though a single channel, namely commodity-specific Control Boards that administered either a fixed price or maintained production controls. The cost of support payments (see Table 1) was severe in years where the subsidies paid in support of protecting farmers domestically against 'exceptionally low' (often heavily subsidized) international prices, but they eventually proved financially and politically unsustainable (Kirsten and Van Zyl 1996).

during the 1970s to 1980s, and the reasons for the continuing decline in on-farm employment since their study was completed has not yet been conclusively identified.

Change processes regarding the agricultural research and extension system followed a similar, albeit slightly different timeline than these broader phases of change affecting South African agriculture. During the first phase, the agricultural research system, then housed largely in the Division of Education and Research, underwent a protracted process to consolidate all the government functions related to agriculture within the Department of Agriculture. Beginning in 1913, the administration of agricultural education, including the agricultural colleges at Elsenburg, Cedara, Potchefstroom and Grootfontein (and Glen in 1919), was transferred from the Department of Education (DoE) to the Department of Agriculture (DoA). In 1920 all extension activities were gradually transferred to the agricultural colleges. In that same year administrative responsibility for the Faculty of Agriculture at the University of Stellenbosch was transferred from the Department of Education to the Department of Agriculture. The Faculties of Agriculture at the Universities of Pretoria and Natal followed in 1940 and 1948, respectively.

During the first 12 years of its existence, the expanding Department of Agriculture gave increasing emphasis to agricultural education. Beginning in 1924, however, the emphasis shifted to providing more extension services. In that year a new Extension Division was established to promote stronger links with the farming community and coordinate the extension effort between the colleges and the various divisions within Department of Agriculture. In addition, it was decided that the five agricultural colleges should concentrate their efforts on the principal farming enterprises in their respective (agro-ecological) regions. For example, Elsenburg was to focus on winter grains and horticulture and Potchefstroom more on summer grains and slaughter cattle. Arguably, this policy placed constraints on the future development of the relevant regions into new or so-called “non-traditional” farming enterprises. In 1926, the colleges were transferred to the Extension Division, which was then reconstituted as the Division of Agricultural Education and Extension, incorporating the Publications Division. Subsequent restructuring during the next two decades saw a shift in focus away from merely transferring knowledge to one of developing new skills and capacities. A concerted effort was also made until the late-1960s to train staff through the provision of bursaries to study abroad in areas where the country had limited skills.

The second substantive phase of institutional change entailed the specialization of services. In 1952-53 the Technical Services branch of the Department of Agriculture was organized into three main branches, 10 national divisions (an additional one was added in 1960), three special institutes (a fourth added in 1956), and six agro-ecological entities referred to as Regional Services and Education (increased to seven in 1961). In 1958 the Department of Agriculture was split into two departments with the new Department of Agricultural Economics and Marketing taking responsibility for developing and administering agricultural economic policy, orderly marketing of agricultural products, government controlled pricing schemes, overseeing cooperatives, commodity inspections, conducting economic surveys of agricultural conditions, collecting statistics, and engaging in marketing research. The Department of Agricultural Technical Services (DATS) focused on production issues and provided services such as agricultural research, education and extension, and certain regulatory and control services (for example, soil conservation and livestock inspection services). During this period remuneration of professional staff was increased substantially.

Early in 1970, responsibility for the faculties of agricultural was again transferred to the Department of Education. This effectively ended the de facto South African version of the U.S. land grant system, wherein the provision of agricultural education, research, extension and training service were integrated into a university based research environment. Soon thereafter (in 1975 to be precise), government expenditures on all non-security departments were severely curtailed to support demands for increased military spending. Extension services were especially hard hit. The farmer settlement program of DACLT was closed and extension officers were directed to work only with farmer study groups within the context of a 'programmed extension' framework. One-on-one visits between farmers and extension officers were discouraged.

Beginning in the early 1980s government structures underwent several additional rounds of rationalization. This introduced a third phase in the development of the nation's public research sector which merged the three departments involved in agriculture into one Department of Agriculture and began the gradual process of establishing national commodity research institutes. The first such institute was the Grain Crops Institute, fashioned from the crop research units within the regional institutes (now known as Agricultural Development Institutes, or ADIs). This change was duplicated in Agricultural Engineering Services in response to recommendations made by several internal committees of enquiry that investigated the provision of agricultural research, extension and training services (Bruwer 1989).

6.3.2 More contemporary developments

In 1984, the move to a tri-cameral parliamentary structure forced the reintroduction of two separate agricultural departments.[9] This reorganization left all the public agricultural R&D agencies residing in a white own affairs department with no mandate to assist in the homeland areas. A notable feature of the public R&D system at this time was the high degree of ineffectiveness of the regional institutes and, specifically, the extension services. Around 40 percent of the total of 809 extension officer positions were vacant at this time, with estimates that a further 329 officers were required to meet the demand for extension services (Bruwer 1989). These inadequacies combined with the growing pressure to deregulate and privatize government services, provided the impetus to establish an Agricultural Research Council in 1992. This Council was to be responsible for all the agricultural research functions of the national government including a mandate to serve farmers in the homelands. It was envisaged that the ARC's establishment would release resources within the DATS to improve the effectiveness of the extension services and allow it to place greater emphasis on 'whole farm planning' (farming systems research).

ARC's establishment marks a possible fourth phase in the institutional evolution of public agricultural research in South Africa. This phase led to a fragmentation of the research and extension services. The establishment of the research focused ARC in 1992 as a standalone parastatal cum public entity was followed by the subdivision of the former seven Agricultural Development Institutes into nine provincial departments of agriculture, paralleling broader public sector changes that came into being as part of the 1994 constitutional reforms. Institutes that formerly operated within broadly defined agro-ecological zones were now structured according to provincial boundaries, which in most cases do not reflect suitable agro-ecological boundaries for conceiving and targeting agricultural R&D. Farmer study group structures that linked with adaptive research and extension activities were severely disrupted, and so too were the institutional arrangements designed to coordinate local initiatives with national research agencies such as the ARC institutes.

With its science council designation, the ARC initially operated under the policy of "Framework Autonomy" (introduced in 1986) funded on the basis of a baseline formula and reporting to

[9] Following a 1983 referendum, a three-chamber parliament divided along racial lines—involving the House of Assembly representing white interests, the House of Representatives representing colored interests, and the House of Delegates representing the interests of Indians—was established in 1984. All government affairs pertaining to agriculture were conducted via a "general" affairs department addressing the concerns of all three chambers and an "own" affairs (technical services) department addressing the specific interests of the House of Assembly and its white constituents. The homelands of the TBVC and SGTs statelets each had their own, supposedly independent, government structures representing the interests of black South Africans, and each with their own Department of Agriculture.

parliament.[10] Oversight of the country's science system was formerly assigned to a Science Advisory Council reporting directly to the State President. This effectively gave the ARC large degrees of freedom in its operations, ostensibly under the guidance of institute-specific advisory panels (that included industry representation) which in practice never became fully operationalized. The national policy on science, engineering and technology institutions (so-called SETIs) was further reconfigured in 1997 with funding mechanisms consisting of a parliamentary grant for core funding and a competitively bidded Innovation Fund designed to direct research toward identified national imperatives (DACST 1996). All non-core income generated through contract research for government departments, industry and the private sector was considered external income, and projects funded by this means were charged on a "full-cost" basis. The principle of selling (research) services to the market is enshrined in the Public Finance Management Act of 1999.

A system wide review of the Science Councils in 1997 (DACST 1998) severely criticized the ARC for its perceived lack of performance, skewed personnel demographics and low involvement in black agriculture and other areas that essentially were the responsibility of the former regional institutes prior to 1994. The ARCs inability to adequately address these criticisms and gain the support from its line department (i.e., the Department of Agriculture) for the maintenance of its funding levels exposed the organization to severe budgetary cuts under the new competitive parliamentary grant system. The first was a 15 percent cut in 1998-99, followed by another 7 percent reduction in 1999-2000, a further 5 percent in 2000-01, and 2 percent cut in 2001-02.[11] These cuts in core funding limited the ARC's ability to honour its informal co-funding agreement with agricultural industries prior to its formation, whereby funding from industry was to be matched on a 30 percent industry versus 70 percent government basis. Levy collection mechanisms were revoked and the industry Control Boards ceased to exist when the new Marketing of Agricultural Products Act came into force in 1996. One immediate, but as it turned out, shorter term consequence was that commodity and producer organizations were no longer able to raise sufficient funds to meet contracted project costs in time to offset the cuts in core funding to the ARC.

Several initiatives have followed since. The first was the creation of a National Agricultural Research Forum (NARF), which as a consensus seeking entity has gained credence as a vehicle to inform the Department of Agriculture and all other stakeholders on agricultural research policy issues. Insights gained from National Agricultural Research Forum deliberations, plus concerns raised by other Science Councils facing similar constraints, moved DACST (which became the Department of Science

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10 The baseline funding included core funding sufficient to cover the "… costs of basic infrastructure (expertise and other capacity) necessary for the realization of the aims of the institution (DNE 1988, p. 43)."

11 In fact all the Science Councils received a large cut in 1998-99, with the exception of the Medical Research Council (MRC) which received a substantial increase in funding to address the HIV/AIDS pandemic.

and Technology, DST, in 2002) to revise its research funding and governance policies under a new national research and development strategy. This new approach a) placed greater responsibility on each line department with administrative responsibilities for a Science Council (for example the Department of Agriculture in the case of the ARC) to fund the science services requested of the Council, and b) created a mechanism for DST and the relevant line departments to fund centres of scientific excellence (DST 2002). Under the guidance of a new national R&D strategy, National Agricultural Research Forum finalized a national agricultural R&D strategy in 2007 that builds on the structures created by DST (DOA 2008).

6.4 General Science and Technology Trends

In FY1966, South Africa's gross expenditure on research and development (GERD) measuring total public and private R&D spending in all fields of science, was R36.5 million ($600.9 million), representing 0.43 percent of gross domestic product (GDP) (HSRC 2007).[12] [13] After growing at an annual average rate of 5.5 percent per year in inflation-adjusted terms during the period 1966 to 2008 (the latest year for which information is available), GERD totaled R21.1 billion (US$4.4 billion) in FY2008, around 0.93 percent of GDP (Figure 6.1).[14] The rate of growth in GERD spending picked up in recent years, averaging 6.7 percent per year from 1993 to 2008, reflecting, in part, the higher priority placed on overall public R&D spending during this period. In contrast, real agricultural R&D spending increased by only 0.06 percent per year over the same period.

Figure 6.2 shows a range of research intensity ratios, including total and public GERD relative to GDP and public agricultural R&D spending relative to agricultural GDP from FY1966 through to FY2008. Overall GERD as a share of GDP grew from just 0.43 percent in 1966 to 0.93 percent in 2008, with a generally increasing intensity of R&D spending aside from the sizable drop in FY1993.[15] An imputed

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[12] These comparisons used market exchange rates to denote output in U.S. dollars. Other values in this chapter are designated in dollars only (as a short hand for international dollars) and use purchasing power parities (PPPs) to perform the necessary currency conversions. PPPs are an alternative currency converter (to the commonly used market exchange rates) that explicitly account for cross-country price differentials. Using PPPs to denote output measures in dollars rather than U.S. dollars, South Africa's per capita GDP is $8,477, dropping the country to 67th in the international per capita GDP rankings in 2006 (World Bank 2008).

[13] Unless otherwise stated, all dollar denominated values in the text were converted to international dollars using the relevant purchasing power parity indexes. Values denominated in U.S. dollars were converted from their respective local currency units using average annual market exchange rates. See Khan and Blankley (2008) for more details regarding contemporary developments in the overall R&D system in South Africa.

[14] The text amounts are denominated in international dollars (as per footnote 12). Using market exchange rates, the FY1966 GERD total in U.S. dollars was $365.6 million and $2,653.1 million in FY2008 (both figures in 2005 prices).

[15] Blankley and Khan (2005) discuss the details of the survey structure and responses that underpin these GERD estimates, thus helping to calibrate their precision and the coverage and consistency of these data.

public-only GERD series is also shown. The pattern of change over time in the intensity of public research mirrors that of total GERD, with the combined share of private for-profit and not-for-profit research changing gradually during this period—in 1983 private research accounted for 49.9 percent of all research, 58.6 percent in 2008.

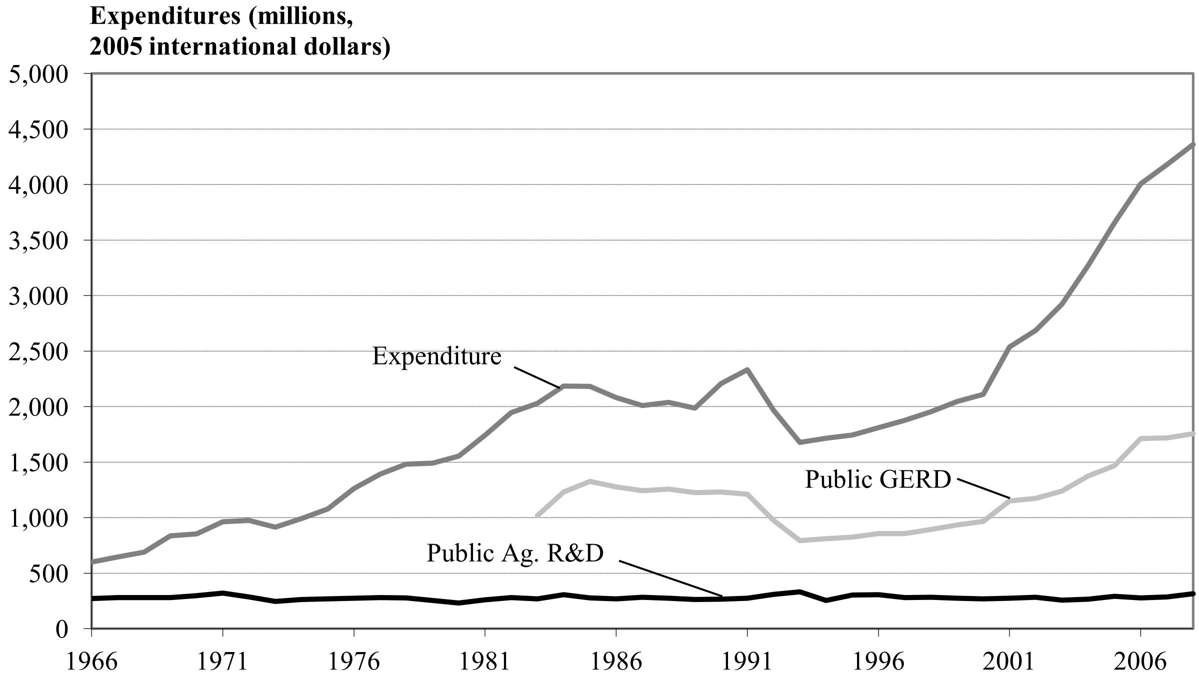


Figure 6.1: GERD and Agricultural R&D Spending, 1966 — 2008

Sources: CeSTII (various years).

Notes: GERD data were reported bi-annually from 1966 to 1993, thereafter, in 1997, 2001 and from 2003 on an annual basis. Intervening years were derived by linear interpolation. Data were deflated using the GDP deflator from SARB (2011).

In 2008, the ratio of public investment in agricultural R&D relative to the value of agricultural output (AgGDP) was 2.5 percent, considerably higher than the 0.4 percent intensity of public investment in all areas of research relative to the overall size of the South African economy (Figure 6.2). Moreover, over the past decade and a half at least there has been no discernible upward trend in the public GERD intensity ratio and almost no growth in the public agricultural R&D ratio over the corresponding period.[16] These similar intensity trends belie the substantial differences that underlie these intensity ratios. Figures 6.1 and 6.4 reveal that growth in real public agricultural R&D spending has stalled for the past thirty years or so (albeit with significant fluctuations around this stagnant trend) whereas public GERD spending increased substantially during the past decade and a half. However, the

[16] In fact both the agricultural R&D intensity ratio and the GERD intensity ratio have changed little since the early 1980s.

substantive real growth in public GERD spending (2.6 percent per year from 1983-2008) was almost matched by the corresponding rate of real GDP growth (2.59 percent per year), and so the intensity of R&D investment in the overall economy barely deepened during this period. Likewise, public agricultural R&D growth of 0.46 percent per year more or less matched the growth in real agricultural GDP (0.56 percent per year from 1984-2008), so investments in agricultural R&D also failed to intensify, but in the case of agriculture the total amount of annual investment failed to grow, whereas overall public investments in science grew quite rapidly.

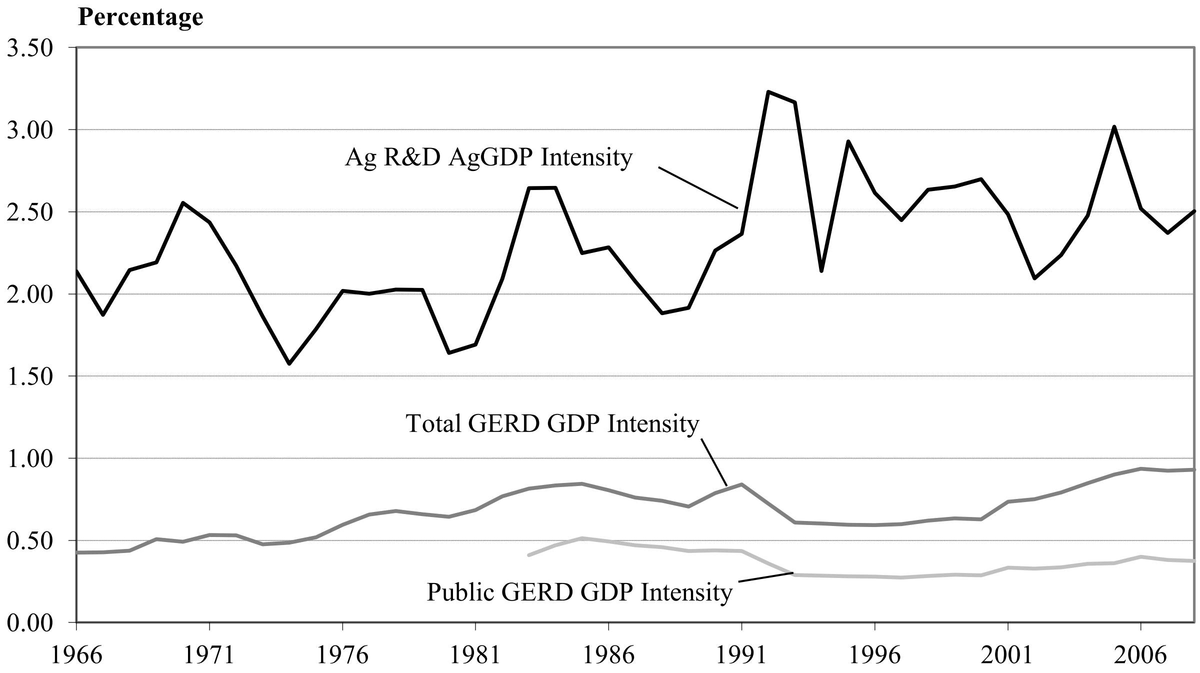


Figure 6.2: Intensity of Total and Public GERD and Public Agricultural R&D, 1966 — 2008
Source: CeSTII (various years), SARB (2011).

These public-sector R&D trends in conjunction with a gradual (and, more recently, accelerating) increase in the overall intensity of public and private R&D investment in the South African economy since 1966 signal a shift in the orientation of South African R&D. Figure 6.3 reveals a significant drop in the share of GERD directed to the applied sciences and technologies (often referred to as problem-solving research), as well as agricultural sciences. The natural sciences, information and

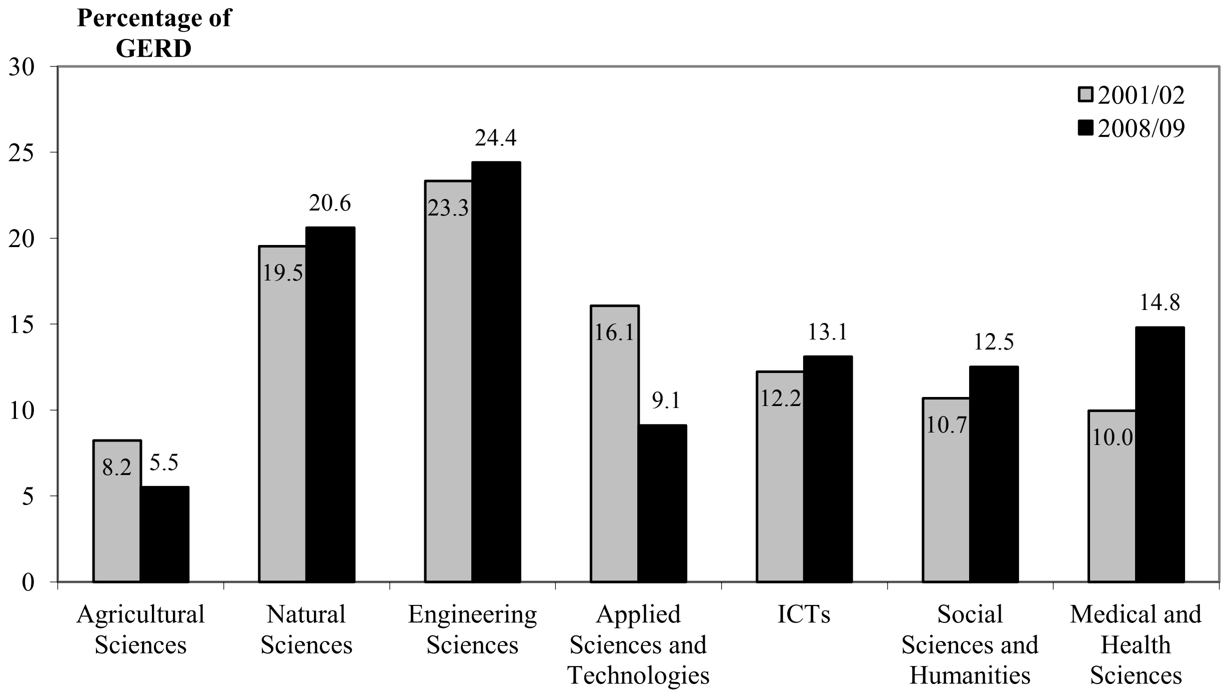


Figure 6.3: GERD Spending by Field of Science, FY2001 and FY2008

Sources: CeSTII (2002 and 2010).

communication technologies, and the social sciences have all increased their respective shares of total science spending. The medical and health sciences saw the greatest gains, jumping from 10 percent of GERD in FY2002 to 14.8 percent just seven years later, more than double the total spending directed towards agricultural R&D in that year.

6.5 AGRICULTURAL R&D SPENDING

6.5.1 Long-run trends

Measured in inflation-adjusted, year 2005 prices, South Africa invested just R63.0 ($16.3) million on public agricultural R&D in 1910. Real public agricultural R&D spending grew steadily by an average of 5.1 percent per year until 1952 (Figure 6.4). The pace of growth accelerated to 7 percent over the subsequent 19 years to total R1,246.2 ($322.0) million by 1971. Spending on public agricultural R&D then declined by an average of 2.9 percent per year in inflation adjusted terms from 1971 to R893.8 ($231.0) million in 1980 and thereafter recovered somewhat to reach R1082.4 ($279.7) million in 2010. Notably, real public spending in agricultural R&D failed to grow significantly after 1972 —

except for a brief jump to R1,290 ($333.3) million in 1993 brought about by structural adjustment payments during the establishment of the ARC. In fact, if external income generated by the ARC is excluded, public agricultural R&D spending for every year in the entire 1971-2010 period was less than the inflation-adjusted 1971 amount of R1,246.2 million.[17] In 2007, with the external income generated by the ARC excluded, direct public investment in agricultural R&D was equal to just 70 percent of the corresponding 1971 figure. Several of the switching points in the growth of public agricultural R&D spending coincide with changes in the administrative structure of public agricultural research agencies, others relate to changes in science policy more generally.

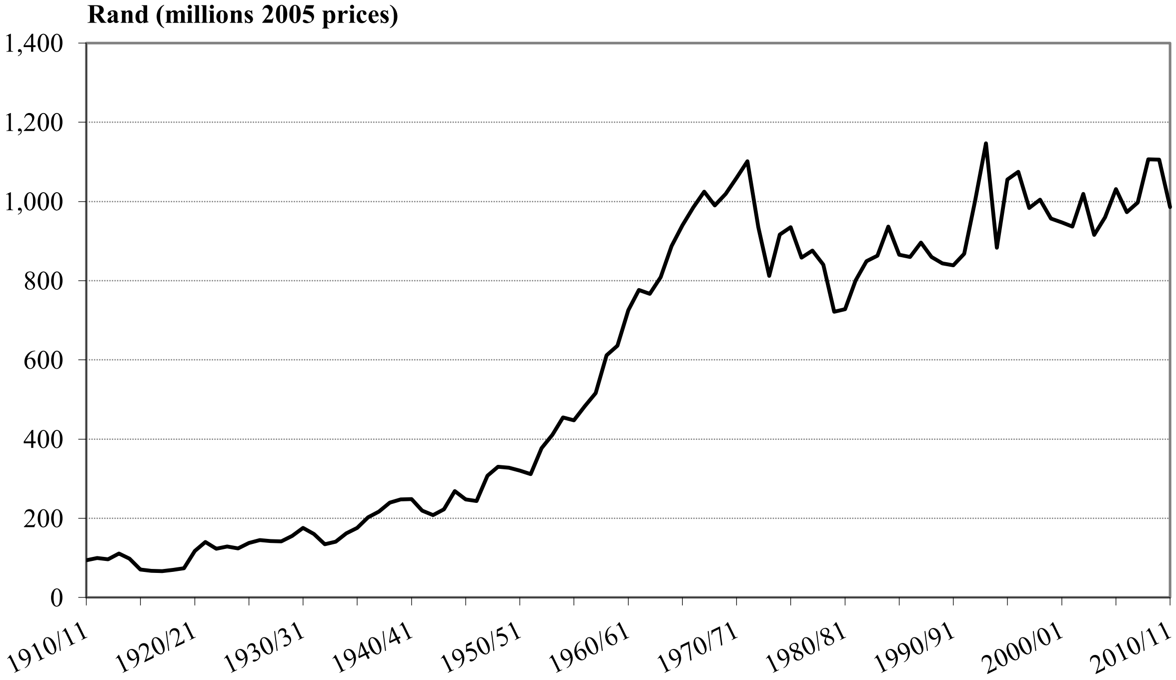


Figure 6.4: Public Agricultural R&D Spending Trends, 1910 — 2010

Sources: Union of South Africa (1910-1959), RSA (1960-2012), and ARC (1993-2011), SARB (2011).

Notes: A nominal agricultural R&D series was deflated using a GDP deflator derived from data provided by SARB (2011).

The institutional implications of these policy changes are revealed in Figure 6.5, Panels a and b. The shares attributable to the national (i.e., ARC and its precursor agencies) and higher education

[17] By way of comparison, in 2007, the United States spent $3.77 billion on public agricultural R&D, equivalent to $1.45 billion (2000 prices) more than it did in 1971 despite a slowdown in the average annual rate of growth during the 1970-2007 period compared with the rate of growth during the previous 50 years (Alston et al. 2010).

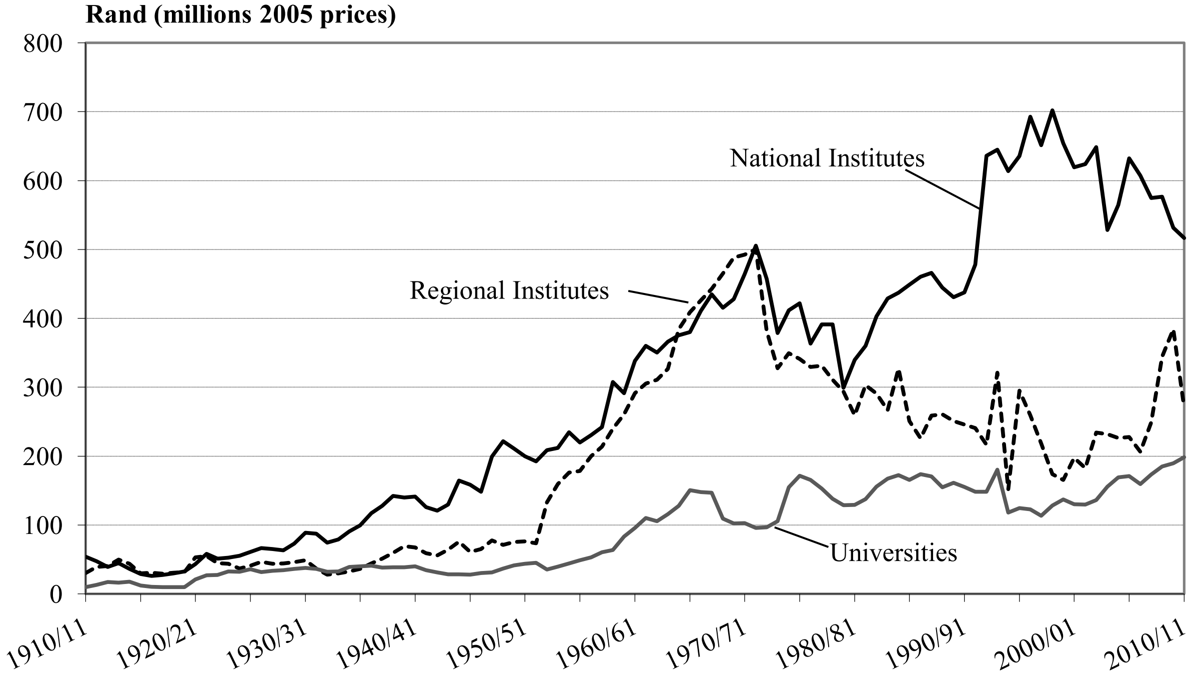
institutions have waxed and waned over the years, but there has been no sustained shift in the share of public agricultural research conducted by national agencies. ARC and its predecessor agencies accounted for 57 percent of the total in 1910, growing to 63 percent in 1948, and 70 percent in 1998, but in the recent decade fluctuated around 58.7 percent. A counterpoint to the generally flat but fluctuating share accounted for by national agencies was an increase in the higher-education share (from 10.3 percent in 1910 to 20 percent in 1986, and 17 percent in the recent decade). The share of public agricultural R&D conducted by regional (now provincial government) agencies has been especially volatile. From 1910 to 1952 regional agencies performed about 33 percent of total public agricultural R&D. This increased dramatically in 1952-53 when the Agricultural Education and Experiment Stations were reconfigured as regional services institutions with a dramatic increase in the estimated research-related budget allocation to these services. The regional share of total public agricultural R&D expanded over the subsequent 19 years (to average 45 percent from 1952/53 to 1973/74). Since 1992/93 they have averaged 23 percent.

Beginning in 1971 the administrative oversight of the faculties of agriculture was moved from the DoA to the DoE. Inflation adjusted spending on agricultural research conducted at the universities increased slightly until 1975 and thereafter stalled at around R156.7 ($40.3) million. From 1967 to 1973 university funding for agricultural research declined, then increased erratically until 1993, followed by a relatively drastic decline in 1994 in the aftermath of the establishment of the ARC. University performed agricultural research inched upward from 1994 until 2003, then grew at a faster pace to reach R198.6 ($51.3) million in FY2010, returning these agencies to the amount spent on agricultural research throughout the 1980s.

Spending on regionally performed R&D experienced a marked downturn during 1971 to 1975 (declining from R500.3 to R341.1 million, or $129.2 to $88.1 million) in the immediate wake of the transfer of the faculties of agriculture to the DoA. It continued to contract at a slower rate until 1993, followed by a jump in 1995 when the provincial dispensation came into effect. Its current level is still well below that of its peak in FY1971.[18] Spending on national and regionally performed agricultural R&D grew in parallel from 1951 through to the mid-1970s, and then also declined until 1979. For the subsequent 15 years spending on R&D done by regional agencies fluctuated around a slowly declining trend, while spending by national institutes contracted sharply. From a localized peak in FY1987,

[18] The changeover to the new constitutional dispensation and with it the incorporation of the administrations of the former homelands and self governing territories, saw a marked increase in the overall public expenditure on agriculture by these regional centres, mostly driven by spending on farmer settlement support and land restitution administration. Their expenditure on R&D, however, remained fairly stable.

Panel a: Institutional orientation, 2005 prices



Panel b: Institutional spending shares

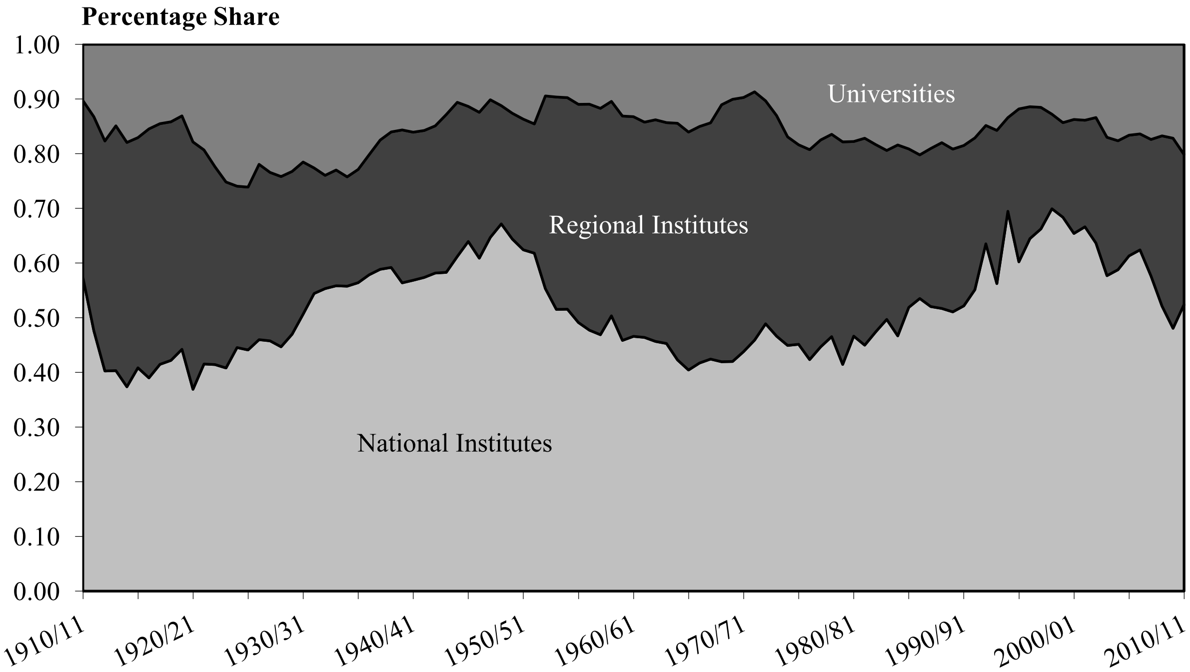


Figure 6.5: Institutional Structure of Public Agricultural R&D Spending, 1910 — 2010

Sources: Union of South Africa (1910-1959), RSA (1960-2012), and ARC (1993-2011).

spending at both the national and regional institutes contracted sharply in inflation adjusted terms over the following four years to FY1990. From FY2000 spending has begun to increase for regional agencies, but has continued to decline for national institutes. Overall the spending patterns in the post-1970 period point to a good deal of institutional instability, with only a marginal rate of growth (0.12 percent per year) compared with the decades that preceded 1970.[19] The combined spending on national and regional institutes has shown a marginally negative rate of growth of -0.16 percent per year since FY1971.

During the period 1910 to 1953 the Department of Agriculture struggled to settle on an institutional structure that best met its perceived service delivery demands. This period saw the transfer of the colleges and faculties of agriculture to the control of the Department of Agriculture under the Research and Extension Division and the creation of a formal Extension Service within this division from 1921 onwards. A separate division for extension was formally inaugurated in 1925 (Van Vuren 1952). It was also an era when racial policies on land segregation and farmer settlement programs to address the so-called ‘poor-white’ issue dominated the R&D agenda. Combating livestock disease epidemics (such as East Coast Fever) dominated budget allocations toward regulatory services and affected the focus of research.

Beginning in the early 1950s, the agricultural development agenda increasingly began to emphasize the modernization of agriculture and regional research gained significant policy and financial support. These funding and institutional shifts accelerated some trends that had already been in place. The livestock emphasis of public agricultural R&D declined, specialist services (addressing soil, climate, water, plant protection and engineering concerns) gained a greater share, as did horticulture (Figure 6.6). Farming systems research (often the emphasis of the revitalized regional institutes) markedly increased its share of R&D spending totals, especially during the 1960s and 1970s.

The formulation and implementation of a policy of “optimal agricultural development” during a 15 year period from 1968 to 1983 (Roseboom et al. 1995), combined with the transfer of the universities to the Department of Education and the termination of the farmer settlement program of the Department of Agricultural Credit and Land Tenure, resulted in marked change in the relative importance of the various research service providers. The higher-education sector marginally increased its share of the agricultural research spending total as the country became increasingly reliant on training its own scientists as international isolation increased as a reaction to the apartheid

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[19] By comparison, spending grew at an average rate of 7.04 percent per year during the period 1952 to 1971, and 5.1 percent per year from 1911 to 1952.

regime. The synergy between the regional and national institutes became less pronounced with strongly diverging trends in spending toward the early 1990s.

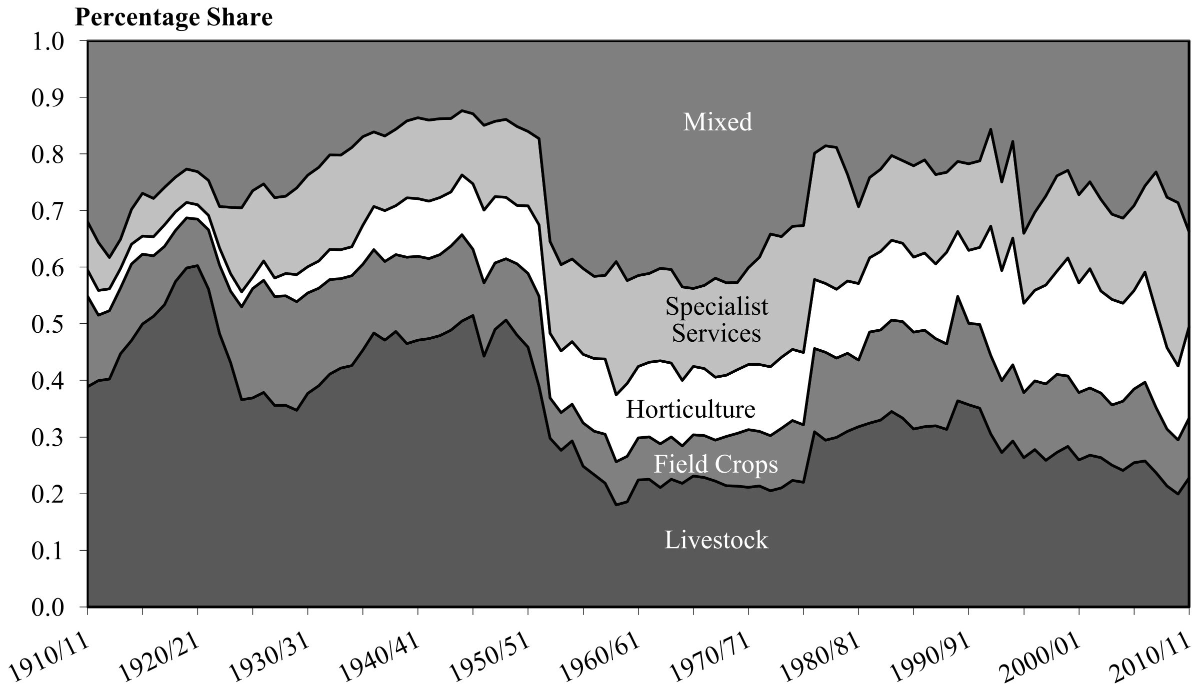


Figure 6.6: Research Focus of Public Agricultural R&D Spending, 1910 — 2010

Sources: Union of South Africa (1910-1959), RSA (1960-2012), and ARC (1993-2011).

Notes: "Specialist Services" refer to spending by the Institutes for Soil, Climate and Water; Plant Protection, and Agricultural Engineering. "Regional" refers in large part to the R&D conducted by the provincial departments of agriculture and the former Agricultural Development Institutes or regional research stations.

The national budget allocations at the time were also dominated by expenditures on the national defence and security forces in response to growing domestic unrest. Spending on agricultural R&D in the early 1990s was influenced by the establishment of the ARC, restructuring of the regional institutes to form the provincial departments of agriculture inclusive of the agricultural administrations of the former homelands, and demands for farmer support as a result of a severe drought which reached its peak in 1991-92. Research services at the provincial departments were hard hit by this given the enormity of the budgetary demands faced by provincial legislatures in meeting the demands of restructuring at the provincial level in order to incorporate the homeland administrations and to take control over certain formerly national functions in education, welfare and security. In the midst of this came the closure of the Agricultural Credit Board and the Control Boards which, in the case of the Credit Board, saw a spike in investments as commitments for farmer assistance under some of its programs were wound up. The ARC was protected from these developments to some extent through its core funding being determined on a base-line (or cost-based) formula arrangement overseen by the Public Service Commission and Department of Finance, but this was soon to change (Liebenberg and Kirsten 2006).

From 1997 the research investment trends of the ARC, the provincial departments and universities followed distinctly different paths. Each agency now falls under different accounting authorities or line departments, with no effective overarching coordinating mechanisms within government to guide investments in R&D across these institutions. The more recent increases in agricultural R&D spending at provincial agencies is largely driven by the farmer settlement and land restitution and reform needs of the Land Redistribution for Agricultural Development Act and the Comprehensive Agricultural Support programs. Moreover, the agricultural research activities of the provincial departments of agriculture lie outside the purview of the National Advisory Council on Innovation that oversees and evaluates the Science Councils such as the ARC. Under the new national R&D strategy the provincial departments do, however, have access to funding from competitive funds and funding from the Department of Science and Technology for Centres of Excellence.

6.5.2 Research intensities

To place agricultural research expenditures in a more meaningful context, it is common practice to scale such data according to the size of the agricultural sector and various other criteria. Table 6.1 shows selected agricultural research and extension intensity ratios for selected decades from 1910 to 1990 and for each year since 2003, revealing wide fluctuations in expenditure intensity over the course of the century. In all cases there was a marked increase in investment intensities from 1910 to the 1930s reflecting the shift in the priorities of rural development policies. The growth in most of these research and extension intensities stalled in 2000, with the exception of investment per farm and investment per farm population. Investment per farm continued to increase from an inflation adjusted R4,456 ($3,371) in 1990 to R43,895 ($7,254) in 2010. This reflects a substantial reduction in farm numbers, evident since the 1993 *Census of Agriculture*, which is also accompanied by an increase in average farm size. After an initial period of growth during the early half of the 20th Century, extension intensities declined to levels that are now well below that of the 1910s, with the strongest decline occurring since the 1970s. Another notable feature of these trends is the divergent pattern of research and extension intensities. From the 1930s to the 1970s, the growth in extension intensities outpaced the growth in R&D intensities. Thereafter extension intensities shrank to levels typically around a tenth or less of the corresponding agricultural research intensities that prevailed in more recent years.

Table 6.1: Alternative Agricultural Research Intensity Ratios, 1910 — 2010

Ratio	1910	1930	1950	1970	1990	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
Relative to farm value added (percent)															
Research	0.88	1.77	0.71	2.48	2.27	2.95	2.55	2.69	3.51	3.45	2.25	2.18	2.35	2.59	2.80
Extension	0.03	30.12	4.19	6.87	0.92	0.32	0.19	0.27	0.41	0.52	0.31	0.28	0.36	0.46	0.58
Relative to Ag. GDP (percent)															
Research	0.66	1.62	0.65	2.13	2.00	2.27	2.34	2.24	2.61	2.49	2.12	2.11	2.38	2.78	2.45
Extension	2.40	27.52	3.84	5.90	0.81	0.24	0.17	0.22	0.30	0.38	0.29	0.27	0.36	0.49	0.50
Relative to farm numbers (real $2005 per farm)															
Research	226	465	707	3,114	3,731	5,191	6,012	5,555	5,972	6,656	6,418	6,806	7,722	7,932	7,254
Extension	104	7,921	4,193	8,623	1,513	558	439	548	692	1.003	887	878	1,167	1,410	1,495
Relative to total population (real $2005 per capita)															
Research	4.07	5.18	6.52	12.29	6.38	5.63	5.78	5.18	5.39	5.78	5.36	5.43	5.92	5.83	5.12
Extension	14.86	88.08	38.65	34.04	2.59	0.60	4.42	0.51	0.62	0.87	0.74	0.70	0.89	1.04	1.06
Relative to farm population (real $2005 per capita)															
Research	248	580	1,464	5,952	14,067	21,458	25,584	23,060	24,226	26,426	24,969	22,345	27,855	31,424	31,557
Extension	907	9,871	8,681	16,483	5,704	2,305	1,868	2,273	2,806	3,982	3,452	2,884	4,212	5,586	6,506
Relative to total farm area (real $2005 per ha)															
Research	0.21	0.54	0.96	3.15	2.80	2.99	3.18	2.86	2.99	3.24	3.04	3.13	3.46	3.45	3.06
Extension	0.10	9.24	5.71	8.73	1.13	0.32	0.23	0.28	0.35	0.49	0.42	0.40	0.52	0.61	0.63

Sources: BCS (1960), SARB (2007), DAS (1957-2009), Union of South Africa (1910-1959), RSA (1960-2012), and ARC (1993-2011).

Notes: The establishment of an extension function within the Division for Education and Extension in 1925 was followed by a substantial increase in investments in agricultural extension services for the subsequent three decades, during which time the extension services were responsible for some research-related functions, such as the oversight and conduct of co-operative experiments. These arrangements and associated funding allocations) changed when the Department of Agriculture was restructured in 1952-1954 with the intent of giving a greater regional focus to the provision of agricultural R&D services.

6.5.3 International intensity relativities

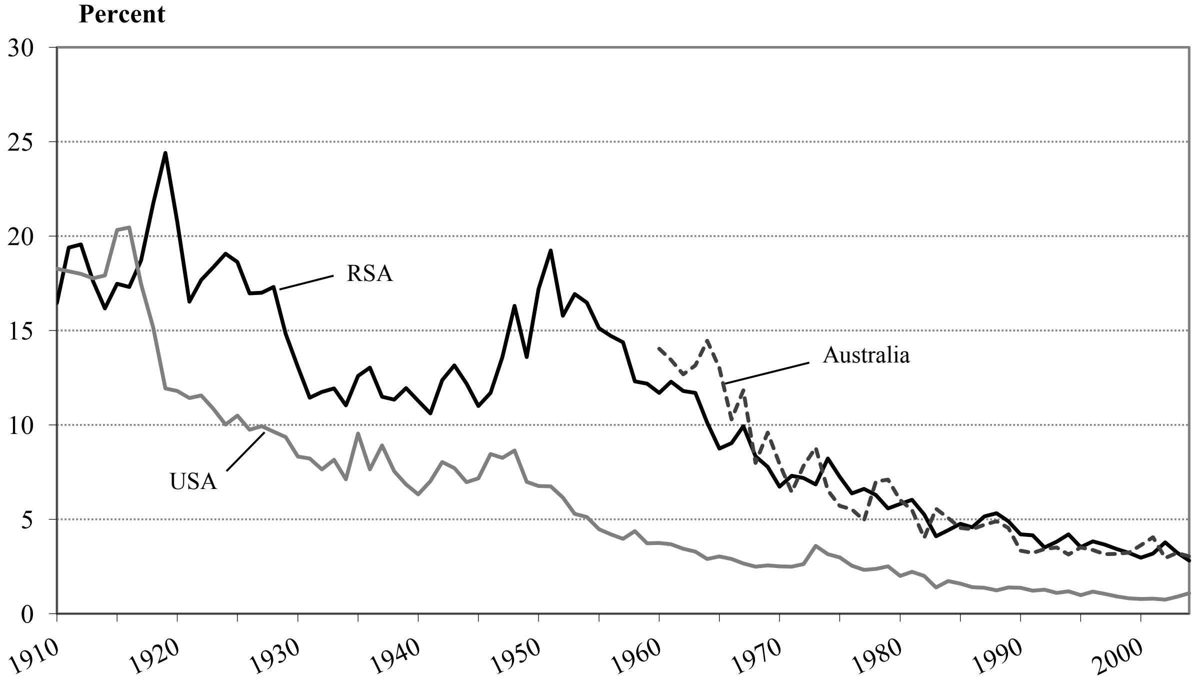
Placing South African developments in an international context, Figure 6.7, Panel a shows that agricultural GDP shrank as a share of overall GDP for Australia and the United States as well as South Africa throughout the 20th Century. The trend (and value) of the agricultural GDP to GDP ratio in South Africa and Australia are similar, but the corresponding ratio for the United States declined at a faster rate (and was generally considerably below) the South African figure. Notwithstanding the Australian and South African similarities in the agricultural shares of their respective economies, Figure 6.7, Panel b reveals that South Africa invested more intensively in agricultural research than Australia (and the United States) for the first three quarters of the 20th Century. In the early 1970s the relativities changed, with South Africa generally falling below Australia (and well below the United States) in terms of public agricultural R&D intensity as the pace of investment in agricultural R&D faltered as did the growth of the South African agricultural economy.

Notwithstanding South Africa's recent poor intensity performance relative to Australia and the United States, in the year 2000, South Africa's intensity of commitment to agricultural R&D per unit of agricultural GDP ($2.50 of research spending per $100 of agricultural output) is on par with the corresponding high-income average of $2.36 reported by Pardey et al. (2008). However, South Africa has about half the spending on agricultural R&D per capita of the general population and about a fifth of the spending per capita of the economically active agricultural population compared with the corresponding average intensity ratios of the high-income countries.

6.6 Scientist Trends

A total of 120 researchers were engaged in public agricultural R&D in South Africa in 1911, about half employed by the Department of Agriculture and the other half (52 researchers) by the faculties of agriculture and the regional experiment stations. This grew steadily to a total of 503 researchers in 1940, declined briefly to 445 researchers during the Second World War, and then resumed growing. In the two decades following World War II, the total number of researchers increased from 618 in 1949 to 903 in 1976 (representing an average annual rate of growth of 1.8 percent per year). The total number of agricultural researchers continued to grow for the following 20 years (at a rate of 2.0 percent per year), peaking at an estimated 1,322 researchers in 1996. From 1997 through 2003, voluntary retrenchments and net attrition in the public and semi-public sectors saw the number of (full-

Panel a: Agriculture as a share of GDP



Panel b: Public agricultural R&D spending as a share of agricultural GDP

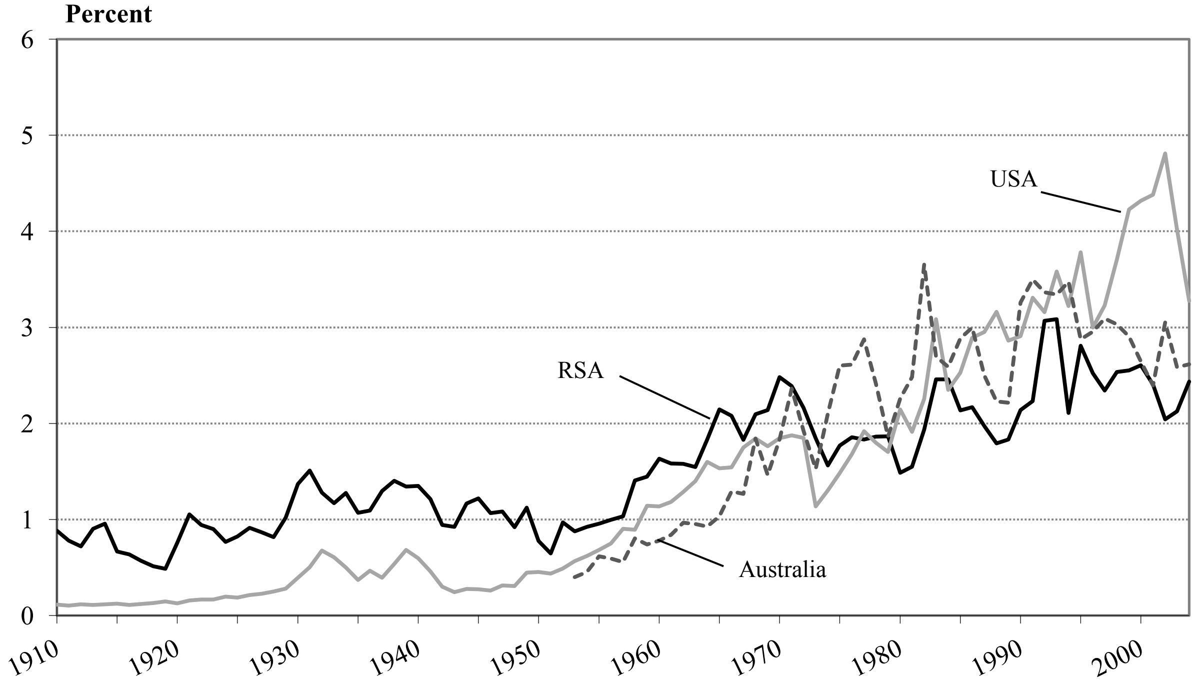


Figure 6.7: Comparative Intensity Trends in the United States, Australia and South Africa, 1910 — 2007

Sources: Union of South Africa (1910-1959), RSA (1960-2012), ARC (1993-2011), Alston et al. (2010), Mullen (2010), US-BEA (2009), USDA (2009), and Australian Bureau of Statistics (2009) time equivalent) fte researchers decline to 1,023 (a contraction of 3.1 percent per year for an overall loss of 23 percent of the country's total scientific research capacity in the agricultural sciences). The number of fte scientists working for ARC peaked in 1996 at 761, dropping precipitously to bottom out at 484 researchers in 2004, and decreased further to reach 462 in 2010. Preliminary estimates suggest that growth in the total number of fte researchers working for public agricultural R&D agencies in South Africa stalled in the mid-1980s and totalled 1,255 fte researchers in 2010, a little lower than the 1,322 fte researchers employed in 1996.[20]

Table 6.2 summarizes the qualification profiles of researchers for various groupings of institutes in the various public-sector research services for various years beginning in 1961 (Roseboom et al. 1995; Liebenberg et al. 2004). Research technicians and other support staff are excluded from these figures. The qualification profile of the different groupings is quite distinctive. A significant share of the fte researchers at the regional institutes and provincial departments of agriculture, ARC institutes, and the universities held postgraduate degrees in 1961 and that share increased as one proceeds from the regional institutes, through the ARC, to the universities. In 1993, 13 percent of the researchers at the regional institutes held a PhD compared with 52 percent at the universities. This in part reflects the fact that the regional institutes focus more on applied and development research, while universities do more basic research. Across all sectors of the system, the qualification profile improved slightly from the 1960s to the early 1990s.

Table 6.2: Degree Status of University and National and Regional Institute Personnel

		Share of Institutional Staff				Share of National Staff		
Agency	**Degree**	**1961**	**1993**	**2000**	**2010**	**1961**	**1993**	**2000**
ARC	Phd	26.8	24.2	28.3	34.4	43.8	41.3	42.5
	MSc	25.6	34.8	44.1	51.3	42.9	55.8	60.4
	BSc	47.6	41.0	27.6	14.3	45.4	64.2	67.3
Regions	Phd	16.9	12.8	15.7	na	23.0	5.5	5.0
	MSc	29.9	47.9	51.5	na	41.7	19.3	52.5
	BSc	53.2	39.4	32.8	na	42.4	15.5	16.9
Universities	Phd	48.2	52.2	58.9	na	33.2	53.2	52.5
	MSc	21.6	26.0	30.2	na	15.3	24.9	24.7
	BSc	30.2	21.7	10.9	na	12.2	20.3	15.8

Sources: Roseboom et al. (1995), Liebenberg et al. (2004), and ARC (2011)

[20] See Kahn et al. (2004) for a discussion of the exodus of R&D personnel from South Africa during this time.

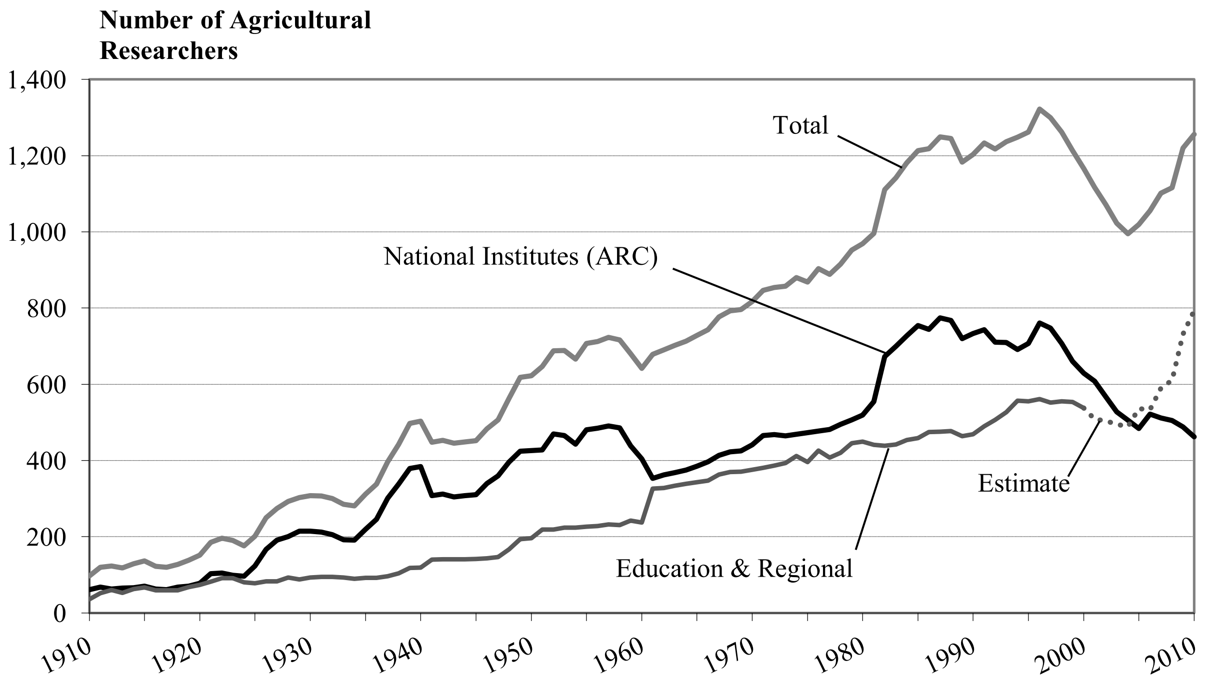
Figure 6.8, Panel a, summarizes trends in the number of researchers at the national and regional (including universities) institutes since 1910. The significant jump in the number of research staff at the regional institutes in the early 1960s coincides with the increase in the number of regional institutes from 6 to 7 and implementation of the amended Soil Conservation Act (Act 37 of 1960), which involved an almost threefold increase in the nominal budget in 1960/61. There was a run up in the total number of researchers during the 1980s when the national institutes received greater autonomy and the status of some was raised from a research centre to that of an institute headed by a Director. A decline in the number of researchers at regional and national institutes began in 1996, initially in response to voluntary retrenchment initiatives introduced to reduce the size of government. During the initial years of this decline the contraction was much faster among the regional institutes. The decline in the number of researchers at national institutes picked up pace after 1998-99 and bottomed out at levels equal to those that prevailed in the pre-1980 period. Figure 6.8, Panel b indicates that the decline in the number of ARC researchers from 1997 to 2008 has disproportionately affected those holding BSc degrees (which decreased by 9.8 percent per year), while those holding PhD and MSc degrees contracted at a slower but still substantial rate (i.e., they declined by 2.46 and 2.94 per year, respectively).

Juxtaposing the personnel trends in Figure 6.8 with the real spending trends in Figure 6.4 gives an indication of the change in overall support per scientist for those working in national institutes. From 1910 to 1930, spending per researcher in the national institutes declined in real terms by 4.6 percent per year. It then increased by 2.8 percent annually until 1957 with the exception of a decrease in the immediate post World War II years that lasted until 1952, when a major restructuring of the agricultural services occurred. Thereafter spending per scientist again grew by 4.7 percent annually until 1971. From 1972 spending per researcher in the national institutes decreased by 2.7 percent per year until 1988, and then resumed growing at 4.9 percent per annum until 2005. Thus real spending per scientist has been quite variable, and in 2010 at R1.15 million ($297,300) per scientist was only 15.5 percent higher than its contemporary peak of R0.996 million ($257,400) in 1970/71; an implied average annual growth rate of just 1.05 percent per year over this 36 year period.

6.7 FUNDING PUBLIC RESEARCH

The sources and forms of funding for publicly performed research not only influence the amount of research conducted but also the types of research undertaken, including the balance between strategic (or longer-term R&D) versus more applied (shorter-term research), or between crops versus livestock

Panel a: Public Sector Agricultural Researcher Trends



Panel b: Staff Qualification of ARC Researchers

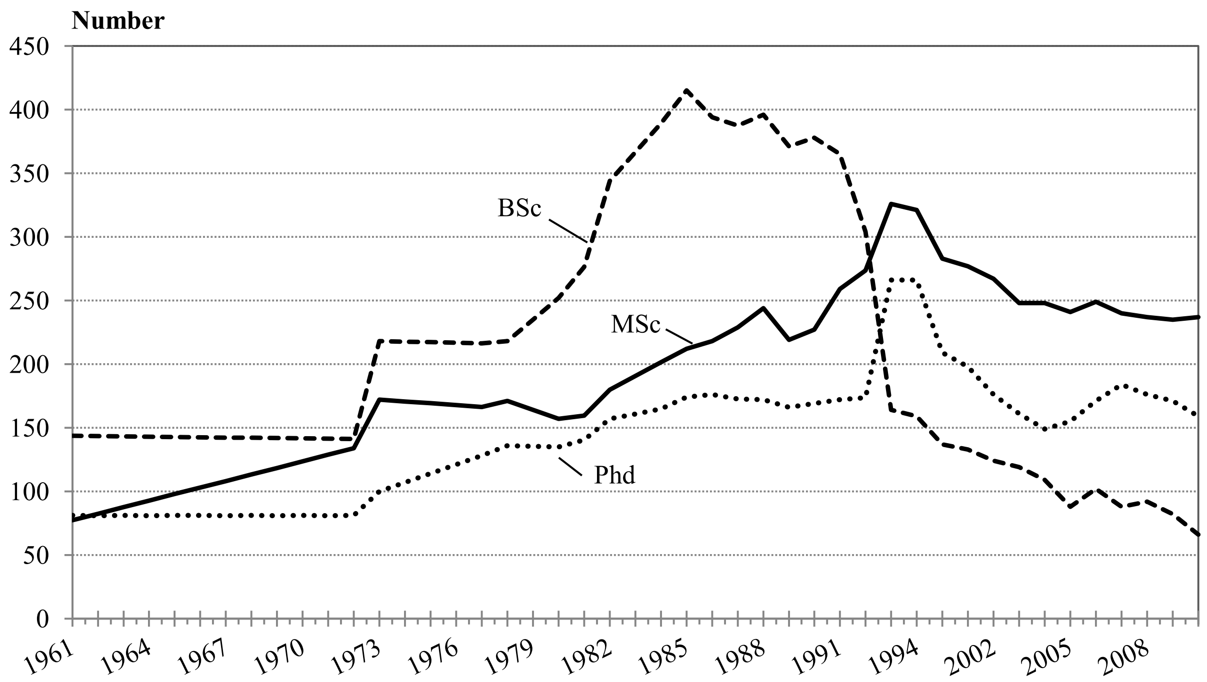


Figure 6.8: Public Sector Agricultural Research Staff Trends, 1910 — 2010

Sources: Union of South Africa (1910-1959 Republic of South Africa (1960-1976), Roseboom et al. (1995), Liebenberg et al. (2004), ARC (various reports), and CeSTII (various reports).

research, or between research on particular crops and particular livestock commodities or specific problems confronting agriculture. The balance between research oriented to maintaining and enhancing farm productivity versus research directed to other aspects such as the environmental dimension of agriculture, food safety, biodiversity, and human health and nutrition can also be influenced by the way in which funds are forthcoming. Here we provide some indications of contemporary changes in the structure of funding of publicly performed agricultural research in South Africa using data on the various sources of funding for research conducted by the institutes of the ARC.

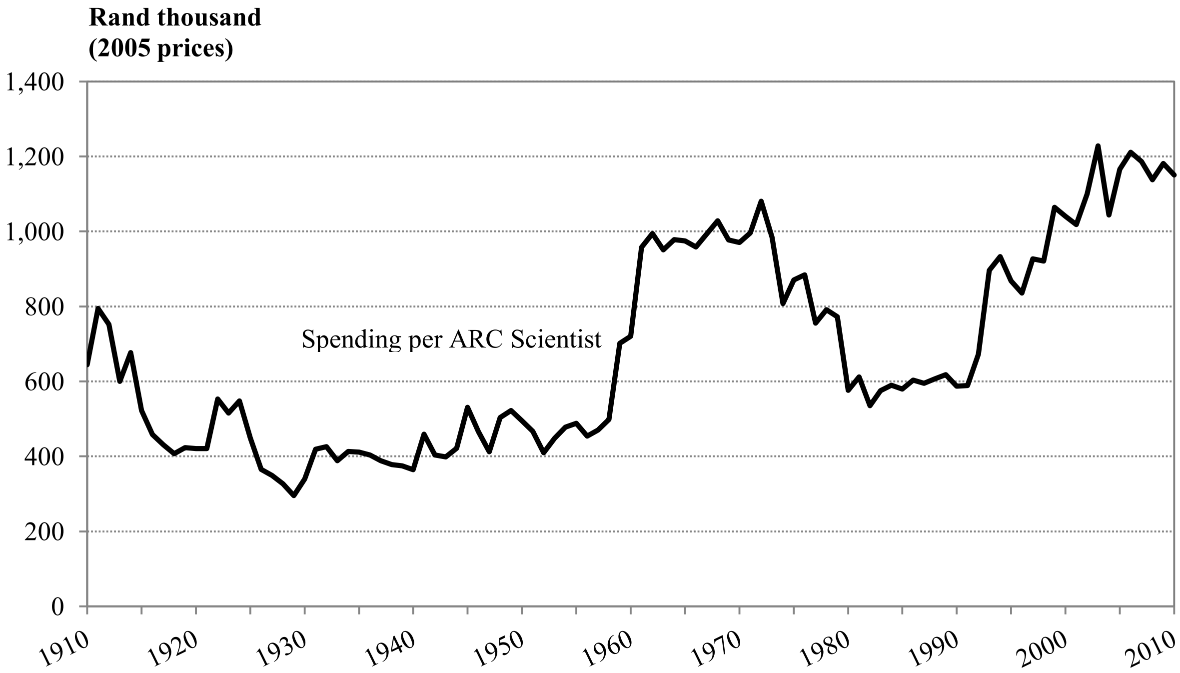


Figure 6.9: Real Spending per ARC Scientist, 1910 — 2010

Sources: Own Calculations

6.7.1 Overview

Until 1992 research by the Department of Agriculture relied heavily on block grant funding from the national government.[21] The commodity oriented Control Boards (such as the Wheat Board, Tobacco

[21] Government budget reports since 1910 show that the Department of Agriculture has typically generated some income through the sale of farm products and research materials, as well as the fees charged for diagnostic services. The share of total income (inclusive of non-research service income) to total expenditure by the departments has varied between 29 and 17 percent from 1915 to 1933. Thereafter it fluctuated around 10 percent until 2005, after which it declined to around 5 percent of total departmental expenditure. An interesting aspect of the pre-depression years was that research

Board, Maize Board and so on) which operated under the statutory marketing structures for agricultural that existed under various guises from 1937 to 1992 were an additional source of support. Allocations to agricultural research were made from levy income generated by way of the marketing schemes promulgated under the Marketing Act as amended in 1968 (Act 59 of 1968).

In 1992, ARC institutes began diversify their sources of funding (Figure 6.10). The reported share of government core funding for ARC dropped from 89.8 percent in 1992-93, to 76.2 percent in 1995-96. The target was to reduce the share of government funding to 70 percent by 2000 in line with a general understanding reached with organized agriculture prior to the establishment of ARC. The ARC exceeded this target by about 11 percent. By 2001-02 the share of ARC funding from government in the form of block grants had fallen to 53 percent of total revenue. Since then core funding has crept up to 62 percent of total funding by 2007-08, mostly driven by increases in funding from the DoA and DST in an effort to redress shortfalls in funding government commissioned diagnostic and research services provided by the ARC. In addition, DST now provides funding earmarked for the maintenance of national assets (genebank, reference collections of fungi, insects and pathogens), while the DoA provides additional funds directed towards the maintenance of the country's physical research infrastructure (RSA 2009).

Income generated by providing diagnostic services and selling research materials, including the sale of plant and livestock products, breeder seed, and revenues from royalties and technology license fees accounted for roughly 11 percent of ARC's non-core income in 1992/93. This form of funding began to increase from 1997, reaching a 24.7 percent share of total funding by 2007-08.

The source of funds varies markedly among ARC institutes. Table 6.3 shows the relative share of the various non-core sources of support for each of the 12 ARC institutes (including headquarters) for each of the fiscal years 1995-96, 2002-03 and 2007-08. For most of the institutes the major source of non-core income was from research services, except for veterinary research, citrus and subtropical crops and agricultural engineering where a range of other sources predominate. Most institutes have quite diversified sources of support, but only in the case of livestock, deciduous fruit, plant protection and soil, climate and water has there been a sustained increase in the share of income generated from research services. The crop related institutes (specifically, the grain crops, industrial crops, and small grains institutes) have sourced a large share of their non-core income from the provision of research

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stations often produced a surplus above costs. In addition during these early years of the 20^{th} Century, expenditure on agriculturally related operations by (Union of South Africa, 1910-1930).

services, whereas agricultural engineering has received none of its funding from this source but relied heavily on the sale of advice services to secure non-core sources of support.

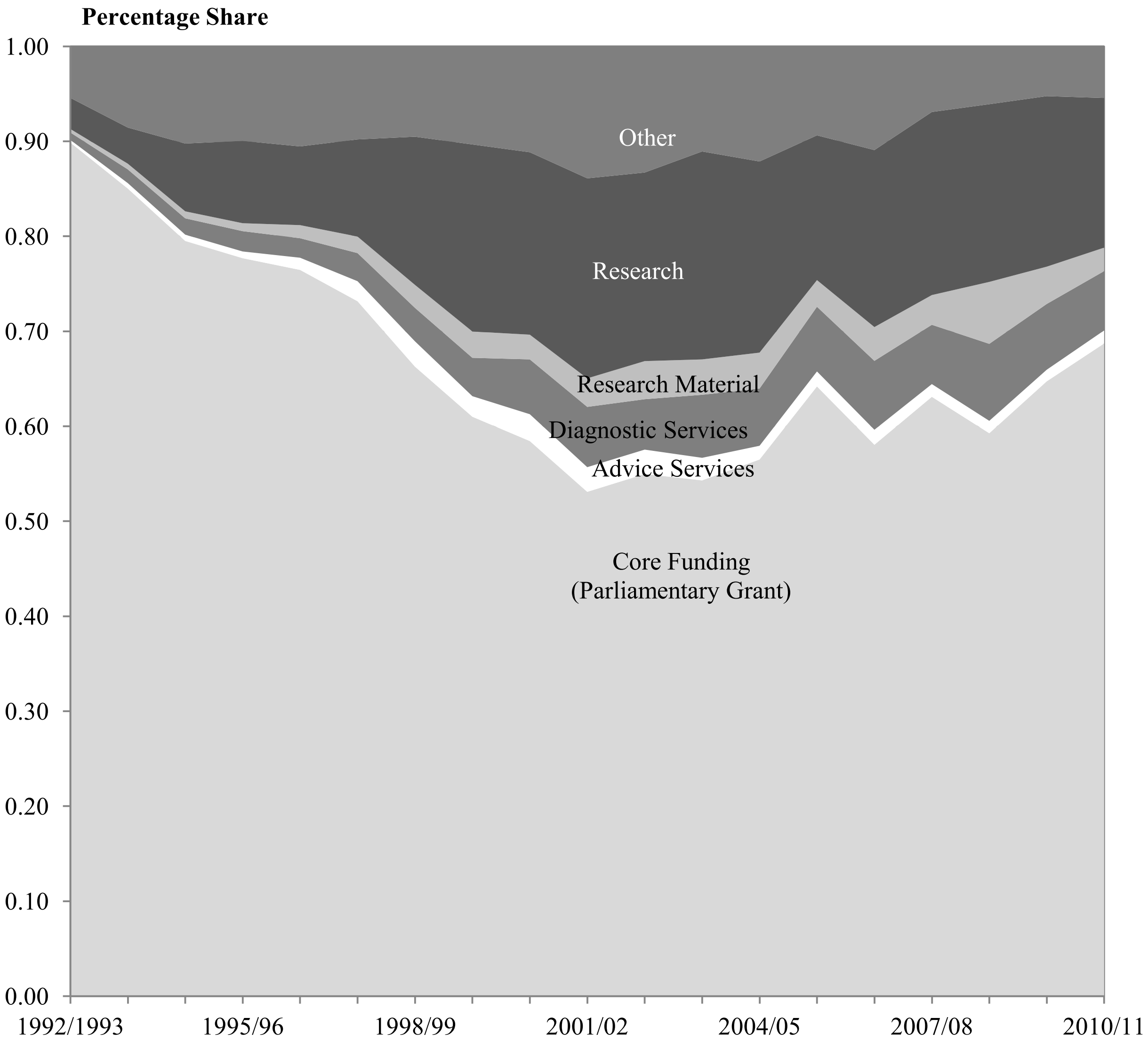


Figure 6.10: Funding Sources for ARC, 1992 — 2010

Sources: Own Calculations

Table 6.3: Non-core Sources of Support for ARC Institutes, Various Fiscal Years

Source	Institute												
	Corporate	Grain Crops	Industrial Crops	Small Grains	Tropical & Subtropical	Infruitech	Vegetables & Ornamental Plants	Animal Products	Veterinary	Plant Protection	Soil, Climate & Water	Agricultural Engineering	ARC Total
	Percentage												
Share of External Income 1995/96													
Advice Services	0.0	0.4	0.0	0.5	5.3	1.5	3.6	4.3	2.0	1.3	3.1	78.1	3.4
Diagnostic Services	0.0	1.2	9.4	5.0	11.2	3.2	1.8	31.2	65.2	5.0	8.2	0.0	18.1
Farm Products	0.0	1.2	5.5	2.1	49.7	8.1	1.0	14.0	0.0	0.0	0.0	0.0	5.4
Personnel Services	4.0	0.0	22.3	0.7	14.6	7.6	11.8	3.7	6.4	0.4	0.0	20.3	5.1
Research Material	60.1	15.7	4.3	27.1	4.4	10.9	29.8	7.5	5.2	1.7	0.1	0.1	13.7
Research Services	14.5	79.5	58.5	63.3	13.2	67.0	52.5	33.5	19.9	91.0	87.7	0.0	45.6
Supporting Services	2.0	0.5	0.0	0.0	2.0	0.0	0.0	1.2	0.4	0.0	0.0	0.3	0.7
Other Income	19.3	1.3	0.0	1.3	-0.4	1.6	-0.6	4.5	1.0	0.6	0.9	1.2	8.1
Share of External Income 2002/03													
Advice Services	0.5	2.1	0.1	0.8	4.2	5.5	2.5	6.8	2.4	2.7	5.4	83.5	5.8
Diagnostic Services	0.0	4.7	4.5	3.8	8.4	2.1	0.9	12.2	47.1	1.6	10.6	0.0	12.0
Farm Products	0.0	13.2	7.3	3.7	21.4	6.4	0.9	11.6	0.0	0.0	0.0	0.0	6.0
Personnel Services	0.0	0.2	6.6	0.6	9.9	4.2	4.9	2.8	9.0	1.1	0.0	5.6	3.8
Research Material	0.0	2.7	7.8	21.1	5.1	11.2	13.1	21.5	2.6	1.9	0.0	0.0	9.1
Research Services	0.0	63.2	43.4	68.1	24.7	59.6	69.6	23.5	28.7	76.7	75.7	0.0	44.8
Supporting Services	2.7	0.2	0.0	0.0	0.7	0.0	0.0	0.1	2.1	0.0	0.1	0.1	0.5
Other Income	96.8	13.8	30.3	1.9	25.7	11.1	8.1	21.6	8.2	16.0	8.1	10.8	18.1
Share of External Income 2007/08													
Advice Services	0.0	0.4	0.0	0.5	5.1	1.5	3.2	4.3	1.7	1.2	2.9	73.4	3.4
Diagnostic Services	0.0	1.1	8.7	4.8	10.7	3.1	1.6	29.3	65.6	4.7	7.6	0.0	18.1
Farm Products	0.0	1.1	5.1	2.0	47.3	6.4	0.9	13.2	0.0	0.0	0.0	0.0	5.4
Personnel Services	4.8	0.0	20.6	0.7	13.9	7.5	10.5	3.5	7.6	0.4	0.0	15.4	5.1
Research Material	52.6	15.2	3.9	26.3	4.2	10.7	26.4	7.0	4.5	1.6	0.1	0.1	13.7
Research Services	16.7	74.6	54.0	61.3	12.6	65.5	46.5	31.9	16.6	86.2	84.7	0.0	45.6
Supporting Services	2.4	0.5	0.0	0.0	1.9	0.0	0.0	1.1	0.4	0.0	0.0	0.3	0.7
Other Income	23.5	7.0	7.7	4.4	4.4	5.3	10.8	9.7	3.5	6.0	4.7	10.9	8.1

Sources: ARC (2009).

6.7.2 Non-government sources of support

The policy governing the activities of Science Councils in South Africa classifies all sources of funding other than the parliamentary grant as private and is commonly referred to as external funding (DACST 1996). For the purpose of this analysis private funding is redefined as funding originating from non-government sources, including commodity trust funds and levies from producer organizations along with research funding from private firms. ARC's formal policy is to charge full cost for all research and other services performed on behalf of external clients. Many clients balked at this pricing policy and as a practical matter the common practice is to currently undertake contracted research on a 50:50 cost sharing basis. Typically only operational costs (i.e., scientist salaries and the cost of materials used in carrying out the research) are included. Some ARC institutes include overhead costs to recoup some of the costs of the physical and administrative support costs of the institutes, but this practice varies among clients and institutes and rarely if ever includes any of the central or corporate headquarter costs incurred by ARC.

The year 1997 was an important transition year with significant implications for industry support for ARC research. In that year the commodity Control Boards overseeing managed marketing schemes ceased to exist, as did the producer levy schemes that underwrote the commodity stabilization funds and other costs incurred by these Control Boards. It took several years before a new set of statutory levy schemes were in place under the legislative authority of the Marketing of Agricultural Products Act of 1996 (Act 47). In 1998, just seven industries agreed to a levy scheme; by 2007 the number had grown to 11 industries. Levy income is used to provide collective goods to farmers in each of the respective industries, including promotional services for local and export markets, product development, quality control, sectoral transformation activities, plant improvement and research. The National Agricultural Marketing Council oversees the collection and disposition of these levy funds. For ARC, another significant source of industry support comes by way of the commodity trust funds that developed as a redeployment of the closing balances of the pre-1997 commodity stabilization reserves that are now overseen by their respective boards of trustees, which includes industry and ministerially appointed representatives.

The share of levy income directed to agricultural R&D varies markedly across industries and among years within an industry (Table 6.4). For example, in 2007 the Citrus Levy directed 64 percent of its levy income to R&D, whereas the Dairy Levy and Red Meat Levy each spent only 3 percent of their income on research. The types of research supported by levy funds also vary. For example, in 2007 around 79 percent of the levy income collected by the winter cereal industry was direct to projects addressing the response of crops to changes in external factors affecting them, such as diseases and pests (NAMC 2007). Notably the share of statutory levy income earmarked for agricultural research projects has declined over the past three years, from 42 percent of the total levy income in 2006 to 32 percent in 2008 (NAMC 2009). The ARC's share of the levy income allocated to research has also declined from 42 percent in 2007 to 37 percent in 2008 (NAMC 2008 and 2009).

Another concern is that even if funding from the commodity trusts to the ARC was increased so that all the levy income collected was allocated to research, this would represent only 23 percent of total ARC external income. Moreover, if all the income generated through research services was assumed to come from private clients, only two thirds of the crops institutes would be deemed to be earning more than half their external (non-core) income from private sources.

Table 6.4: Annual Contribution by Commodity Organizations to Agricultural Research, 1999 — 2008

Source	Contribution						
	1999	2000	2001	2002	2006	2007	2008
	Rands in millions						
Trust contributions							
Crops	13.06	18.73	21.34	n.a.	n.a.	n.a.	n.a.
Horticulture	5.28	4.20	3.68	n.a.	n.a.	n.a.	n.a.
Livestock	3.58	3.47	7.22	n.a.	n.a.	n.a.	n.a.
Subtotal	21.92	26.40	32.25	n.a.	n.a.	n.a.	n.a.
Levy income							
Crops	11.19	11.49	12.34	n.a.	19.47	n.a.	23.20
Horticulture	19.16	25.67	27.52	n.a.	40.16	n.a.	46.22
Livestock	n.a.	n.a.	n.a.	n.a.	0.46	n.a.	1.26
Subtotal	30.35	37.16	39.86	38.41	60.09	74.42	70.68
Total contribution by commodity organizations							
Crops	24.25	30.22	33.68	n.a.	n.a.	n.a.	n.a.
Horticulture	24.44	29.87	31.21	n.a.	n.a.	n.a.	n.a.
Livestock	3.58	3.47	7.22	n.a.	n.a.	n.a.	n.a.
Total	52.27	63.56	72.10	n.a.	n.a.	n.a.	n.a.

Sources: Unpublished information provided by various trusts and commodity organizations (1999-2001) and NAMC (2007-2009).

As a share of non-core funding, contract research executed by ARC increased from an average of about 30 percent during the first three years of its establishment to 38 percent in 1995-96. By 2007-08 this has increased to 49 percent. However, many of these contracts are with public agencies and often government parastatals such as Onderstepoort Biological Products Ltd. and other Science Councils. Thus the increase in the share of contract research performed by ARC overstates the degree to which government has reduced its share of funding for publicly performed agricultural R&D. But at a minimum this contract-client arrangement has laid the basis for a market for R&D goods and services that, in principle at least, can increase the degree to which this public system is responsive to the demands placed upon it.

6.8 CONCLUSION

Government sponsored agricultural research in South Africa stretches back more than a century. In 1911 public agencies employed a total of 120 scientists and spent a total of R68.9 million (or, $16.3 million both in 2005 prices) on agricultural research. In 2010, there were 1,255 scientists and the investment had grown to R985.5 ($254.7) million. Agricultural research spending grew unevenly over time: real spending grew by an average of 5.1 percent per year from 1911 to 1950, increasing to 7 percent per year from 1950 to 1971, at which point spending effectively ceased growing. During the rapid growth phase of the 1950s and 1970s, spending on agricultural research grew faster than agricultural output so that the intensity of investment in public agricultural research (i.e., agricultural R&D spending as a share of agricultural GDP) increased from 0.8 percent in 1911 to 2.63 percent in 1983, but barely budged over the subsequent two and a half decades reaching only 2.67 percent by 2010.

The early 1970s was a switching point in another notable sense. During the six previous decades South African agriculture maintained a higher intensity of investment in public agricultural research than two of its main global competitors, the United States and Australia. South Africa gradually fell behind after the early 1970s, and now trails the United States and Australia in terms of its public agricultural research intensity. Perhaps not surprisingly, South Africa appears to have sustained a competitive edge during the decades prior to 1970, with a strong growth in agricultural exports and more muted but still pronounced growth in its net agricultural trade surplus. However, agricultural exports and net trade balances have declined precipitously in more recent decades.

The balance of public agencies conducting agricultural R&D has also changed over the past century. National and regional agencies performed the lion's share of the research for the first half of the 20th century. The regional institutes reached their zenith by the early 1970s, at which time they performed around 48 percent of the public agricultural R&D compared with 42 percent conducted by national institutes and 10 percent by universities. By 2010 the balance among research performers had changed markedly. The regional share had fallen to 27 percent, not much in excess of the university share which stood at 20 percent, while the national share had grown to 52 percent.

For a good part of the past 50 years, industry has financed some of the research conducted by public agencies. The share of funding from industry sources has fluctuated over time and varies among commodities and types of research. Most of it is now directed to research conducted in national institutes, and in recent years accounted for about 20 percent of the funds flowing to the Agricultural Research Council.

From a long-term perspective these developments are generally positive. From small beginnings at the turn of the last century, South Africa grew its capacity to educate agricultural scientists and developed the institutional capacity to self finance and conduct the R&D required to develop its agricultural sector. From a short-term perspective the picture is less rosy. The amount of real funding for public agricultural R&D has failed to grow since 1992, the intensity of investment in agricultural R&D has stagnated, and the country has lost a substantial number of well trained and experienced agricultural scientists. These more recent developments are cause for concern and suggest it is time to carefully and creatively rethink and revitalize South African agricultural R&D. The policy decisions and institutional actions taken over the next few years will help determine the destiny of the country's agricultural sector for the century that lies ahead.

CHAPTER 7

PRODUCTIVITY PATTERNS

7.1 INTRODUCTION

A conventional productivity index is a measure of the quantity produced compared with the quantity or cost of inputs used to produce it. The most widely used productivity measures, called a partial productivity index (PFP), express the quantity of a particular output with the quantity of a particular input such as land or labour. A total factor productivity (TFP) index would include an index of all inputs used in production. This type of index is comprehensive in that all of the relevant outputs are included in the output quantity index and all the relevant inputs are included in the input quantity index. In practice the available data make it impossible to get a truly comprehensive accounting of all the inputs used in production, thus a TFP index is really a conceptual construct rather than a practical reality. What are typically reported are multi-factor productivity (MFP) indices that account for a subset of the inputs and, since some inputs are omitted from this index of input quantities, the MFP index is only an approximation of the TFP index.

As Alston et al. (2010: 100) state; "Fewer inputs are omitted in the MFP index than in the PFP measure, but this only changes the degree of the problem of interpreting productivity measures where some inputs are omitted; it does not eliminate the problem of omitted inputs (or omitted outputs). Measures of MFP growth may be greater or less than the TFP growth being approximated, depending on what has been left out and how the left-out variables have changed over time. Typical MFP growth measures do not account fully for changes in the quality of inputs and inputs represented by infrastructure, and other public goods (e.g., R&D or education investments), and they leave out certain types of outputs (e.g., environmental amenities from rural landscape). Such omissions cloud the interpretation of the productivity measures."

The revised output and input indexes derived in chapters 3 and 4 can now be used to investigate the productivity trends in South African agriculture. The MFP analysis is limited to the period after 1945 as the detailed measurement of capital and purchased input use only commenced after the Second World War. As shown in chapters 5 and 6, increased public sector investment in the development of the agricultural sector pre-dates the Second World War by at least a decade and only gained further momentum after the Second World War. Other public sector interventions, such as the support to farmer settlement through subsidised loans, training, etc. preceded the increased public spending on agriculture and can be traced back to the decade prior to the establishment of the Union of South Africa in 1920. It is thus suspected that some of the observed growth in agricultural output after the Second World War can be attributed to investments and interventions made prior to the war. To extend our measured understanding of the history of productivity trends in South African agriculture and elicit the effect of the policy changes prior to the Second World War the trends in partial productivity measures are extended to the establishment of the Union.

This chapter first review the results from past studies juxtaposed with productivity studies done for other Sub-Saharan Countries. I then present the partial productivity metrics for the period from 1910 to date and compare the results of the Fisher indexes with that of the extended Thirtle indexes formed by replicating earlier methods for the period after the Second World War. Finally, the differences in the estimated value of agricultural output attributable to productivity growth yielded by the different indexing methods are highlighted.

7.2 Prior Evidence

The upper half of Table 7.1 reports an effort by Liebenberg and Pardey (2010) to extend the aggregate input, output, and MFP measures first reported by Thirtle, et al. (1993) and updated in Schimmelpfennig et al. (2000) for the period 1947 to 2007. Thirtle, et al. covered the period 1947 to 1991, and Schimmelpfennig updated this to 1997.

According to the revised and extended measure of Liebenberg and Pardey (2010), South African MFP grew, on average, by 1.49 percent per year from 1945 to 2010. The 1965-1988 period had the highest rate of growth for the post-1945 period studied, an impressive (and perhaps questionable) 3.03 percent per year. This is substantially higher than the 1.64 percent per year rate reported for the immediate post-World War Two decades up to 1971. Notably, MFP was stagnant during the period 1987-2007, reflecting a decline in the rate of output growth coupled with an increase in the rate of measured input use in agriculture.

Recent studies by Conradie, Piesse and Thirtle (2009a, b) extend the earlier methods used by Thirtle and colleagues to compile regional estimates of aggregate input, output, and MFP growth for South African agriculture. They focused on the Western Cape region of the country. This region has distinctive agro-climatic attributes: specifically, it is the only region within South Africa that experiences winter rainfall, and so its agricultural output is dominated by deciduous fruit and wine grapes whereas output in the rest of the country consists mainly of field crops and livestock products.

Table 7.1: Growth of South African Agricultural Output, Input, and MFP Indexes, Various Estimates, 1947—2007

Period	Attributes of Study					Study Source	
	Output	Input	MFP	Labour	Land	Authors	Date
	Percent per year						
1947-1970	3.43	2.81	0.62	3.27	3.36	Liebenberg and Pardey	2010
1970-1988	3.28	-0.70	3.98	4.91	3.50		
1988-2007	0.96	0.95	0.02	3.23	1.12		
1947-2007	2.69	1.20	1.49	3.87	2.78		
1947-1991			1.30			Thirtle, Sartorius von Bach, and van Zyl	1993
1947-1997			1.30			Schimmelpfennig et al.	2000
1965-1994			0.28			Nin, Arndt, and Preckel	2003
1952-2002			1.87			Conradie, Piesse, and Thirtle	2009a

Notes: For the four other studies reported here the corresponding MFP growth rates found by Liebenberg & Pardey (2010) are 1.70 percent per year for the period 1947-91, 1.67 for the period 1947-97, 2.59 percent per year for the period 1965-94, and 1.31 percent per year for the period 1952-2002. Thirtle et al. (1993) reported an MFP growth rate of 0.0 percent per year for the period 1947-65 (compared with ours of 0.19), 2.15 percent per year for the period 1965-81 (cf. 3.62), and 2.88 percent per year for the period 1981-91 (cf 1.35).

Conradie, Piesse, and Thirtle (2009b) estimate that during the period 1952-2002, MFP in the Western Cape grew on average by 1.22 percent per year. This is about the same overall rate for MFP growth at the national level, but the regional versus national pattern of growth over comparable time periods was considerably different. Measured MFP at the national level grew at a considerable pace beginning in the mid-1960s (averaging 4.02 percent per year from 1965-1975) whereas MFP growth in the Western Cape region only began to pick up in the early 1970s. Moreover MFP growth in this part of the country was just 0.89 percent per year from 1971 to 2002 (compared with 1.73 percent per year at national level for the period 1971-2002), less than half the corresponding national rate of growth, which Conradie, Piesse and Thirtle (2009b, p. 12) put at more than 2 percent per year compared with our estimate of 1.73 percent per year. Again differences in data sources and treatment may account for some of the national cum regional disparities in South African MFP growth, but it is also likely that differences in the composition of output and inputs and other factors played a role, as they did regarding the considerable national versus state differences in productivity patterns for the same era reported for the United States by Alston et al. (2010).

Table 7.2 shows the estimates of MFP growth for a series of other studies for other countries in sub-Saharan Africa. Extracting plausible patterns from this evidence is difficult, in part because of substantive differences in data and methods, but also given the paucity of studies that are available. One fairly consistent finding is that the reported rates of MFP growth in Africa are generally low compared with those reported for other countries worldwide (see, for example, the cross-country evidence reported in Alston, Babcock and Pardey 2010). That said, differences in sectoral coverage and analytical methods may account for the very considerable differences in reported growth rates for similar periods in the studies by Alene (2010) and Ludena et al. (2006). The Africa-wide results of Alene using Malmquist methods concur with those reported here (Table 7.1, upper half) for South Africa using Divisia aggregation approaches, to the extent they suggest that the rate of MFP growth has slowed in recent years. However, the "sequential Malmquist" results from Alene show no evidence of a slowdown. Irz and Hadley (2003) found a marked difference in MFP growth rates for commercial versus traditional farmers in Botswana, highlighting the fact that aggregating over different types of farmers may pose substantive measurement and interpretation challenges analogous to those confronted when forming national versus state or provincial estimates.

7.3 PARTIAL FACTOR PRODUCTIVITY

Partial productivity indexes relate output to a single input, such as labour or land. These measures are useful for indicating factor-saving biases in technical change but are likely to overstate the overall improvement in efficiency because they do not account for changes in other input use. For example, rising output per worker may follow from additions to the capital stock, and higher crop yield may be due to greater application of both fertilizer and the use of improved varieties. Nonetheless these measures remain useful to gain an understanding of the nature of the observed growth trends.

7.3.1 Long run average crop yields

The most familiar partial productivity indexes are yields, which are given in terms of output per hectare, per animal, or per worker. Crop yields in South Africa are susceptible to significant year-on-year variation given that much of the production comes from rain-fed systems with average rainfall in the range of less than 250 mm per year in the west to 750 mm in the east, at the lower end of the ideal range for the crops in question (DOA 1957). On average, more than 80% of the country's total land mass receives an average annual rainfall of 750 mm or less, with 30% receiving less than 250 mm per annum. Rainfall typically varies widely from year-to-year and within a season, leading to wide inter-season variation in yields.

Table 7.2: Sub-Saharan Africa MFP Growth Rates, Various Studies

Authors	Date	Region	Crop/Industry	Methodology	Sample Period	Average Annual Growth Rate
						Percent per year
Irz and Hadley	2003	Botswana	Agriculture:	Input Distance		
			Traditional Farmers		1979-1996	-2.3
			Commercial		1968-1990	1.16
Dhehibi and Lachaal	2006	Tunisia	Agriculture	Tornqvist	1961-2000	3.6
Ludena, Hertel, Preckel, Foster, and Nin	2006	Middle East & North Africa	Crops	Malmquist	1961-2000	-0.03
			Ruminants		1961-2000	-0.02
			Non-Ruminants		1961-2000	0.64
			Average		1961-2000	0.03
		Sub Saharan Africa	Crops		1961-2000	0.15
			Ruminants		1961-2000	0.36
			Non-Ruminants		1961-2000	0.5
			Average		1961-2000	0.21
Alene	2009	Africa	Agriculture	Malmquist	1970–1980	-0.9
					1981–1990	1.4
					1991–2004	0.5
					1971-2004	0.3
				Sequential Malmquist	1970–1980	1.4
					1981–1990	1.7
					1991–2004	2.1
					1971-2004	1.8

Notes: The input distance function used by Irz and Hadley (2003) is a conventional measure of the largest factor of proportionality by which the input vector x can be scaled down to produce a given output vector y with the technology that exists at a particular time t. The premise of the sequential Malmquist TFP index used by Alene (2009) is that past production techniques are also available for current production activities. The distance metrics in this instance are calculated using linear programming techniques formulated with respect to a "sequential" technology frontier.

The long-run crop yields summarized in Table 7.3 reveal substantial gains in average crop yields during the twentieth century. Corn yields increased more than 4-fold since the 1910s, wheat by 4.4-fold, and sorghum by more than 7-fold. Drought is an enduring reality of South African agriculture and had a detrimental impact on crop yields, especially during the first half of the 1930s, 1980s, and 1990s. The growth in yields during the first half of the twentieth century was associated with increased mechanization and increased use of improved seeds (with a corresponding marked increase in the use of chemical inputs, including fertilizers, herbicides, and pesticides) helping to also spur crop yield growth after the 1960s.

A factor that suppresses the national yield levels is the relatively low yields achieved by black farmers in the former homeland areas. Figure 7.1 shows the trend in yield of white and black farmers over the past century. Particulars on the area planted in the reserves and by squatter farmers on white owned farms were first recorded in the 1954/55 census (BCS, 1958). Prior to this, estimates on the area planted by these farmers were made by the Department of Agriculture. In 1954 yields obtained by black farmers were 39.9 percent of the average achieved by white farmers. Over the subsequent decade this ratio decreased to 26.3 percent in 1964, thereafter it increased to about 51.6 percent of white farmers by 1993 according to the estimates of the Department of Agriculture. Based on the estimates of SAGIS (2011) since 1994 the yield of black farmers thereafter declined to 26.5 percent in 2010 — sometimes as low as 15.5 percent of commercial yields in 2004.

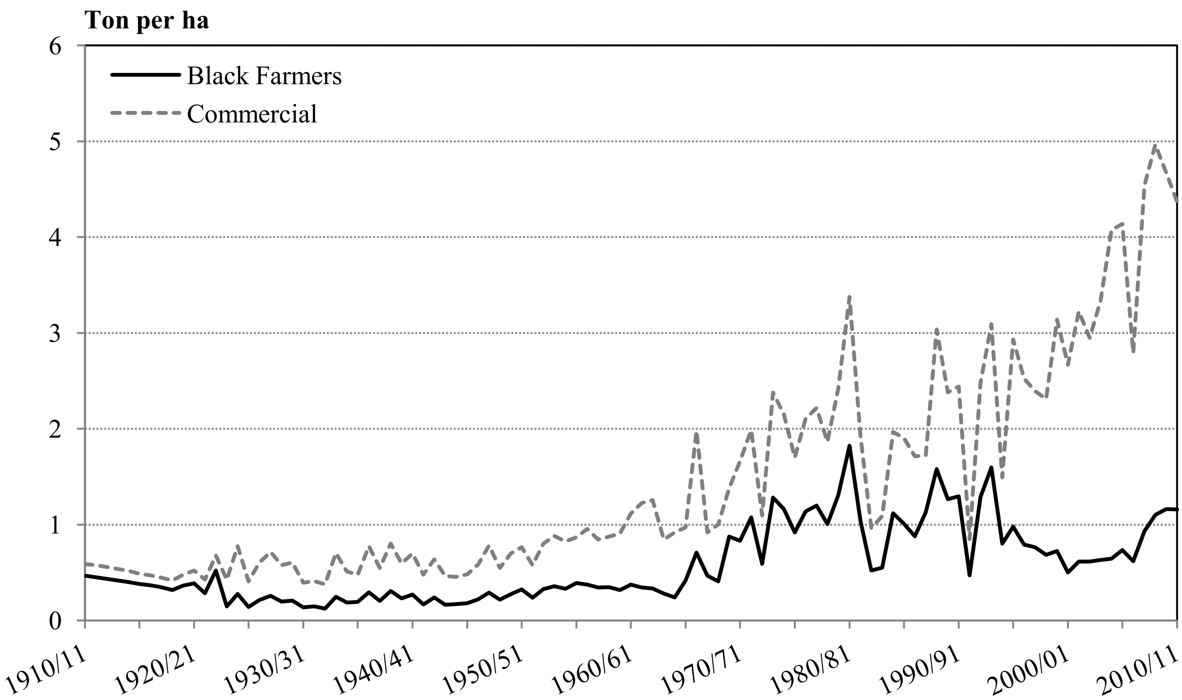


Figure 7.1: Long-run Maize Yields; Commercial versus Black Farmers, 1910 — 2010

Source: Own calculations

The livestock "yields" presented in Table 7.3 are harder to interpret and may reflect the difficulty of meaningfully measuring productivity in these sectors. For instance, the decline in the average slaughter weight of pigs reflects a largely demand-driven shift to leaner pork products. The slaughter weight of sheep also declined steadily after the Second World War, from an average carcass weight of 39.1 kg per head during the 1930s and 1940s to just 19.8 kg per head in more recent years. Again the shift in consumer preferences has played a role — with leaner and much younger (i.e., lamb versus mutton) cuts of meat being preferred — but massive structural changes in the sheep industry have also played their part. As wool demand slackened over the past three decades or so, growers shifted from sheep-for-wool to sheep-for-meat systems of production, with associated shifts in the average age of the sheep population (i.e., a move to younger and hence smaller animals), and with direct consequences for average carcass weights. As evidence of this trend, merino sheep accounted for up to 80% of the national sheep herd in the 1960s (and up to 86% if dual-purpose breeds are also included), whereas now the merino share has declined to 50% (or 71% if dual-purpose breeds are included). The total number of sheep in the country has also declined from 37.4 million head of sheep in 1966 to 21.9 in 2008, with numbers of merino sheep declining from 28.3 million to 11.6 million over the same period (DAFF 2012).

Table 7.3: Average "Yields" for Selected Commodities for Various Periods

Period	Livestock			Crops		
	Cattle	Sheep	Pigs	Maize	Wheat	Grain Sorghum
	Kg per head			*Kg per hectare*		
Five-year averages centred on						
1911/12	na	na	na	765	592	445
1920/21	235	39	na	737	501	580
1930/31	205	30	90	465	717	952
1940/41	251	29	85	771	488	963
1950/51	226	33	78	826	518	987
1960/61	223	29	81	1,235	590	872
1970/71	217	25	64	1,480	811	1,201
1980/81	215	25	66	2,082	1,103	1,816
1990/91	228	22	61	2,074	1,460	2,360
2000/01	231	18	62	2,606	2,449	2,822
2005/06	259	20	74	3,326	2,583	3,272
Average annual growth						
	Percent per year					
1910/11-1929/30	na	na	na	-1.29	0.30	-1.43
1930/31-1949/50	0.82	0.59	-0.76	3.39	-2.72	3.29
1950/51-1969/70	-0.26	-1.25	-1.07	2.04	1.29	-1.89
1970/71-1989/90	0.53	-0.26	0.13	0.28	2.33	2.27
1990/91-2007/08	0.98	-0.01	1.19	4.58	3.34	3.03

Sources: Own calculations on Field crops; for livestock, DAFF (2012)

7.3.2 Land, labour and capital productivity trends

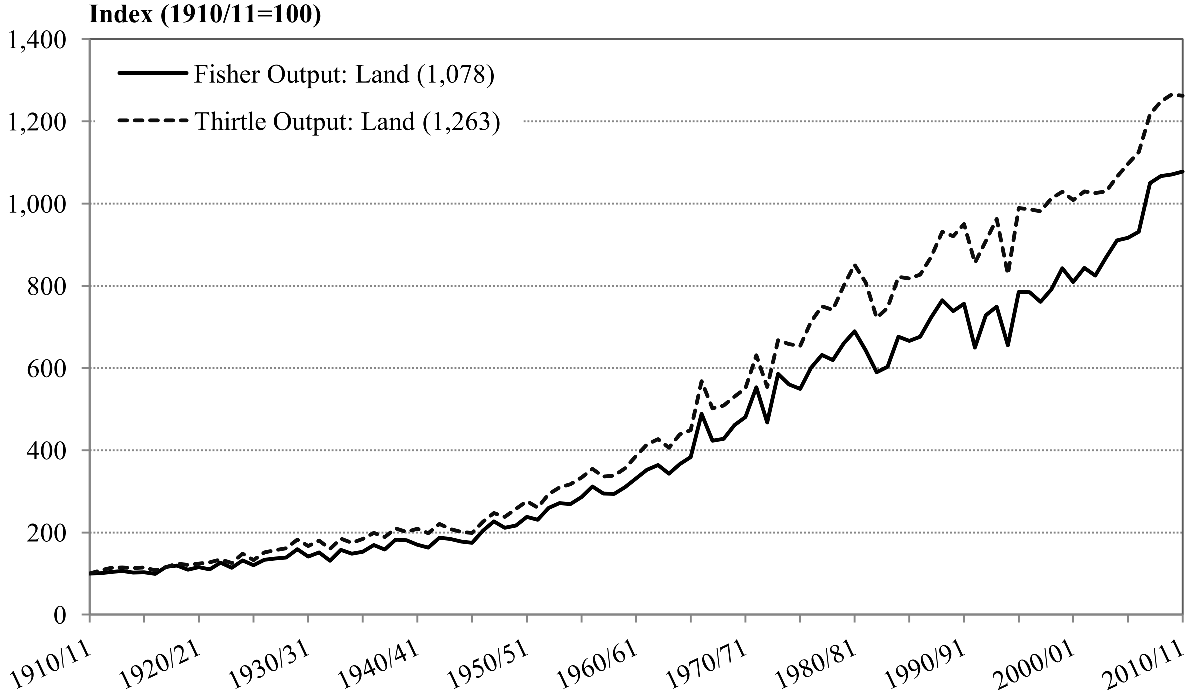
In Table 7.4 and Figure 7.2 trends in land and labour productivity, expressed as a ratio of the Divisia index of land (total land in farming) or labour to the Divisia index of output, are shown from 1910 to 2010. Throughout the twentieth century there were three phases of distinct growth patterns in these two partial productivity measures. From 1910 to 1937, land productivity grew at an average annual rate of 2.13 percent per year, much higher than the corresponding rate of labour productivity growth, which declined by 0.08 percent per year. The rate of growth of both land and labour productivity picked up over the subsequent four decades (i.e., the period 1937-1980), averaging an impressive 4.29 percent per year for labour productivity and 3.85 percent per year for land productivity. From 1980 to 1994, productivity growth rates for both land and labour slowed considerably, down to 0.94 percent per year for labour, and a decrease of 0.05 percent per year for land productivity. However, the rate of growth over the past 17 years was approaching that of the 1937 to 1980 period.

Table 7.4: Ten-year Average Growth in Land and Labour Productivity, 1910 — 2010

Period	Fisher		Thirtle	
	Output: Land	Output: Labour	Output: Land	Output: Labour
	Percent per year			
1910 - 1919	1.20	0.68	2.28	1.87
1920 - 1929	3.13	-0.03	3.57	-0.08
1930 - 1939	2.14	-0.53	1.99	-0.70
1940 - 1949	2.14	1.56	2.10	1.54
1950 - 1959	3.59	3.38	3.23	3.02
1960 - 1969	4.15	2.99	4.50	3.04
1970 - 1979	3.93	6.37	4.19	6.55
1980 - 1989	1.84	1.60	1.89	2.03
1990 - 1999	1.28	4.99	1.48	5.40
2000 - 2009	2.75	4.20	2.21	4.22
2010 - 2011	0.52	3.61	0.56	3.58
1910 - 2010	2.76	2.68	2.83	2.76
Policy Phases	*Percent per year*			
1910-1937	2.13	-0.07	2.67	0.36
1937-1980	3.85	4.29	3.85	4.24
1980-1994	-0.05	0.94	0.07	1.21
1994-2010	3.32	4.54	2.78	4.23
1980-2010	1.92	3.38	1.88	3.41

Sources: Own calculations

Panel a: Output to land partial productivities



Panel b: Output to labour partial productivities

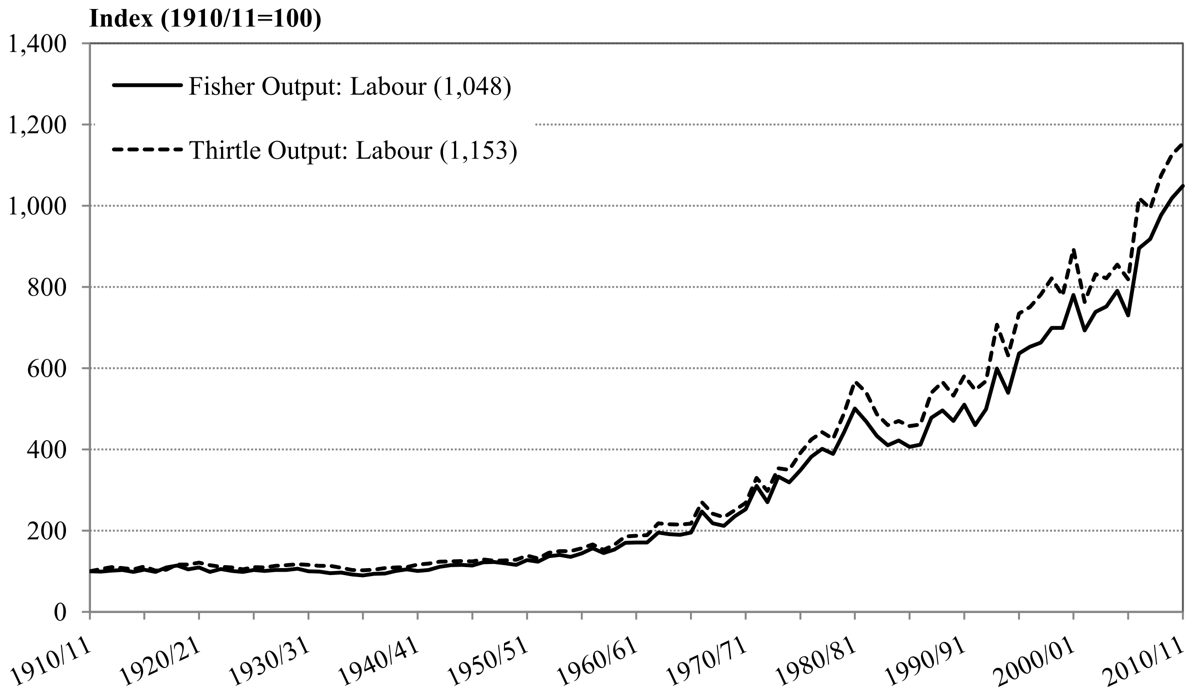


Figure 7.2: Fisher versus Thirtle Quantity Index of Land Used, 1910 – 2010

Sources: Own calculations

Also shown in Table 7.4 and Figure 7.2 (Panel, a and b) are the comparative statistics for the Thirtle indexes, the formation of which were discussed in Chapters 3 and 4. In general, the Thirtle indexes tend to yield higher growth rates during the periods where the Fisher indexes yield moderate growth rates and vice versa. Over the whole century the cumulative effect is that the annual average rate of growth of the Thirtle indexes is slightly higher than the results obtained with the Fisher indexes as can be observed from the terminal values indicated in the legends of Figure 7.3, Panels a and b.

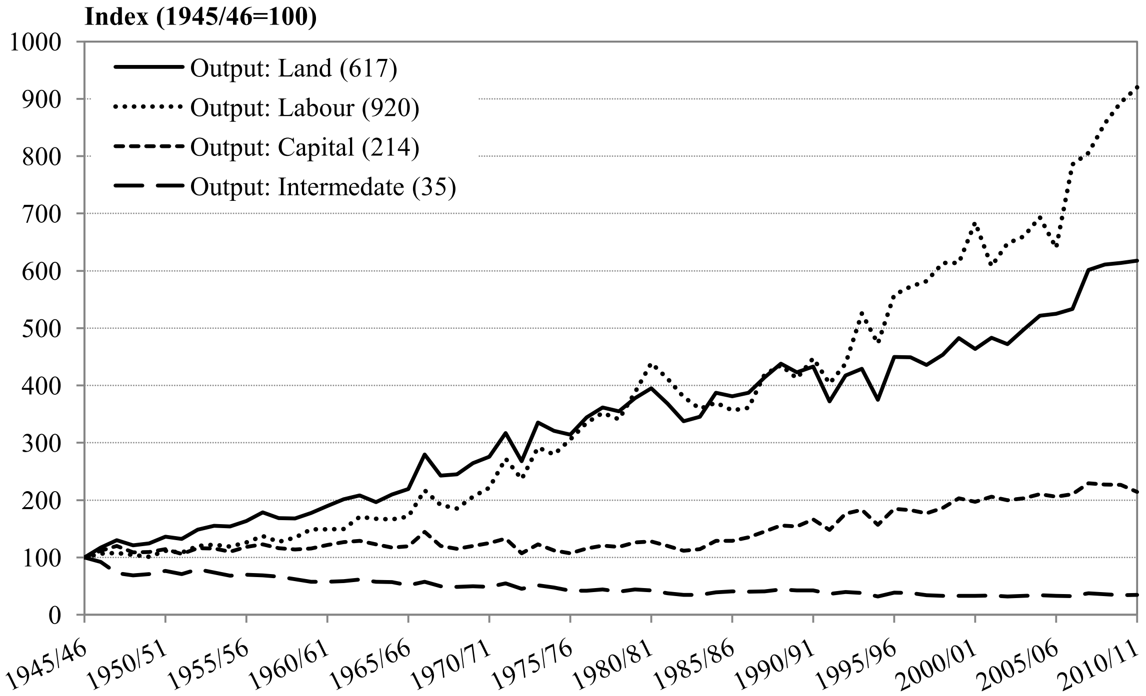
7.3.3 Capital and purchased inputs productivity trends

By extending the selection of partial productivity measures to include capital and purchased inputs the period of analysis shifts to the six and a half decades since 1945. The first observation that can be made from Figure 7.3 Panel a, is that in recent decades labour productivity growth was higher than that of any other input category, whilst the productivity index for purchased inputs shows a negative trend throughout the whole period. When compared to the Thirtle indexes shown in Panel b, the terminal values of the Fisher based productivity indexes are generally lower than that of the Thirtle indexes highlighting the extent to which aggregation bias in the index numbers of the method followed to form the Thirtle index distort the results. The ten-year annual average growth rates in the productivity of land, labour, capital and purchased inputs are shown in Table 7.5 for both the Fisher and Thirtle based indexes.

During the three and a half decades following on the Second World War both capital and land productivity showed a rate of growth of three to 5 percent per annum before it stagnated over the subsequent two decades to 1995 before it resumed growing over the next decade and a half. In the case of capital, the productivity growth stagnated from 1955 to 1975, but regained momentum from the mid-eighties and reached its highest growth rate per year during the decade from 1995. From 1945 to 1980, capital productivity grew at 1.04 percent per year; since then its growth rate nearly doubled during the deregulation phase and increased slightly after 1994.

The ten-year average annual growth rates in labour productivity have been relatively high throughout the whole period since the Second World War. After reaching a peak during the 1965 to 1975 decade its ten-year average growth rates have never been less than the levels achieved during the period when harvesting began to be mechanized. Compared against growth rates for the policy phases, labour productivity was at its highest during the state sponsored industrialization phase up to 1980, followed by the post-1994 period when labour legislation was amended to include farm workers, the sector has experienced an exodus of labour out of the agricultural sector, which explains the resurgence in labour productivity growth.

Panel a: Fisher partial productivity indexes



Panel b: Thirtle partial productivity indexes

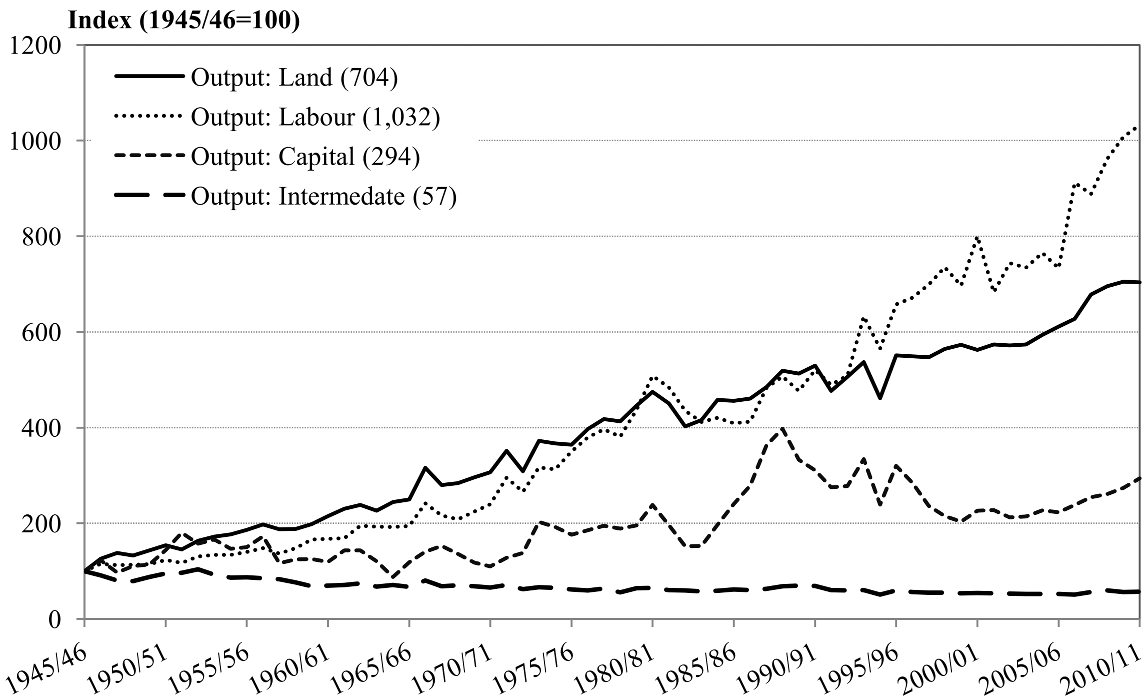


Figure 7.3: Land, Labour, Capital and Intermediate Inputs Productivity Trends, 1945 — 2010

Sources: Own calculations

Table 7.5: Ten-year Average Growth Rates in Partial Productivity Indexes, 1945 — 2010

Period	Fisher Indexes				Thirtle			
	Output to				Output to			
	Capital	Purchased	Land	Labour	Capital	Purchased	Land	Labour
	Percent per year							
1945-2010	1.48	-1.28	3.17	3.86	2.97	-0.59	3.33	4.05
1945-1955	1.96	-3.11	5.29	2.50	5.38	-1.06	6.72	3.58
1955-1965	0.73	-1.71	3.26	3.62	-3.52	-1.81	3.41	3.90
1965-1975	0.35	-1.24	5.23	6.23	9.69	-0.44	4.82	5.68
1975-1985	1.57	-1.50	2.11	3.15	1.37	-0.61	2.45	3.38
1985-1995	2.41	-1.76	0.00	2.95	3.62	-1.22	0.32	3.49
1995-2005	3.16	1.03	3.55	4.16	0.34	0.46	2.70	3.46
2005-2010	0.42	0.36	2.94	5.19	4.43	1.57	2.90	5.51

Sources: Own calculations

The Thirtle indexes once again yield index values that are much higher than the equivalent partial productivity indexes based on the Fisher indexes. The Thirtle approximation of the capital productivity index is also highly erratic and shows little relation to the policy changes discussed here for the reasons discussed in chapter 4. The situation is compounded by the problem observed in the reported price index for purchased inputs observed from 2003 and discussed in Chapter 4. As a result of the suspiciously high input price increases reported by the Department of Agriculture the Thirtle productivity indexes for purchased inputs reveal an increase in productivity that is higher than the Fisher based productivity index for which adjustments have been made to address the caveat.

Comparing the growth rates in partial productivity of South African agriculture observed here with that of the trends observed for the USA agriculture reveals some interesting contrasts. Alston et al. (2010) report a fourfold increase in land productivity and a fifteen fold increase in labour productivity for the period 1949 to 2007. South African agriculture shows a threefold and fourfold increase for land and labour productivity respectively for the period 1945 to 2010.[1] The productivity of purchased (materials) inputs in the USA agriculture contracted by only 0.20 percent per year since 1949, whereas South African agriculture experienced a 1.28 percent decrease. Capital productivity in the USA agriculture increased by 1.28 percent, or about the same as land productivity. Capital productivity growth in South African agriculture is 1.48 percent per year, but about half the rate of growth in land productivity. Taken together, these dissimilar trends raise concern for the future competitiveness of South African agriculture. Not only are our farmers much more exposed to foreign competition

[1] If the South African quantity index for labour was adjusted for changes in the quality of labour since 1945 the resulting labour productivity index would be lower, i.e. labour productivity growth would be lower and much worse in comparison to the United States where the level of education of farm workers has increased faster than in South Africa. See Alston et al. (2010) page 94 for a discussion of the effects of quality adjustment on labour.

through our liberal trade protection policies, but our degree of farmer support is also much less since the early 1990s when compared with countries such as the USA (Sandrey and Vink 2007).

7.3.4 Land and labour productivities

To illustrate the trends in land and labour productivity differently the graphical technique used by Hayami and Ruttan (1971) is used in Figure 7.4 based on data from various Agricultural Census and Survey Reports since 1910. The productivity loci were formed by taking a ratio of the value of aggregate output and the respective land and labour inputs. The horizontal axis measures labour productivity (in logarithms) and the vertical axis measures land productivity (in logarithms). Output is an estimate of the total value of agricultural output (spanning all crops and livestock commodities) expressed in 2005 real values. Land is a measure of planted and permanently pastured area, and labour is a head count of the regular, casual proprietor and family labour in agriculture. Since both axes are measured in natural logarithms a unit increase in either direction is interpreted as a proportional increase in land or labour productivity, and the length of the productivity locus is an indication of the average annual rate of change in productivity. The diagonals indicate constant labour-to-land ratios. As the productivity locus crosses a diagonal from left to right, it indicates a decrease in the number of workers in agriculture per hectare.

From 1910 to 1967 changes in productivity growth were biased toward using more labour per hectare as witnessed by an increase of 68.28 percent in the total labour force from 1910. Hereafter, the labour force decreased by 98.36 percent to 662 730 in 2010. As shown in Chapter 4 the area harvested expanded during the first six decades after 1910 and especially since the outbreak of World War II. The mechanization of draught power up to the 1960s followed by the introduction of mechanical harvesting reduced the levels of employment and forced a bias toward labour saving productivity growth. Through this area per farm worker reached 126 hectares in 2010 as opposed to only 50 hectares per worker in 1967.

From Figure 7.4 one can deduce that the annual average rate of change in productivity was the highest in the period spanning from about 1934 to 1952. This would suggest that an analysis of post-war trends in multifactor productivity would fail to capture the lion's share of the benefits that are expected to have followed from the increased public investment in agricultural technology and rural development made in the years after the great depression.

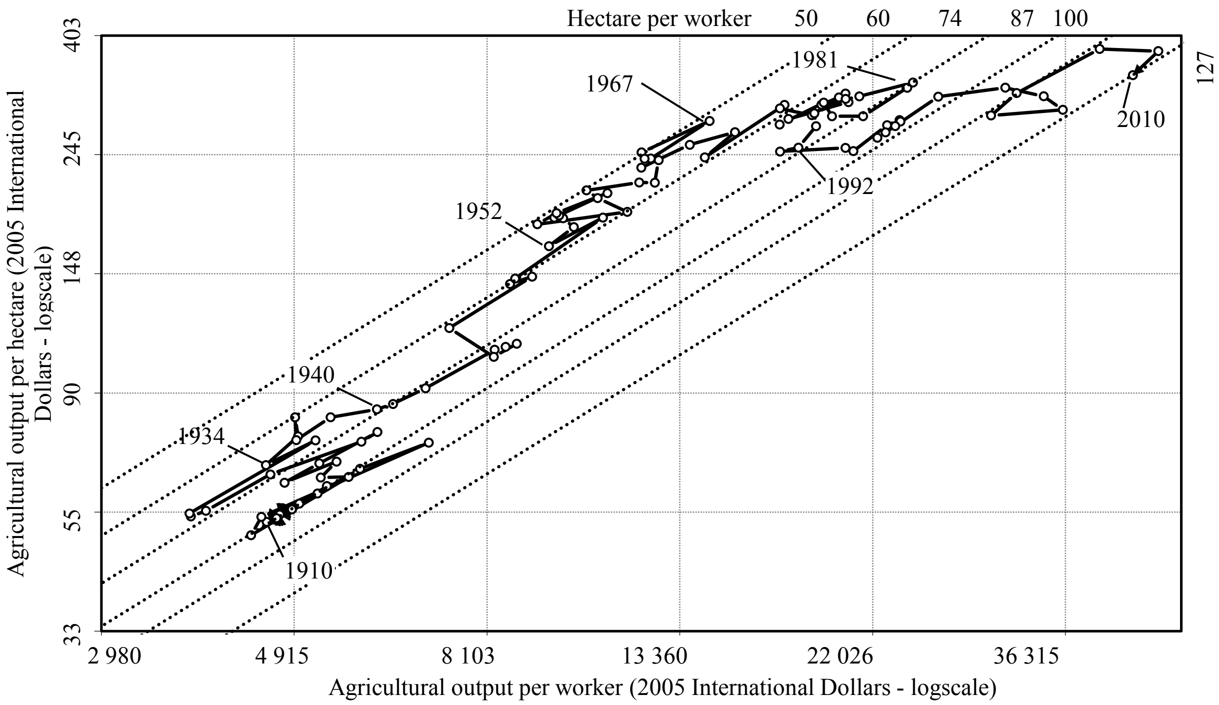


Figure 7.4: Agricultural Labour and Land Productivity in South Africa, 1910 — 2010

Sources: Own calculations

Naturally, one would expect very different trends in productivity growth at a sub-national level. In Figure 7.5 the trends at provincial level are shown for the past three decades — the period within which the area planted to crops predominantly decreased. The farming area represents the total area in farming. Provinces that experienced the strongest decrease in farming area are Limpopo, followed by Mpumalanga, KwaZulu-Natal and Gauteng. With the exception of the Western and Northern Cape provinces all the provinces experienced a decrease in farm employment, with the Free State showing the highest decrease, followed by the Eastern Cape and North West. The combined effect, in terms of area per worker, shows that the Free State and North West experienced the highest growth in area per worker of almost three times the national average.

Gauteng province exhibits the highest output per worker and per hectare of all provinces with the Northern Cape showing the lowest ratios on both metrics due to its land size and predominantly extensive livestock farming. With the exception of the Northern Cape, Limpopo, and Western Cape the annual average rate of change in productivity since 1993 was relatively strong. All provinces, however, experienced a drop in land and/or labour productivity during the 1980s.

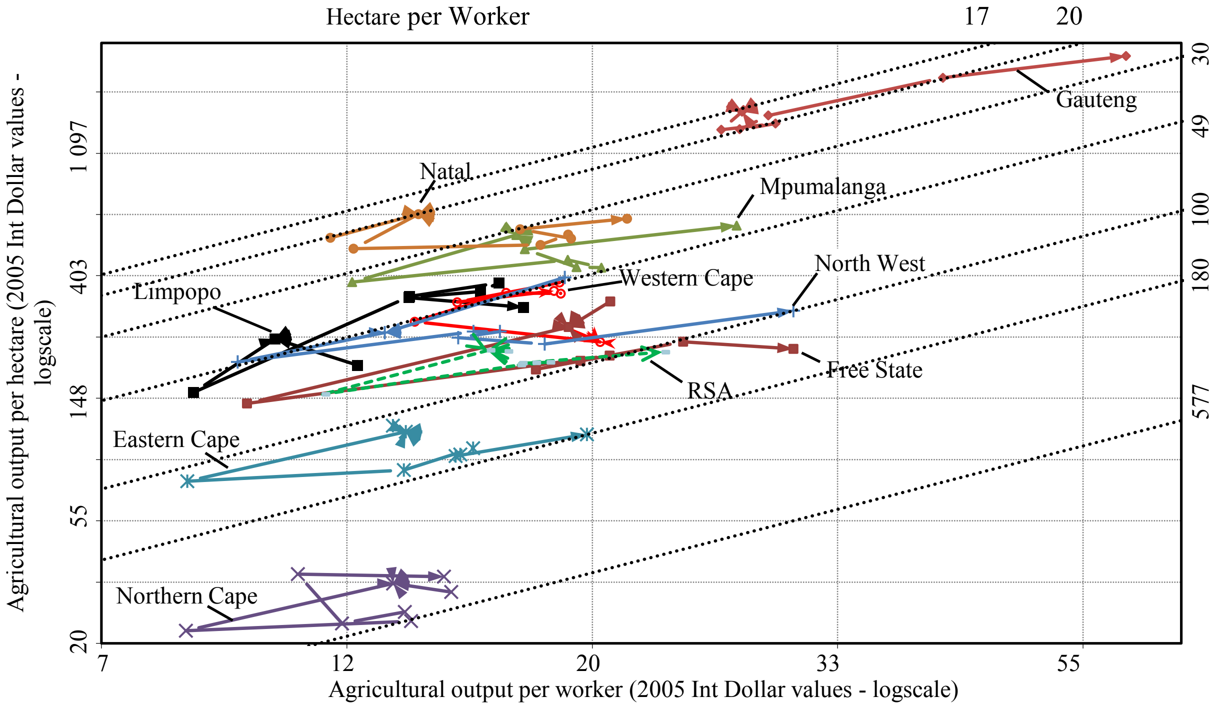


Figure 7.5: Provincial Level Agricultural Labour and Land Productivity in South Africa, 1980 — 2007

Sources: Own calculations

Figure 7.6 draws on Food and Agriculture Organization (FAO) data to place land and labour productivity measures for South Africa into a broader African context. Productivity loci for five regions in sub-Saharan Africa plus Nigeria and South Africa are included. Output is an estimate of the total value of agricultural output (spanning all crops and livestock commodities) expressed in 1999-2001 average purchasing power parity agricultural prices obtained from FAO (FAOSTAT Database, 2011). In this analysis the economically active population involved in agriculture forms the basis for the labour statistics, which would result in area per worker ratios that differ from those shown in Figure 7.5.

The South African and Nigerian (and North Africa) productivity loci follow distinctly different paths from the other regions of sub-Saharan Africa plotted in Figure 7.6. Both countries had increases in land and, especially, labour productivity that were at considerably higher rates than the rest of Africa. Moreover, the value of output per unit of labour in 2009 for both countries was also considerably higher than the rest of Africa: $4,453 per worker in the case of South Africa and $1,714 per worker for Nigeria compared with an average of $465 per worker for the rest of Africa. South Africa is

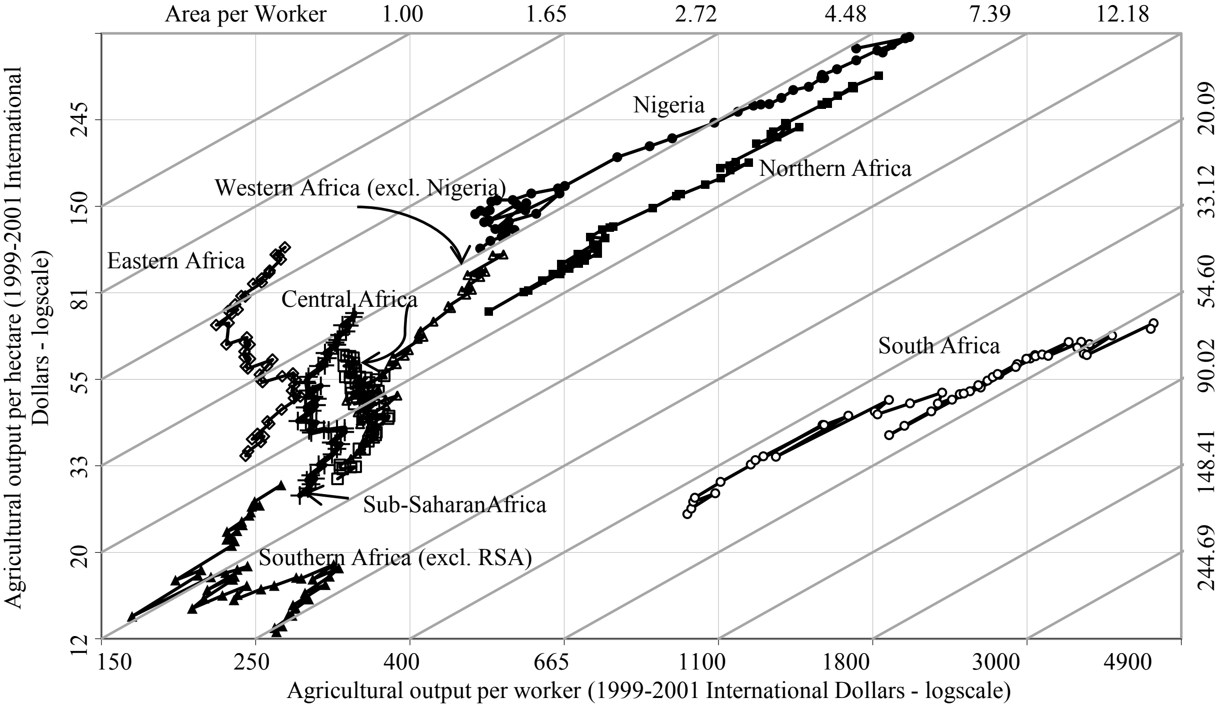


Figure 7.6: Agricultural Labour and Land Productivity in Sub-Saharan Africa, 1961 — 2009

Sources: FAOSTAT (2011)

Note: Employment data is based on the FAO estimates of economically active population involved in agriculture as opposed to the revised farm labour data series used for South Africa in Figure 7.4

distinctive in that it is the only entity depicted in Figure 7.6 for which the land-labour ratio increased to any great extent over time (implying more pronounced growth in labour versus land productivity): from 39.59 hectares per worker in 1961 to 60.9 hectares per worker in 2009. In Nigeria, the land-labour ratio (starting from a much smaller initial value) increased a little: from 4.4 to 4.6 agricultural hectares per worker over the comparable period. In almost all the other regions depicted, real output per worker stagnated (or in the case of Eastern it actually declined, although land productivity in all regions improved over time. Thus the horizontal spans of the productivity loci were smaller than their vertical spans so that land-labour ratios were smaller on average in 2009 than they were a quarter of a century earlier.

West Africa (excluding Nigeria) is an exception compared with the general rest-of-Africa (i.e., sub-Saharan Africa minus South Africa and Nigeria) productivity pattern. This region saw labour productivity grow by 0.96 percent per year from 1961 to 2009 (compared with 2.88 percent per year for South Africa and 3.28 percent per year for Nigeria). Labour productivity in Central Africa barely changed, and in Southern Africa (excluding South Africa) it increased marginally from $261 per worker in 1961 to a lowly $266 per worker in 2009. These productivity trends speak to the dismal record of poverty and chronic food insecurity that befall a large share of the populations in these parts of Africa.

Perhaps ironically, these dismal labour productivity trends in Central, Eastern and Southern Africa (excluding South Africa) belie their comparatively rapid rates of growth in total output. These three regions report real agricultural output growth in the range of 1.4 percent to 2.35 percent per year over the period 1961-2009, in some instances much faster than the comparative rates of growth in total output for South Africa, which averaged just 1.82 percent per year. However, South African agriculture ended the period with fewer agricultural workers than it had in 1961, whereas the economically active population in agriculture in the rest-of-Africa regions (like their populations generally) grew in the range of 0.46 percent to 2.48 percent per year. Thus, the poor labour productivity performance of Central, Eastern, and Southern Africa (excluding South Africa) reflects a failure of labour to leave agriculture for gainful employment elsewhere in these economies rather than a comparatively low rate of growth in agricultural output. Moreover, although the land area in agriculture has continued to expand in these parts of Africa, it has done so at a rate less than the rate of growth in agricultural workers. With land-labour ratios ranging from 2.30 to 8.97 hectares per worker, it is difficult to envisage raising output per worker to substantial levels, especially given the generally poor rural infrastructure and other market and environmental constraints that limit the transition to higher-valued forms of agricultural output.

7.4 Multi-Factor Productivity Measures

In a multi-output, multi-input enterprise such as agriculture, land and labour productivity trends like those described in the previous section give an imperfect measure of technical change, since they are also influenced by how intensively other inputs are used in production. A more meaningful measure of changes in productivity attributable to R&D-induced changes in technology is given when ideal index number procedures are used that account properly for all inputs, and index number problems are minimized.

According to Alston et al. (2010) the measures of multi-factor productivity (MFP) growth may be greater or less than the total factor productivity growth being approximated, depending on what was left out and how the left-out variables changed over time. In the MFP growth measures constructed here changes in the quality of inputs (e.g., the size and power of machinery and other capital inputs, or the schooling of workers and other human capital attributes) have not been addressed. For this to be possible the panel of underlying data used in the analysis must be expanded to include information on variables such as, more detailed long-run changes in the types of capital assets and the levels of education of labour. The intention here was to collect the primary production account data and to construct a consistent and properly validated long run dataset in support of the analysis. Quality aspects, thus, still present a challenge for further refinement of the productivity indexes.

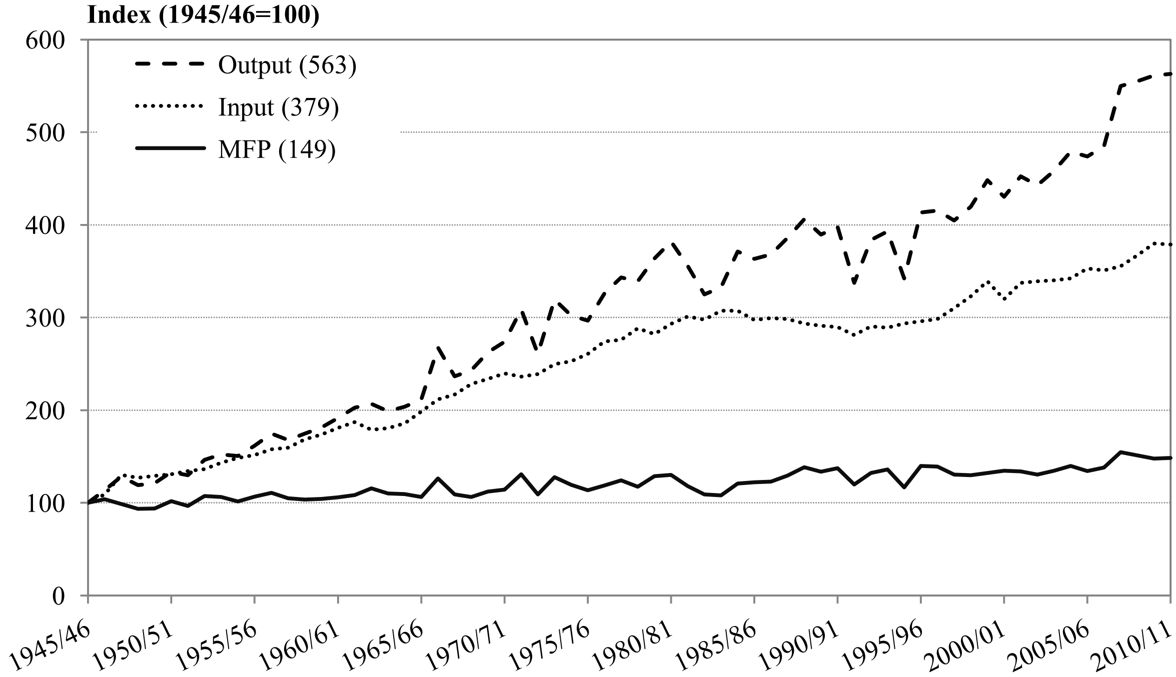
7.4.1 Output, input and MFP trends and growth rates

Figure 7.7 shows the trends in the aggregate output, input and MFP indexes for both the Fisher and the Thirtle indexes since 1945. The average annual growth rates that coincide with the identified phases in policy change are shown at the bottom of Table 7.6. For comparative purposes the growth rates that correspond to the policy phases and the phases identified in earlier studies are presented at the bottom of Table 7.6.

For the first three and a half decades after World War Two growth in the Fisher based MFP estimate was 1.04 percent per year compared to 2.53 percent per year for the Thirtle estimate. Over the subsequent decade and a half it contracted by 0.37 percent per year before it started to increase by 0.76 percent per year following the liberalization of agricultural trade, the deregulation of agriculture and the introduction of democracy. The comparative estimates of the Thirtle indexes are 0.80 and 0.67 percent respectively. Over the whole period MFP increased by 0.86 percent per year using the Fisher index measures, or 1.84 percent if measured with the Thirtle index measures.

Comparing the results on the basis of the periods of MFP growth identified in the earlier study of Thirtle et al (1993) a different pattern emerges. Over the whole period from 1947 to 1991 the Fisher based MFP estimate increased by only 0.86 percent per year as opposed to the 2.05 per year measured with the Thirtle MFP index (Thirtle et al. (1993) was 1.26 per year). During the period from 1947 to 1965 the MFP results are almost the same at 0.41 and 0.44 respectively for the Fisher and Thirtle estimates. However, from 1965 to 1981 the estimated rates of productivity growth differ significantly. This study finds that MFP growth more than doubled from the 1947-1965 phase. The Thirtle estimate shows an almost eightfold increase in the rate of MFP growth (Thirtle et al. found 0.0 and 2.15 percent annual growth rates for the respective periods). From 1981 to 1991 the respective growth rates are 0.39 and 1.55 per year — compared to 2.88 percent per year estimated by Thirtle et al.(1993) — which signals a similar decrease in the rate of growth of between 0.58 and 0.56 percent per year for both it would appear that for South African agriculture the productivity growth rate has improved since 1994, if compared to the decline in productivity growth from 1980 to 1994. It could be argued that this resulted from the policy changes introduced during the last 17 years. However, the choice of the growth phases, as well as concerns over the quality of the primary data gives reason to be cautious about making such a claim. First, the choice of the turning points in history is often an arbitrary choice of the analyst based on the observed trends, or (as was done here) observed changes in policy evolution. The first method is prone to be influenced by events (droughts and other natural disasters) and the latter fails to give recognition to the fact that the effects of policy changes take time to reflect in input and output markets.

Panel a: Fisher Input, Output and MFP Indexes



Panel b: Thirtle Input, Output and MFP Indexes

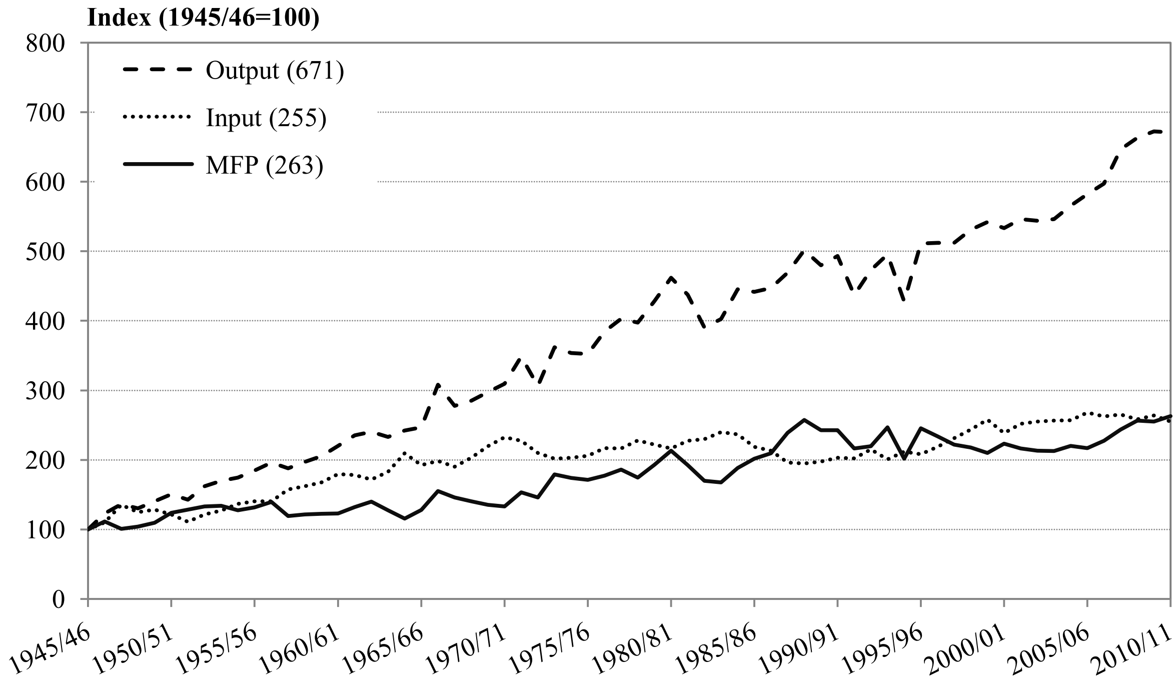


Figure 7.7 Input, Output and MFP for South African Agriculture, 1945 — 2010

Sources: Own calculations

Table 7.6 Fisher and Thirtle Input, Output and MFP Indexes, 1945 — 2010

Year/period	Fisher			Thirtle		
	Input	Output	MFP	Input	Output	MFP
1945/46	100.0	100.0	100.0	100.0	100.0	100.0
1946/47	109.3	113.8	104.1	110.0	122.9	111.7
1947/48	130.1	128.6	98.8	135.6	136.5	100.7
1948/49	127.1	119.0	93.7	125.0	130.3	104.2
1949/50	129.0	121.2	93.9	128.5	140.6	109.4
1950/51	130.8	133.2	101.9	121.4	150.6	124.0
1951/52	134.4	129.8	96.6	111.1	143.0	128.7
1952/53	136.4	146.6	107.5	121.8	162.3	133.3
1953/54	143.3	152.5	106.4	127.2	170.2	133.8
1954/55	148.4	150.7	101.6	136.6	174.4	127.7
1955/56	151.6	161.7	106.7	140.4	184.6	131.5
1956/57	157.8	174.9	110.9	140.5	196.0	139.5
1957/58	159.6	167.8	105.1	157.7	187.8	119.1
1958/59	168.4	174.7	103.7	162.1	197.3	121.7
1959/60	173.7	181.6	104.6	167.6	205.5	122.6
1960/61	180.9	191.8	106.0	179.4	220.3	122.8
1961/62	187.1	203.1	108.6	178.2	235.4	132.1
1962/63	178.9	207.2	115.8	171.7	240.5	140.1
1963/64	180.5	199.0	110.3	182.7	233.2	127.7
1964/65	185.8	203.8	109.7	209.5	242.2	115.6
1965/66	198.6	211.8	106.6	192.4	246.6	128.2
1966/67	211.6	268.0	126.6	198.4	308.3	155.4
1967/68	216.8	236.9	109.3	190.0	277.5	146.1
1968/69	228.2	243.2	106.6	203.0	285.3	140.5
1969/70	234.0	262.6	112.2	219.7	297.6	135.4
1970/71	239.6	274.0	114.4	232.6	309.3	133.0
1971/72	236.2	309.1	130.9	227.6	348.6	153.2
1972/73	239.0	261.1	109.3	209.9	306.3	145.9
1973/74	249.8	319.8	128.0	201.9	361.8	179.2
1974/75	252.7	302.5	119.7	203.3	353.9	174.1
1975/76	260.8	297.1	113.9	205.7	352.3	171.2
1976/77	274.3	326.2	118.9	217.0	384.4	177.1
1977/78	276.0	343.5	124.5	216.4	403.0	186.3
1978/79	288.4	339.4	117.7	228.0	397.5	174.4
1979/80	282.3	364.1	129.0	222.1	428.2	192.8
1980/81	293.4	382.3	130.3	216.5	461.7	213.3
1981/82	301.3	356.1	118.2	227.4	437.4	192.3
1982/83	297.9	325.4	109.2	229.6	390.7	170.1
1983/84	307.3	332.9	108.3	239.9	402.7	167.8
1984/85	307.2	371.7	121.0	236.6	445.2	188.2
1985/86	297.2	363.7	122.4	218.8	441.7	201.9
1986/87	299.3	368.4	123.1	213.2	446.9	209.6
1987/88	298.5	386.6	129.5	196.4	469.2	238.9
1988/89	293.4	406.5	138.5	194.8	501.3	257.3
1989/90	291.2	389.9	133.9	197.7	479.7	242.7
1990/91	289.7	398.3	137.5	203.2	493.2	242.7
1991/92	281.4	337.8	120.1	202.0	437.1	216.4

Table 7.6: (continue)...

Table 7.6 (Continued)

Year/period	Fisher			Thirtle		
	Input	Output	MFP	Input	Output	MFP
1992/93	289.5	384.0	132.6	215.2	472.9	219.8
1993/94	288.8	393.5	136.3	200.6	495.6	247.0
1994/95	293.4	342.5	116.8	211.9	427.8	201.9
1995/96	296.4	413.8	139.6	208.2	511.2	245.5
1996/97	299.9	415.7	138.6	218.7	511.9	234.0
1997/98	313.4	405.2	129.3	231.0	512.3	221.8
1998/99	326.7	420.0	128.6	243.6	531.1	218.0
1999/00	342.3	448.5	131.0	257.9	542.1	210.2
2000/01	323.1	430.9	133.3	238.6	533.3	223.5
2001/02	338.6	452.9	133.8	252.1	545.9	216.5
2002/03	332.3	443.2	133.4	255.0	543.9	213.3
2003/04	330.6	458.9	138.8	256.7	546.0	212.7
2004/05	331.2	479.6	144.8	256.9	565.3	220.0
2005/06	339.6	474.3	139.6	268.2	582.0	217.0
2006/07	337.5	485.3	143.8	262.4	597.3	227.6
2007/08	355.7	550.3	154.7	265.5	646.5	243.5
2008/09	364.7	555.5	152.3	258.5	663.0	256.5
2009/10	384.0	561.7	146.3	263.8	672.5	254.9
2010/11	383.1	563.4	147.1	255.0	671.1	263.1
Policy Phases	*Ten-year annual averages*					
1945-1980	3.19	4.24	1.04	2.46	4.75	2.53
1980-1994	0.28	(0.08)	(0.37)	(0.21)	0.28	0.80
1994-2010	1.72	2.37	0.67	1.50	1.98	0.67
1945-2010	2.15	3.01	0.86	1.62	3.23	1.84
Thirtle phases	*Ten-year annual averages*					
1947-1965	3.09	3.44	0.41	3.93	3.97	0.44
1965-1981	2.91	3.87	0.92	0.61	3.93	3.49
1981-1991	(0.67)	(0.26)	0.39	(1.10)	0.23	1.55
1991-2010	1.68	2.97	1.29	1.33	2.46	1.34
1947-1991	2.34	3.02	0.68	1.74	3.55	2.05

Sources: Own calculations

estimates. As indicated by Liebenberg and Pardey (2010), who found a 3.98 percent growth rate for the two decades from 1970, this high rate of growth is questionable and will be elaborated upon in the next section.

A major concern in recent literature on agricultural productivity growth is whether the growth rate in MFP is slowing down. Alston (2010) found that for the USA, mounting evidence that indicates a structural slowdown in the growth rate of U.S. agricultural productivity which has been "substantial, sustained, and systematic". Fuglie (2010: p 87) reported that "TFP growth may in fact be slowing in developed countries while accelerating in developing countries". Alston, Babcock and Pardey (2010) contest this and point out that the evidence is mixed and that results reflect, in part, the differences in availability of data among countries and measures and methods. Here, from the evidence in Table 7.6

The increase in commodity prices in 2008 also provided an incentive for farmers to increase production, and agricultural output increased by 3.62 percent per year from 2005 to 2010 (2.93 if measured with the Thirtle index). Over the same period the growth in the Fisher based quantity of input use — and here the effect of differences in measurement methods is even more profound — is estimated as 1.44 percent per year (as opposed to -0.98 when using the Thirtle indexing method). This yields conflicting results in the measured MFP growth; the Fisher estimate for this period is 2.18 percent per year in contrast to the Thirtle estimate of 3.96 per year. The decrease in input use measured by the Thirtle indexing method may be explained by the growing support of conservation agriculture. Whether, this change could have resulted in such a marked decrease in input use over such a short period could only be determined once the problem in the national statistics has not been adequately addressed.

7.4.2 Alternative measures and measurement methods

A number of factors would explain the sometimes, substantial differences between the Fisher based MFP index and the Thirtle MFP index as observed here. The influence that the use of 'spliced' Laspeyres indexes may have has already been discussed in Chapter 3 and shown to overstate the growth in the agricultural output quantity index. This was shown to be the most pronounced with horticultural production, where the historic records initially omitted the production of some important industries and that the number of products enumerated increased significantly over time. The situation is more complex with the input quantity indexes, where a number of other caveats in the methodology followed to form the Laspeyres input price indexes used in the Thirtle indexing method are at play.

First it has been shown in Chapter 4 that the prices of purchased inputs reported by the Department of Agriculture reveal an unusually high degree of correlation in prices monitored since 2003 in virtually all purchased input categories. This leads to the conclusion that the underlying price data are no longer based on actual observations, but are rather being formed as indexed adjustments of past prices. A comparison with price indexes reported by Stats SA revealed that the price indexes of the Department of Agriculture grow at rates that far exceed those for similar products produced in the economy. This would yield imputed quantity estimates that understate the actual amount of input use. Using the farming requisites price indexes of Department of Agriculture to form the Thirtle index would overstate the MFP estimates from 2003 onwards. For example, the input index for the Fisher index (formed from a set of prices for purchased inputs that were based on the price indexes of Stats SA from 2003) yield an annual growth in input use of 2.15 percent since 2003. Over the same period the Thirtle input quantity index predict a decrease of 0.06 percent per year in the use of purchased inputs.

The effect on MFP estimates becomes evident when comparing the average annual growth rates for the period from 1991 to 2003 with that estimated since 2003. The estimated growth for the Fisher based index is 1.29 changing to 0.91, or 70 percent of the growth rate of the earlier period. The comparative estimates for the Thirtle estimates are 0.35 and 3.12 percent per year, representing an eightfold increase in the annual growth rate.

A second reason for the Thirtle MFP index to be higher than the Fisher MFP index (formed from the underlying price and quantity data) is the revisions to the agricultural production estimates as discussed in Chapter 3. The changes to vegetable and fruit production estimates results in higher than reported production of vegetables for the period prior to 1958. This removes the understatement of vegetable production prior to 1958. In addition, milk production estimates were adjusted for the period from 1945 to 1992 to address the double count of milk used for processing purposes. Collectively, these changes to the data underlying the Fisher indexes explain the lower index values of the Fisher output quantity index to that of the Thirtle output quantity index which is based on the reported statistics of the Department of Agriculture. In contrast, correcting for the understatement of fertilizer use by the Department of Agriculture since 1981 yields a Fisher quantity index for purchased inputs that is higher than the equivalent Thirtle index.

Finally the significantly different trend patterns in aggregate input use can be further explained by the different methods followed in forming the capital input use index (See Chapter 4). The approach followed to form the Thirtle capital input quantity index estimates the service flow from capital inputs from the service flow emanating from capital stocks as the sum of running costs, interest and depreciation (Thirtle, et al. 1993). The depreciation series formed by the Department of Agriculture is based on an assumed homogenous age distribution of the capital stocks. In so doing this method does not account for differences in service life and depreciation of the different classes and types of capital used in agriculture. The Fisher index for the quantity of capital input use represents a major deviation from the earlier studies in that it accounts for the changing age distribution in line with the estimated service life of a capital input class. This explains the differing trends between the Fisher capital input index and its Thirtle equivalent, e.g. the Fisher input quantity index first peaked in 1983 — after the slump in tractor sales in 1981 — whilst the Thirtle input quantity index reached a peak in 1970.

7.5 Accounting for Output Growth

The value of South African agricultural output increased from R258.5 million in 1945 to R138.4 billion in 2010 in nominal terms. After dividing by the GDP deflator (real 2005 Rand values) to account for inflation, the value of agricultural output showed a threefold increase from R31.5 billion in

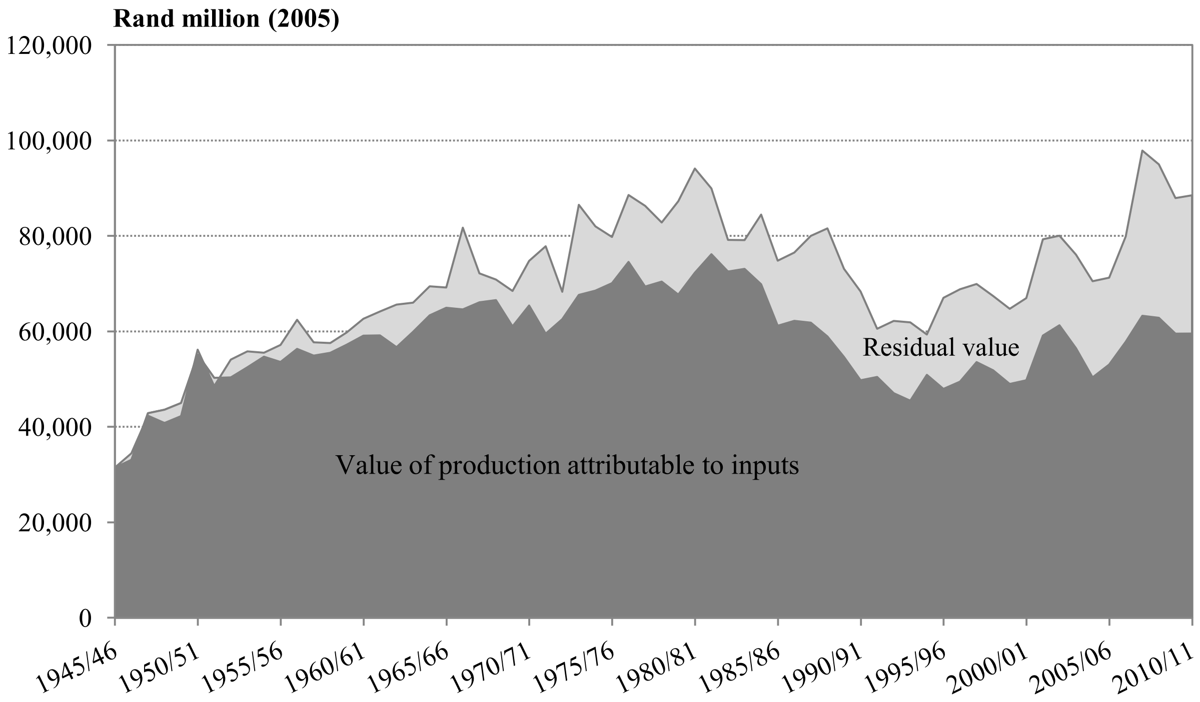
1945 to R88.5 billion in 2010, reaching a peak of R97.8 billion in 2007. From 1980 the real value of output declined to 1994 and is now fluctuating around the 1980 value. Output quantity, however, grew throughout this period, albeit at a slightly slower pace than the two decades preceding 1980 as a result of agricultural productivity growth.

7.5.1 The value of productivity growth

In annual rate-of-change terms, aggregate South African agricultural output increased by an average of 3.00 percent per annum over the period 1945–2010; aggregate inputs used in agriculture increased by 2.13 percent per annum, and so measured MFP grew by 0.88 percent per annum. Following the analysis of Alston et al. (2010) and compounding the growth rate of 0.88 percent per year over 65 years, the index of productivity grew from 100 in 1945 to about 148.6 in 2010 (Figure 7.8, Panel a). That is, if inputs had been held constant at their 1945 quantities, output would have increased by a factor of 1.49. In other words, of the actual output in 2010, 67.3 percent (i.e., 100/148.6 = 0.67) could be accounted for by the increased use of conventional inputs using 1945 technology, holding productivity constant. The remaining 33 percent (i.e., 48.6/148.6 = 0.33) is accounted for by the increase in productivity. Hence, of the total production, worth R88.5 billion in 2010, 67.3 percent or R59.6 billion could be accounted for by conventional inputs using 1945 technology, and the remaining R38.3 billion is attributable to the factors that gave rise to improved productivity. Among these factors is new technology, developed and adopted as a result of agricultural research and extension.

The Thirtle approach gives a vastly different view of developments. Using these indices and repeating the procedures described above, the conclusion is that 38.0 percent (or R33.6 billion) of South Africa's agricultural output in 2010 is attributable to the growth in input use since 1945, while 62.0 percent (or R64.2 billion) of the output is attributable to productivity growth.

Panel a: Fisher based estimates



Panel b: Thirtle based estimates

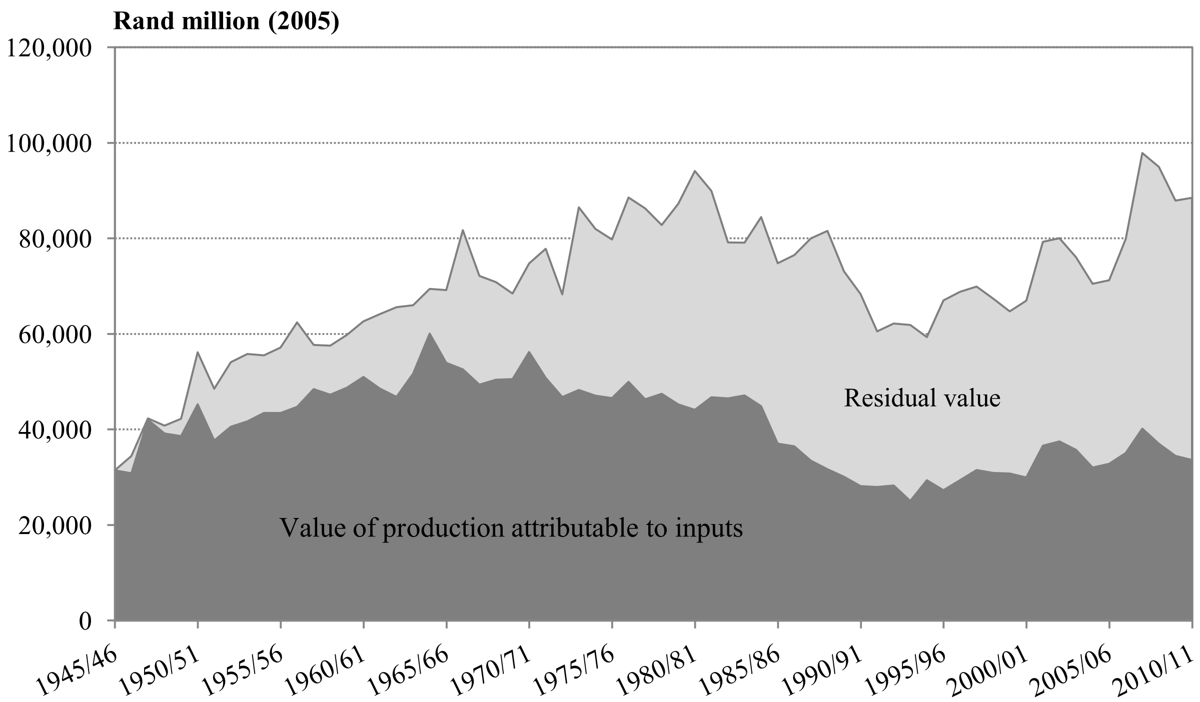


Figure 7.8 Agricultural Output Value Attributable to Productivity Growth, 1945 — 2010

Sources: Own calculations

The trends in these metrics are shown in Figure 7.8 Panels a and b, for the both Fisher and Thirtle based estimates. The results for the Fisher based estimates in Panel a show that from 1945 to 1981 growth in output value was mostly attributable to inputs, but since 1987 the growth in output value was largely attributable to productivity growth. The value of production attributable to inputs reached a peak in 1981, but then decreased sharply over the subsequent 15 years before it recovered by 31 to reach the same levels experienced in the 1960s. The Thirtle estimate yields a remarkably different trend. Here the value of agricultural output attributable to inputs peaked in 1964 before it slowly declined to 1983, before it rapidly contracted to 1993 from where it recovered by 34 percent to currently fluctuate around the values achieved in the mid-1980s.

The trends in the share of production value attributable to productivity growth for both the Fisher and Thirtle based estimates are shown in Figure 7.9. The Thirtle estimate is higher throughout the period of analysis, on average about 2 times that of the Fisher based estimate. Up to 1973 the Thirtle estimated share of output value attributable to productivity growth was about 25 percent higher than the results obtained from the Fisher based analysis. From here the Thirtle estimate increasingly exceeded the Fisher estimates until 1992 before the difference contracted to again reach about 28 percent currently.

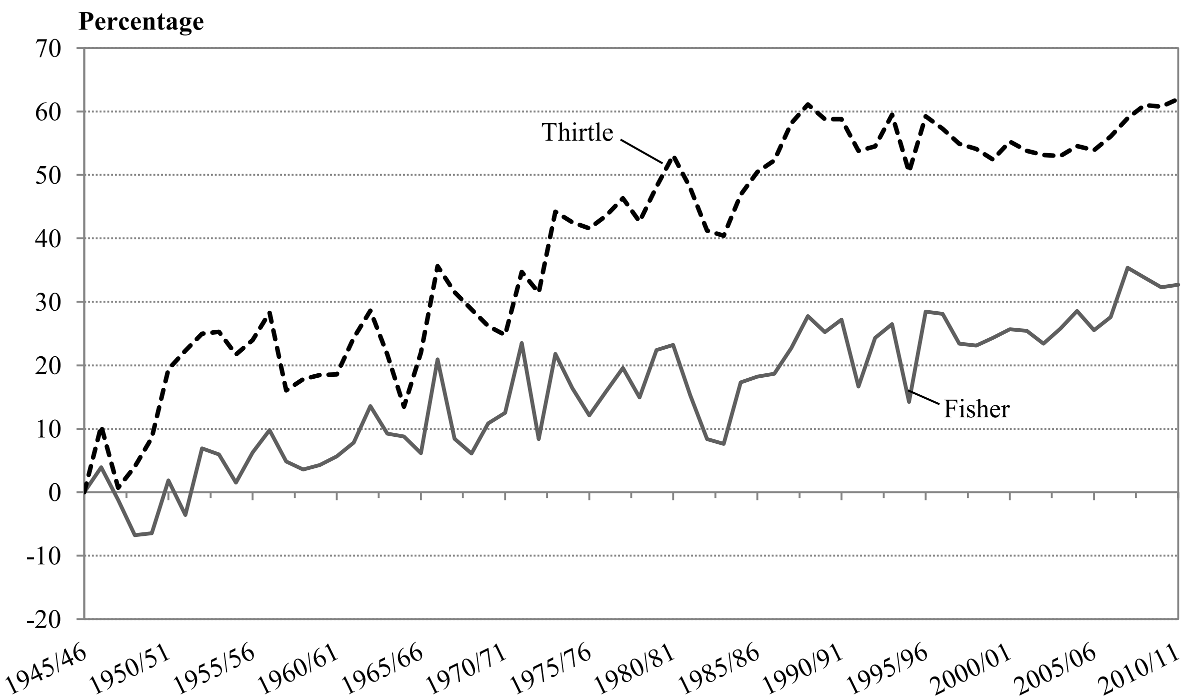


Figure 7.9 Comparative Shares of Agricultural Output Value Attributable to Productivity Growth, 1945 — 2010

Sources: Own calculations

Alston (2010) found that 39 percent of the growth in the value of production in USA agriculture is attributable to inputs and 61 percent follows from productivity growth. This is contrary to the Fisher based findings for South African agriculture. However, whereas it appears that the share of production value attributable to agricultural productivity growth in the USA has stagnated around 60 percent, it appear that for South African agriculture it is still growing.

7.6 CONCLUSION

While the adjustments made in this thesis to the measured history of output growth in South African agriculture have had measureable consequences for certain sub-sectors of agriculture — particularly milk, poultry, vegetables and fruit — the overall trend in aggregate output is broadly similar to those in prior estimates. A caveat that still exists in this regard is the identified under reporting of vegetable and fruit production for the years prior to 1958 when the standardization of packaging made it possible to more comprehensively report on the true extent of production. Here the estimated production largely still reflect the production trends of processed and fresh produce sales and do not capture the on farm production and direct sales outside of the formal markets. The notable results in this thesis are that our measured views of agricultural input use and partial and multi-factor productivity growth are now substantially different than those of past studies.

The analysis of the partial productivities of land and labour indicate that improved productivity of both land and labour from 1937 to 1951 had a substantial effect on the growth in agricultural productivity with a distinct bias toward land use. From the 1970s the agricultural sector has shown a distinct labour saving bias in its technology choices, especially so since the early 1990s. However, the period since 1994 also shows a growth in the share of production value attributable to input use characterised by a growing reliance on labour saving technologies spurred by labour related policy changes introduced since 1997. Comparing the trends in increased yields over time, it was found that the output per unit of land has increased markedly since the late 1980s, but that black farmers have failed to benefit from the improved seed and other agricultural input technologies to the same extent as commercial farmers.

Growth patterns in multi-factor productivity estimated in this study differ substantially from those of earlier studies, especially in terms of magnitude, and present different results on the estimates of the growth in agricultural output that is attributable to productivity growth. Although the results seem to point at improved rates of growth in the aftermath of trade liberalization, other factors in the economy and developments in the basis of measurement of agricultural activity (quality of price reporting by the Department of Agriculture since 2003 and sampling errors in agricultural censuses since 1994) may have a bigger explanatory value in the measured increase in productivity growth since 1994. The first two decades since World War Two saw remarkable growth in agricultural productivity as agricultural mechanization took place leading to an increase in area planted and higher employment in agriculture.

This coincides with the era in which the R&D services were integrated around the regionally placed Agricultural Development Institutes. From the 1980s, and possibly influenced by developments such as the restructuring of the R&D services, agricultural productivity growth contracted marginally as declining investment trends, deregulation initiatives and the economic upheavals of the time exerted their effect.

CHAPTER 8

SUMMARY AND CONCLUSION

8.1 INTRODUCTION

The objective of this study was to provide a more complete understanding of the changing pace and nature of production and productivity growth in South African agriculture during the 20th century and the associated changes in R&D investments and institutions that affect agricultural input, output and R&D variables. To this end the agricultural production accounts were revised to address the legacy of South Africa's history of racial segregation and the issue of changing statistical methods and procedures. An original set of annual, national prices and quantity variables for agricultural output and its components, for the period 1910/11 to 2010/11 were generated. The production contribution of some previously omitted crops was estimated and included in the new production accounts. The analytical counterpart to the production accounts that focus on the evolution of aggregate input use and its components was also revised. A newly constructed aggregate land and labour input series is presented for the period from 1910/11. Special attention was also given to the construction of two capital flow series. One series estimates the flow of services from physical capital such as fixed improvements, tractors, combines, ploughs, etc. The second series measures the annualized services flowing from the stock of biological capital. Aggregate measures of purchased input use were revised. An assessment of changes in input cost shares, input factor ratios, and corresponding movements in relative factor prices is presented.

A completely new panel of data were constructed to track the investment in agricultural R&D and researcher staff capacity and to account for the numerous structural and organizational changes the public sector R&D services since FY1910. The changing format of budgetary reporting over the century since Unionization was also addressed and in so doing, the measurement error in tracking the history of public agricultural investment was addressed. Using the data series on public spending on agriculture, in general, and R&D investment in particular, the evolution of the phases in policy development were discussed with a detailed focus on the changing shape and nature of the public sector agricultural R&D services over the century.

Finally, the new estimates on output production and input use were used to quantify and describe the evolution of agricultural output over the past century, offering new insights in the economic evolution of South African agriculture. This was done by employing modern indexing methodologies and working with the primary price and quantity variables instead of pre-aggregated Laspeyers indexes of production quantities and input prices as reported by the Department of Agriculture. The results of the Fisher Ideal Divisia indexes thus formed were compared to the earlier indexing methods of Thirtle et al. (1993) throughout the analysis to illustrate the effects of working with the revised panel of data and the extent of aggregation bias that followed from the earlier methods.

8.2 Summary of Results

In revising the measured history of agricultural production in this country a number of caveats in the published records of agricultural production were found. First, the data on production originating from black and homeland farmers often revealed inconsistencies in their inclusion. The periodic variation led to erratic trends in the reported long-run quantity of production data series. Two other sources of measurement error appeared in the estimates on horticultural production that have direct implications for the Laspeyres quantity of production index reported by the Department of Agriculture. The first is the changing composition of the sub-aggregate indexes themselves and the second is measurement errors in the estimation of production quantities, as well as omissions in the products enumerated. Taken together the reported Laspeyres quantity of production indexes understate the trend in output prior to 1958 and overstate the increase in output from this point with the increase in the number of products included in the reported production quantity index of the Department of Agriculture.

The analysis of agricultural input use also revealed similar problems of understatement of input use. Fertilizer is a pertinent case in point, where the changes made in the estimates by the Department of Agriculture were underestimated by up to 44 percent in some years, spanning from 1981 to about 2007. An issue has also emerged with the quality of purchased input prices from 2003 where an exceptionally high degree of correlation is apparent in the prices monitored. Coupled to the exceptionally high rates of increase in the prices reported by the Department of Agriculture when compared with analogous data from Stats SA, it is concluded that the price series reported by the Department of Agriculture is most probably an over estimate and would lead to understating the level of purchased input use. It is suspected that the same problem may exist with most of the capital input prices monitored by the Department of Agriculture as the reported price indexes for capital equipment remained constant from 2003 to 2008.

Data on capital input use were disaggregated and revised to enable the use of an alternative method to form the flow of services from capital inputs in the formation of the Fisher indexes. The aggregate quantity of capital input use formed by using the new methods yielded indexes that are both more robust and more clearly reflect the changing policy phases.

With land use the revised long-run series on area cultivated, area under irrigation and range and planted pastures indicate that earlier method of indexing land use overstated the trend in land use by about 9 percent when compared with the quality adjusted Fisher index on land use.

The revised data on on-farm employment and the Fisher labour index formed from this revealed that earlier methods overestimated the trend in labour use and reflected the policy changes that impacted on agricultural employment slightly better in terms of the points when these changes were introduced.

It was found that factor proportions in South African agriculture changed markedly over the past 66 years. Since 1945, the materials: labour and materials: land ratios on average increased the fastest by 4.92 and 4.32 percent per year respectively reflecting changes in production practices and technologies. The strong decrease in the labour: capital and land: capital ratios until 1981 was mostly aided by the strong mechanization drive in commercial agriculture. Since 1981, the land; capital ratio increased slightly until 1993 before it gradually started to decrease to hover around the same ratios experienced in the early 1980s. The labour: capital ratio followed the same pattern, but decreased at a much more rapid rate to reach levels in recent years that are below that of the early-1980s. As a consequence of these offsetting price and quantity effects, the increase in the share of total costs attributable to purchased inputs is much more muted than the increase in the quantity of purchased inputs used. Capital services used increased whilst its share in total costs have declined over the period since 1945.

The historic trends in public sector investment in the agricultural sector indicate that support to farmers, especially prior to 1937 when the sector first experienced a major increase in direct support from government, were mainly aimed at support to farmer settlement. The extent of the investment in the various schemes is not explicitly captured in the published records and represents an understatement of public sector investment in agriculture for the years prior to 1930. The nature of these settlement schemes differed significantly from the support measures implemented since 1994 and could explain the observed productivity trends — as indicated by the partial land and labour productivity metrics — post World War II to an uncertain and as yet untested extent.

The analysis of the R&D investment and staff capacity trends revealed how after an initial phase of capacity building the R&D system developed a measure of synergy in its activities as observed in the spending patterns between the national and regional institutes (inclusive of the faculties of agriculture), which from 1926 to 1971 were integrated around the regional centres. This synergy in the funding of the various entities came to an end in 1980 when the regional and national institutes were restructured as autonomous and pseudo independent institutes and the faculties of agriculture were, by then, the responsibility of the Department of Education. In aggregate, the public sector investment in agricultural R&D stagnated from 1978 and today is still fluctuating around the levels of investment of the late seventies.

The productivity indexes formed from the revised data series in production and input quantities reveal very different patterns to that of earlier methods in both the rates of growth and in the pattern it followed during the different policy phases. Growth rates were found to be much lower than earlier estimates and, in contrast to earlier studies, showed a marginal contraction in agricultural productivity during the deregulation phase that was also characterised by increased sanctions against South African exports, domestic unrest and adverse economic conditions — as is to be expected. During the last phase of policy evolution characterized by trade liberalization initiatives, the closure of the control boards on marketing, and the general improvement in economic growth in the economy, the rate of productivity growth improved marginally, but this is more likely the result of developments in data quality concerns. The differing trends in productivity growth culminate in the surprising result that the share of growth in production value due to productivity growth is much less when estimated with the Fisher Ideal Divisia index than what has formerly predicted by the Thirtle indexing method.

8.3 Conclusions

The first hypothesis was that by adjusting inconsistencies in the underlying data in terms of the inclusion of homeland agriculture, and constructing output indexes based on the primary price and quantity data instead of using pre-aggregated variables, it is expected that the resulting output estimates would differ significantly from past estimates. This hypothesis is partly rejected as it was found that the new indexes on output revealed largely similar trends to that formed using the earlier methods.

The second hypothesis was that by using more consistently constructed data and modern statistical methods the resulting input indexes would correlate more closely with the structural changes (policy changes) in the identified policy phases. This hypothesis is accepted, as it was found that not only did the earlier methods yield indexes that overstate growth patterns, but trended more erratically and in poor concordance to the timing of policy changes. It must be borne in mind that over the last two decades data quality issues posed limitations for the accuracy of both methods, which would influence results if these issues were addressed. These changes, however, would not change the fact that earlier methods suffered from aggregation bias in their index numbers.

The third hypothesis was that the combined effect of the changes made in forming the output and input indexes would yield productivity estimates that would differ significantly from past estimates and lead to different qualitative and quantitative perspectives on the performance of the South African agricultural sector and its ability to contribute to income redistribution. This hypothesis is accepted as the growth patterns in partial and multi-factor productivity estimated in this study differ distinctly from those of earlier studies, especially in terms of magnitude, and present different results on the estimates of the growth in agricultural output that is attributable to productivity growth.

Finally it was postulated that significant differences exist in the degree of public sector investment in agricultural development during various policy phases and that this has strongly influenced the nature and focus of agricultural R&D investment. This hypothesis is accepted as the analysis has shown that the structure, governance and research focus has shifted over time in line with the evolving agricultural policy focus as represented by the identified policy phases.

8.4 LIMITATIONS OF THE STUDY

A critical constraint of the indexes on input is that quality adjustments for labour and capital were not done. In the case of labour the levels of education have changed over time as is periodically reported in the population census. Failure to capture this leads to an understatement of labour use in the indexes formed here. Whether the effect would be as significant in South African agriculture as was found for the United States is doubtful as educational attainment of farm labour have not improved as markedly in this country. An even more critical area where quality adjustment needs to be done is with capital inputs. Data captured for this study was restricted to the aggregate of the capital classes, which precludes the adjustment for quality made possible by the formation of the index starting from the types of capital within a class. Another aspect that deserves attention is the assumed age profile of on-farm capital inputs. Here the ratio of the average age of tractors to their service life was used to estimate the age of other capital input classes for which information was not available and an effort should be made to find information pertinent to each class.

Major concerns exist with respect to the inadequate/outdated methods to impute overall capital sales used by AGFACTS and reported by the Department of Agriculture. The ratios employed today date from 1994 and in view of the changing nature of cultivation practices and mechanization technology these ratios have become obsolete. As these estimates also form the basis for the estimates of national income done by the South African Reserve Bank it raises concern over the whole spectre of policy decisions based on these potentially incorrect data. A matter that is closely related to the former is the increased correlation (and exceptionally high rate of increase) in input prices monitored by the Department of Agriculture. In this study it was found that upwards of sixty percent of the input prices monitored are perfectly correlated, hinting that the underlying data may not be based on actual observations anymore. As the indexes on agricultural input prices form the basis for contractual pricing decisions in the sector, overstating the inflation in input prices undermines the economic survival of the sector and eventually the consumer as well.

Linking to the suspected influence that earlier interventions in supporting agriculture must have had on productivity growth in agriculture during the period from 1937 to the 1950s, it would be highly desirable to extend the productivity analysis to at least 1936. From the ledger files of the Department of Agriculture (and the fact that input prices were monitored from this date) it was observed that expenditure aggregates on inputs purchased are available. Efforts to track the detailed data from which this series was formed, unfortunately, had no success. Failure to extend the analysis to this point in the sector's history potentially would lead to biased results in the accounting for the factor that contributed to the growth in productivity during the earlier years.

There is also an increasing tendency for the Department of Agriculture and public entities, such as the Agricultural Research Council, to limit reporting on expenditure to corporate aggregates. This undermines the ability to replicate studies such as this one and limits the future ability of agricultural economists to conduct sound policy analysis. Coupled to this are the increasing eloquence in naming program activities to the point where it bears no relation to the technical nature, or intent, of the activity. This in turn will (and has) lead to erroneous conclusions in subsequent analytical work and it would be advisable for government to return to the more technically descriptive basis of reporting that was in use in the 1980s and preferably before the early 1970s.

Finally, a major asset for studies of this nature is the availability of detailed statistics on farming activities as reported in the agricultural census and survey reports. However, even here the level of detail is declining and the same habit of only reporting sub-aggregate numbers is evolving to an alarming degree. Not only is less information enumerated, but the sampling procedure leads to the selection of only the bigger commercial farmers. Even with the limited information available it has become impossible to access the underlying database, as used to be possible, or is possible in other countries such as the USA. The limitations this places on the conduct of rigorous analysis to formulate sound policy advice need not be elaborated.

8.5 Implications For Future Research

Now we finally can begin to meaningfully analyze the role of R&D and productivity growth in South African agriculture. In so doing we expect to get new insights relative to past efforts, not least as we are starting with different measured views of the MFP and R&D histories. However, there are areas that still deserve further refinement in the analysis done here:

1) Although a concerted effort was made to 'fill the gaps' in the horticultural production accounts, further work needs to be done on estimating the production prior to 1958 to properly present the contribution of this sub-sector. Information to do this is available, but careful analysis needs to be done to construct a robust production record for the 'missing industries'. The same is true of the ostrich industry and specialty crops where little is known about the total contribution these industries made and is increasingly making.

2) A need exists to extend the multi-factor productivity index to the years prior to World War II years. This is essentially the formative years of the sector and in the former Transvaal and Free State provinces it would shed light on the impact of the massive investments in rural infrastructure to unlock the productive potential of agriculture in these areas. This would naturally call for a thorough analysis of government investment during these years, the full extent of which was not captured in the investment series presented here.

3) The panel of data on agricultural input use needs to be extended to enable quality adjustment on capital assets and employment as this would impact on the estimates of input use and yield a more appropriate estimate of the quantities of input use.

4) The partial productivity analysis for the nine provinces done in this study shows that productivity trends at the sub-national level differ substantially from the national aggregate estimates. By replicating this study at a more disaggregated level we would be able to improve our understanding of the factors that have led to the changes observed in national multi-factor productivity.

The revisions made to the production accounts and input accounts and the inconsistencies revealed in this study allude to a need to re-visit a number of the studies done in the past where long-run data was used. There is reason to believe that the results of earlier long-run studies were affected by the same caveats in the primary data.

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