An economic assessment of the implications of changes in wheat quality standards in South Africa

by

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DECLARATION

I, Zwiafhela Naledzani, solemnly declare that the work contained in this dissertation submitted to The University of Pretoria in partial fulfillment of an MSc in Agricultural Economics is of my own work and has not been submitted before to this or an any other institution.

Signature: ______________________

Date: __________________________

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John 5:17 "But Jesus answered them, My Father is still working, so I am working too."

ABSTRACT

An economic assessment of the implications of changes in wheat quality standards in South Africa

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South Africa has been a net importer of wheat for the past two decades. Due to the inverse relationship between quality and yields, it has been argued that the pursuit of the high wheat quality standards as set by government has led to greater financial loss, rather than financial gain. Various stakeholders in the wheat value chain are said to lose more than they gain from the high quality standards that are required to be maintained.

Given the industry claims of the required wheat quality standards being too high, the aim of the study is to evaluate the economic implications of government intervention in the wheat industry through their enforcement of quality standards. The specific objectives of this study have become the determination of historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry, and to determine the returns from the current government-required wheat quality standards.

The Fisher Divisia index method was used to determine the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry. It was found that the output of both non-bread-baking and bread-baking wheat quality had a declining rate. However, the output of wheat of bread-baking quality was declining at a faster rate than that of wheat of non-bread-baking quality.

To determine the returns from the current wheat quality standards, econometric modelling was used along with a benefit-cost analysis. It was found that the application of quality standards as set in the Agricultural Product Standards Act No. 119 of 1990 (APS) has led to an average total cost of R45.6 million and associated benefits of R28.2 million between 1999 and 2014. This has resulted in a benefit-cost ratio of 0.62. This implies that for every Rand invested in public breeding for quality improvement, 38 cents has been lost. This further suggests that for any amount invested in breeding solely for the purposes of quality improvement, a significant amount has not been recovered. There are therefore cogent reasons to consider reforming the Agricultural Product Standards Act.

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CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

Wheat is the second most important grain crop produced in South African agriculture (DAFF, 2015) and has contributed three percent to the gross value of agriculture in the 2004/05 season (DAFF, 2006). Scientifically known as *Triticum aestivum*, different wheat cultivars have been developed over the years to suit the different production regions in South Africa. The first locally developed wheat varieties were issued to farmers as early as 1915 (van Wyk, 1961a). The main use of wheat in South Africa is for human consumption of products such as bread, cakes, cereal, rusks, pasta, and biscuits. Other important uses of wheat is that of producing various animal feeds, storage as seed, and industrial uses such as in the production of ethanol.

South Africa has imported wheat to supplement its own production for decades. However, since the 1930s South African wheat has shown to be better adapted to the various local production regions than imported seeds (van Wyk, 1961a). Thus, wheat seeds bred in South Africa during the 1930s showed superiority in quality and quantity as compared to imported seeds. During the 1960s, however, the country commenced producing wheat that was of inferior quality as compared to that of imported wheat (van Lill & Purchase, 1995). To date, the country is involved in both the import and export of wheat and its products.

Currently, seed improvement in South Africa is undertaken by both the public and private sectors. Companies with the highest market share of improved cultivated wheat seeds are Sensako, Pannar and the Agricultural Research Council-Small Grain Institute (ARC-SGI) (Stander, 2012). ARC-SGI is a public entity while Sensako and Pannar are private companies. Efforts in wheat breeding are not only directed towards improving wheat yields but also towards improving wheat quality.

According to Maynes (1976), quality is subjective, it is based on the weighted average characteristics of a product by an individual. Maynes (1976) further defines these characteristics as the services that give rise to utility. Good quality wheat is defined by Reimer (2011) as “a particular wheat’s ability to consistently produce a flour that will perform well in the production of a finished product." The definition of good quality wheat will differ by market and by user. What is considered to be high quality wheat by a farmer may not necessarily be of high quality to the miller. According to Louw (2011) of the Southern African Grain Laboratory (SAGL), grain quality has different meanings for different members in the value chain. Producers, processors and consumers attribute quality to different traits of wheat. Producers regard a good quality grain as that which has high yields, is resistant to disease and drought, and also shows consistency in production over different regions and seasons. Louw (2011) further describes good quality grain from the perspective of processors as that which has a constant milling quality, shows good extraction yield, has nutritional value for animal and human consumption, and also shows good dough qualities (including dough development time, dough strength, dough extensibility, good loaf volume, etc). The consumer's view of good quality wheat has been described by Louw (2011) as the wheat's ability to produce food safe for consumption with a long shelf life, which looks appealing, and can be used to produce innovative products.

Wheat quality is more clearly defined by a set of parameters associated with the grain. Similar to Louw (2011), Hruskova & Svec (2009) noted in a Czech Republic study that wheat quality cannot be clearly defined since it changes depending on workers and its end use. The study linked quality to a number of grain attributes. Those parameters were test weight, thousand kernel weight, grain hardness, grain ash content, grain protein content, grain falling number, semolina yield, semolina reduction, flour yield, flour ash content, flour protein content, and Zeleny's test. Like most countries, the United States of America (USA) has defined wheat quality according to certain specific parameters. According to Slaughter *et al.* (1992), during the late 1980s the United States Department of Agriculture (USDA) identified the following parameters in defining wheat quality: protein content, moisture content, hardness, test weight, kernel weight, sedimentation, water absorption, tolerance, peak time, loaf volume, crumb grain, and crumb texture.

In South Africa, wheat quality and grain standards are set by the DAFF and evaluated by SAGL. The Southern African Grain Laboratory considers numerous parameters when defining grades of wheat. There are similarities in wheat parameters of most countries that test for wheat quality. While it is true that the quality of a product is a subjective matter, characteristics of a product that raise utility can be identified and often measured, as is the case with wheat quality. In South Africa, before a new bread wheat cultivar is released, it must show superiority to previous cultivars and has to fulfil certain primary and secondary criteria (see appendix A). According to SAGL (2010) as cited in Miles (2010), primary parameters are inflexible. These primary parameters include alveogram dough strength, alveogram stability/distensibility (P/L)-values, hectolitre mass, protein content, mixogram peak time, farinogram water-absorption, loaf volume, falling number, flour colour and yield.

Standards for these parameters have changed over the years, influencing the quality and quantity of wheat that is produced by the South African wheat industry. The changes in wheat quality standards have economic implications which are felt by all stakeholders: producers of seed, farmers, as well as consumers. Van der Merwe (2015) argues that the changes in standards in order to pursue higher wheat quality have led to measurable losses by the South African wheat industry. Van der Merwe (2015) estimates that R606 million in net farm income is lost per annum due to the current standards. The economic implications of public breeding under the legislated quality standards have not been quantified. In this study, econometric modelling is used in order to quantify the losses or gains associated with breeding for quality. This study uses public breeding done by the ARC as a case study.

1.2. PROBLEM STATEMENT AND JUSTIFICATION

South Africa remains a net importer of wheat. Given the inverse relationship between quality and yields (Brill *et al.*, undated; Purchase *et al.*, 2000), it has been suggested that the gap between import and export can be reduced by lowering the quality standards which are required to be met for South African wheat, thus increasing national income. Most economic evaluations of breeding programmes calculate the benefits of the entire programme (Brennan *et al.*, 2004; Pardey *et al.*, 2004; Barkley *et al.*, 2008; Nalley, 2008; Nalley *et al.*, 2011; Stander 2012; Dlamini *et al.*, 2017). To date these evaluations have shown high returns on investments, justifying the need for increased investment. However, no evaluations have quantified the costs associated with the objective of breeding for quality improvements. As stated earlier, Van der Merwe (2015) found that the costs of high quality standards have led to a net farm income loss of R606 million per annum. This study extends the work of Van der Merwe (2015) in an attempt to determine the economic implications associated with adherence to the current quality standards from a public breeding perspective.

1.3. RESEARCH QUESTIONS

Studies on the economics of wheat breeding have mainly focused on the returns of investment in order to justify investment in agricultural research and development. Stander (2012) identified the economic benefits of wheat breeding in South Africa both attributable to the public and private sectors. Stander's (2012) analysis of wheat breeding programmes was also used by Brennan *et al.* (2004) for the New South Wales wheat breeding programmes. The studies calculated the rate of return using benefit-cost ratio, internal rate of return (IRR), and the net present value (NPV). While most studies (Pardey *et al.*, 2004; Barkley *et al.*, 2008; Nalley, 2008; Nalley *et al.*, 2011) attach certain benefits and costs to an entire breeding programme, none have isolated quality standards adherence as a cost in the calculation of a benefit-cost ratio. The following research questions arise: how much do breeders gain from breeding for quality; how much do breeders lose out when breeding with quality objectives in mind; and what impact has government intervention in setting such standards had on wheat outputs and quality?

1.4. OBJECTIVES

The main objective of this study is to determine the economic implications of adhering to the wheat quality standards required to be met by South African breeders.

The specific objectives of this study are:

- determining historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry;
- identifying high yielding and quality satisfactory ARC cultivars in the different production regions of South Africa
- determining the returns from the current wheat quality standards set.

1.5. HYPOTHESES

The hypotheses of this study are:

- Government intervention in the wheat industry through quality standards has historically led to a greater and positive output change in wheat of non-bread-baking quality.
- The ARC's high yielding cultivars are not of satisfactory quality.
- The costs of breeding towards fulfilment of the current wheat quality standards exceed the benefits thereof.

1.6. OUTLINE OF THIS STUDY

Chapter two of the study discusses the government intervention measures through legislation and public breeding. The increase in wheat production is investigated and brought in line with agricultural legislation and the release of publicly bred cultivars.

Chapter three discusses production trends in the South African wheat industry. These production trends are investigated by region and gross value. It also discusses the South African import and export wheat market.

Chapter four takes into account the quality of wheat being produced. Wheat production of bread-baking quality is compared to that of non-bread-baking quality. Furthermore, the various classes of wheat during the Wheat Board era and post-Wheat Board era are discussed.

Chapter five discusses the different methodologies considered and employed in this study to fulfil each of the three specific objectives.

Chapter six outlines the results of the study objectives.

Chapter seven concludes the results of the study and provides recommendations based on the research processes and results of this study.

CHAPTER 2
INSTITUTIONAL DEVELOPMENTS

2.1. INTRODUCTION

This chapter discusses government intervention measures that have influenced the wheat industry, whether through legislation or public breeding efforts. In view of the legislation determining the Agricultural Research Council (ARC) as a public research entity, its role in output is investigated through its release of cultivars.

2.2. INSTITUTIONS AFFECTING THE SOUTH AFRICAN WHEAT INDUSTRY

2.2.1. Why government intervenes

Government plays a major role in molding society by creating and enforcing rules within the country's various industries, for the purpose of social cohesion. Its major role can be seen as that of ensuring the wellbeing of society.

According to Alston *et al.* (1998), the main justification for government intervention in research and development stems from the assumption that market failure has its roots in the private funding and production of research and development. Hauknes & Nordgren (1999) agree, and go on to state that the main rationale for government intervention in the development of science and technologies is to address market failure. Market failure occurs when the forces controlling industrial supply and demand fail to allocate resources efficiently. Factors causing market failure include, but are not limited to, externalities, indivisibilities of goods and/or services, and asymmetric information (Kirsten *et al*., 2009).

Hauknes & Nordgren (1999) identify system failures as a further motivation for government intervention. According to Salmenkaita and Salo (2002), innovative systems can be viewed as a set of institutions that influence the innovative performance of the stakeholders in research and development. System failures exist when the priorities, incentives, and working practices of stakeholders involved in research and development are optimal at the level of the individual but the whole innovative sphere is sub-optimal. In other words, system failures occur when the priorities of stakeholders differ from each other. This leads to a decline in the long-term performance of innovation systems. The state can intervene to create incentives that encourage information transfer between the different stakeholders during the various stages of the system (Salmenkaita & Salo, 2002).

There exists a degree of structural rigidity in innovation systems, and this provides the rationale for government intervention (Salmenkaita & Salo, 2002). The specific ways in which innovation systems work are found to be highly path-dependent. Technologies are developed using the same frameworks and methodologies as existing technologies. Government may intervene to create new pathways for technological developments.

The nature of the product generated by research (i.e. knowledge) makes it hard for it to be completely protected by property rights. The existence of externalities separates the marginal social benefits (MSB) from the marginal private benefits (MPB). Externalities also separate the marginal social costs (MSC) from the marginal private costs (MPC). Social welfare is maximized when; (i) MSB=MPB; and (ii) MPC=MSC. When the assumption of profit maximisation and cost minimisation of business organisations holds, the technologies they produce would lead to negative externalities (e.g. pollution or a reduction in a gene pool). This would lead to MSC>MPC and MPB>MSB. From this, it becomes clear that society would be worse off if the production processes of business organisations were not influenced by government intervention, specifically with regard to innovation.

If MSB>MPB due to incremental investment in research and development, there will be an underinvestment from the society (Alston *et al.*, 1998), making government intervention necessary in order to balance the scales between social and private benefits/cost.

Government intervention in innovation occurs through policies which either regulate the behaviour of participants (e.g. The Plant Breeders Rights Act No. 15 of 1976) or enable organisational structures to form and play the critical roles needed in an industry (e.g. The Agricultural Research Act 86 of 1990). Salmenkaita and Salo (2002) define innovation policies as policies aimed at influencing the behaviour of public and private organisations in respect to the development and commercialisation of new technologies. Without government intervention, social welfare will not be prioritised in the innovation process. These policies are discussed in more detail below.

2.2.2. South African intervention measures

The quality and quantity of different crops also depend on the quality of seed. It stands to reason therefore that government intervenes to ensure the production of seed of sufficiently high quality (van Wyk, 1961c). Historically, the private sector has concentrated on research geared towards seed (Alston *et al*., 1998).

The South African government has a long history of intervention in the wheat industry and agricultural sector at large (Meyer, 2002). Under the governing of the Union of South Africa, a high level of intervention measures in the agricultural sector were regarded as a necessity. A year after the Union was formed, the Department of Agriculture was founded. This department had eighteen divisions including: Tobacco and Cotton, Veterinary Sciences, Chemistry, Brand Marks and Fencing, Grain inspection, etc. It is clear that the quality of grain was of importance as there was a division that was dedicated to inspect the nature of the various grains on the market (Roseboom *et al*., 1995).

Further attempts to intensify agricultural production and development with better coordination between stakeholders led to the transfer of agricultural colleges from the Department of Education to the Department of Agriculture in 1913. Moreover, in 1920 all extension services were transferred to these colleges (Roseboom *et al*., 1995).

According to Van Wyk (1961c), legislation relating to seed breeding has been in existence since 1907. Van Wyk (1961c) further suggests the need to revise legislation over time in order to accommodate the increasing needs that come with the growth of the wheat industry. Table 2.1 shows some of the legislation affecting the South African agriculture sector and more particularly, the wheat industry.

Table 2.1: Legislation Affecting South African Wheat Industry

Year	Act Title	Aim	Policy Instrument
1937	Agricultural Marketing Act	To give stable prices to farmers and reduce the gap that exists between farmer and consumer prices	Wheat Control Board
1961	The Seed Act	To prevent products of unacceptable quality reaching the market by regulating the seed industry	Seed certification scheme Registration of seed dealers Seed export scheme
1961	The Foundation Seed Act	"Make available sufficient quantities of foundation seed of all principal varieties or in-bred lines of horticultural, field and grazing crop species."-Van Wyk (1961c)	Foundation Seed Board Foundation Seed Certification
1976	The Plant Improvement Act	To regulate the sale of certain plants and their propagation material in local and international markets in order to maintain quality and ensure usefulness of their products for agricultural and industrial purposes	Seed certification
1976	The Plant Breeder's Act	To provide a system in which plant breeders can register certain varieties of certain kinds of plants and be granted intellectual property rights thereof	Certification scheme
1978	Patents Act	"To provide for the registration and granting of patents for inventions and for matters connected therewith."- Patents Act No. 57 of 1978	Patents
1990	Agricultural Product Standards Act	Provides the restrictions for the selling and exporting of certain agricultural and related products	The Southern African Grain Laboratory (SAGL)
1996	Marketing of Agricultural Products	To allow for intervention in the marketing of agricultural products	National Agricultural Marketing Counsel

Sources: Van Wyk (1961c); Faire (1962); Plant Improvement Act No. 57 of 1978; Patents Act No. 57 of 1978; Agricultural Pests Act No. 36 of 1983; Agricultural Product Standards Act No. 19 of 1990; Restitution of Land Rights Act No. 22 of 1994; DAFF (2010); DAFF (2011); DAFF (2014).

Agricultural Marketing Act (Act No 1 of 1937)

The Agricultural Marketing Act was the foundation of commercial agricultural policy (Meyer, 2002). According to Kassier (1992) as cited by Meyer (2002), the aim of the Agricultural Marketing Act was to facilitate orderly marketing. The Agricultural Marketing Act led to the formation of various marketing boards including the Wheat Board. The Wheat Board had the sole right to buy and sell all commercially produced local wheat.

During the 1930s farmers received lower prices for their produce than what they believed it was worth. The low prices were said to be caused by the presence of middlemen and market speculators. The Agricultural Marketing Act was implemented to set fair and stable prices (Meyer, 2002). According to Williams *et al.* (1998), control boards were designed to protect the farmers from the effects of unfavourable changes in prices, variable climate and international markets. Protection from international markets was done by monopolising imports and selling them at domestic prices. Local production was sold for export at world prices (Williams *et al*., 1998). Until 1991 the Wheat Board used pre-season pricing without taking into account international wheat prices (Stander, 2012). Farmers would receive the same price for their wheat regardless of their location (Meyer, 2002; Williams *et al.*, 1998). However, the method of delivery would affect the money received by farmers(WBR, 1947). Announcing wheat prices before planting season helped farmers with land allocation. The elimination of price risk associated with wheat farming was intended to incentivise farmers to allocate more farmland in order to increase wheat production.

Government subsidies were used to bridge the gap between producer and consumer prices. Regulation of agricultural markets was maintained through integration with complementary markets, including transport and silos (Williams *et al*., 1998).

According to Meyer (2002), the Agricultural Marketing Act showed inefficiencies such as:

- surpluses in production while the majority of the population lived under the level of subsistence; and
- land prices that were higher than the production value of the farm.

Although the Agricultural Marketing Act created an unsustainable economic system, it achieved its objective of increasing wheat production along with other crops. As far as quality was concerned, the Wheat Board made it compulsory for wheat to be graded before it was made available for industrial use (Sellschop, 1953). The quality of wheat was tested by the Board upon delivery. Due to enhanced breeds that led to the increased quality of bread wheat, it became necessary to make way for new grades of bread wheat in the 1950s (Neveling, 1954;

WBR, 1959; RCAG, 1956). However, during the 1960s the quality of South African-produced wheat deteriorated (van Lill & Purchase, 1995). At that time, the Wheat Board extended loans to farmers, including those using inefficient methods of production that hampered both yield and quality levels, to enable farmers to purchase required implements. It was only after 1994 and the resulting reformation of the country that the marketing boards, along with the Wheat Board, were abolished by the Marketing of Agricultural Product Act (Act 47 of 1996).

The Seed Act of 1961

During the 1960s South Africa was producing wheat of poor quality (van Lill & Purchase, 1995). The Seed Act of 1961 was a revision of the Seed Act (Act No. 36 of 1947). Its purpose was to prevent products of poor quality from reaching the market. The Seed Act of 1961 increased regulations by controlling the activities of breeders and sellers of seed. Under a Seed Certification Scheme, standards for handling seed had long been established. However, it was not until 1961 that the Seed Certification Scheme had the legal authority to enforce compliance with the set standards. The objective of the Certification Scheme was to ensure the production of seed of the highest quality in South Africa (van Wyk, 1961c). All cleaners and sellers of seed were required to be registered with the then Department of Agricultural Technical Services, in order to ease the enforcement of the Act. It was anticipated that unacceptable cleaners and sellers of seed would not qualify for registration, resulting in a general improvement in the standard of seed being sold.

Further efforts to promote the production and exportation of good quality seed in South Africa led to the introduction of a seed export scheme. The scheme allowed for international breeders to contract local farmers to grow seed for multiplication purposes. Restrictions were placed on the importation of seed, the rationale being that these restrictions would promote the local seed breeding industry by reducing competition from well-established international seed breeders. Provision was made to allow seed imports only under certain conditions, including research purposes, importation of varieties already listed, reproducing for export and the importation of seed for consumption purposes (van Wyk, 1961c).

To ensure control over the quality of seed traded to farmers, the Seed Act of 1961 restricted the use of a single variety name for more than one cultivar, and the reference to a single cultivar by different names was disallowed. In doing so, farmers could rely on their experience when it came to cultivar selection without being manipulated into buying the same cultivar that had proven not to be best suited for their region.

The Foundation Seed Act

The main objective of the Foundation Seed Act was to make sufficient foundation seed of all principle varieties available to be used as propagation material. Similar to the Seed Act of 1961, the Foundation Seed Act enshrined certification as a measure to ensure seed quality. The Foundation Seed Act allowed for the establishment of a Seed Board which registered plant breeders, foundation seed producers, and seed dealers (van Wyk, 1961c).

The Plant Improvement Act 1976 (Act No.53 of 1976)

The Plant Improvement Act replaced both the Seed Act and the Foundation Seed Act (ACB, 2012). The Plant Improvement Act created an arena for the handling of seed and its varieties. Currently, a certification scheme is used to ascertain the quality of seed producers. However, amendments need to be made in order to set standards for seed production that protect both local and cross-border buyers of South African seed. By setting seed quality standards with the Plant Improvement Act, seed released is more certain to be of a higher quality (Sadie, 2015).

The Plant Breeders' Rights Act (Act No.15 of 1976)

The Plant Breeders' Rights Act is crucial in promoting the wheat breeding industry. The Plant Breeders' Rights Act protects the intellectual property of a developer of new seed. It ensures that the developer is remunerated for the use of their cultivar by a third party. The Plant Breeders' Rights Act allows for the exclusive production, selling and marketing of a seed by its developer, for a limited time. After the time allocated for sole marketing has elapsed, the breeder should give interested groups licences for the production, selling and marketing of the seed.

According to DAFF (2011), the objectives of the South African Plant Breeders' Rights Act's policies are to:

- ensure the availability of varieties of seed in the South African agricultural industry with the purpose of stimulating economic growth;

- have internationally recognised plant variety protection measures in place; and
- contribute towards the sustainable use and conservation of plant genetic resources used in the food and agricultural sectors.

The Plant Breeders' Rights Act provides farmers with higher quality and better yielding crops, of both local and foreign origin. Seed developers are encouraged to release new varieties of seed when intellectual property is well protected. South Africa's Plant Breeders' Rights Act is in line with the International Union for the Protection of New Varieties of Plants (UPOV). A study of some UPOV member countries showed that where the rights of breeders were adequately protected there was:

- an increase in the number of cultivars being developed;
- an increase in the performance of protected varieties; and
- the introduction of more foreign varieties into the agricultural sectors of member countries (DAFF, 2011).

The Patents Act 1978 (Act No. 57 of 1978)

The Patents Act allows for the right of a developer of a cultivar to produce, sell and market a cultivar exclusively. While the Plant Breeders' Rights Act was designed to protect the rights of breeders, patents are used to protect a specific part of the variety such as its gene sequence (DAFF, 2011). The Patents Act may limit the availability of good quality seed if the patent owner (i.e. the holder of the right to produce) lacks the capacity to meet the demand for the variety which is protected by the patent. However, the Patents Act does provide for an increase in property rights and encourages breeders to develop and release more varieties.

The Agricultural Product Standards Act (Act No. 119 of 1990)

The Agricultural Products Act is arguably the most influential Act in the South African wheat industry. During the Wheat Board era, South Africa had various wheat classes with fixed premiums associated with each grade under each wheat class. Higher quality classes would obtain higher wheat prices. The Agricultural Products Act brought about a reform to the wheat classes system, leaving only one main wheat class, that being Class B with grades B1, B2, B3, and B4. Following the abolition of the Wheat Board through the Marketing of Agricultural

Products Act in 1996, wheat of higher quality was no longer assured the high fixed premiums that it used to receive under the Wheat Board.

The Marketing of Agricultural Products Act (Act No. 47 of 1996)

For many years the South African agricultural marketing system was based on the 1937 Agricultural Marketing Act, which showed bias in favour of commercial white farmers who largely benefited from subsidy schemes and a guaranteed market for their products. This government intervention system became inefficient as the intensive commercial support of farmers led to a financial burden on the state. As an example, the prices paid to farmers for maize did not keep up with inflation. Further, the share of the price received by consumers steadily declined (Williams *et al*., 1998). According to The Central Economics Advisory Board (1986) as cited in Williams *et al.* (1998), the credit and interest rate policies that supported the Agricultural Marketing Act of 1937 had led to a misallocation of resources. Farmers would borrow at extremely low or even negative interest rates (Meyer, 2002).

In 1992, the Kassier Committee was assigned to evaluate the South African agricultural marketing systems. The Committee recommended that the statutory single-channel marketing system should be discontinued. It was also recommended that government allow the establishment of an agricultural marketing council. According to Van Zyl *et al.* (2001), the recommended agricultural marketing council would help manage deregulation.

The Marketing of Agricultural Products Act came about to reduce government intervention in the agricultural market. Through the Marketing of Agricultural Products Act, the control boards were abolished and government intervention in agriculture was minimised. The Marketing of Agricultural Products Act was a radical departure from the market regime that South African farmers had become used to since the 1930s (van Zyl *et al*., 2001). Following the recommendations of the Kassier Committee, the National Agricultural Marketing Council was formed under the Marketing of Agricultural Products Act. According to DAFF (2010), the main reasons for the Marketing of Agricultural Products Act's intervention were that:

- agriculture had twice the labour multiplying factor of low skills as compared to other industries, resulting in support measures in the agricultural sector having huge potential for creating employment;

- the capital multiplier for agriculture was higher than that of the economy;
- stability in the production of raw materials is a necessity for the development of a competitive agro-processing industry;
- rural development through agriculture can be critical in slowing down rural-urban migration and mitigating the problems associated with it;
- there is greater sustainability in agricultural development than in most urban industries e.g. mining; and
- land reform needs supporting structures to assist settling farmers and to maintain or improve productivity.

South Africa deregulated its markets faster than was required by the World Trade Organization (DAFF, 2010). By the early 2000s, South Africa's subsidies for agriculture were lower than those of Australia and New Zealand, traditionally the lowest agricultural subsidisers in the world (OECD, 2006). As a result, prices received by farmers are perceived to be actual market prices since there is little distortion of pricesthrough government intervention.

Through the deregulation of markets, the Act created safeguards to protect disempowered smallholder farmers (van Zyl *et al.*, 2001). Intervention is allowed when it is considered essential, and is aimed at addressing shortcomings in the market environment, service structure and market mechanisms (DAFF, 2010). DAFF (2010) further suggests that policy interventions should be in the form of:

- guarding product prices and preventing monopoly situations;
- setting competitive tariffs that would still protect the growth of local industries;
- providing information and infrastructure that allow for an export orientated agricultural sector;
- supporting the formation of smallholder farmer associations;
- capacity building and skills development; and
- ensuring that smallholder farmers have access to sufficient financial resources.

Current government intervention encourages small-scale farmers' participation in export markets, thereby incentivising small-scale farmers to increase production - either through better cultivar selection, better farming practises or both - allowing them to earn more foreign currency. By participating in export markets, farmers have to comply with phytosanitary measures and produce output of a certain quality. In so doing, the quality and quantity of wheat produced in South Africa are affected.

2.3. TRENDS IN SOUTH AFRICAN WHEAT PRODUCTION

Figure 2.1 shows the trend in the production of wheat in South Africa from 1910 to 2015. The figure shows a general increase in the level of wheat produced in the country. With advances in technology and cultural practises, this is to be expected. Figure 2.1 is discussed in four different phases, i.e. 1910 to 1937, 1938 to 1966, and 1967 to 1989, and 1990 to 2015.

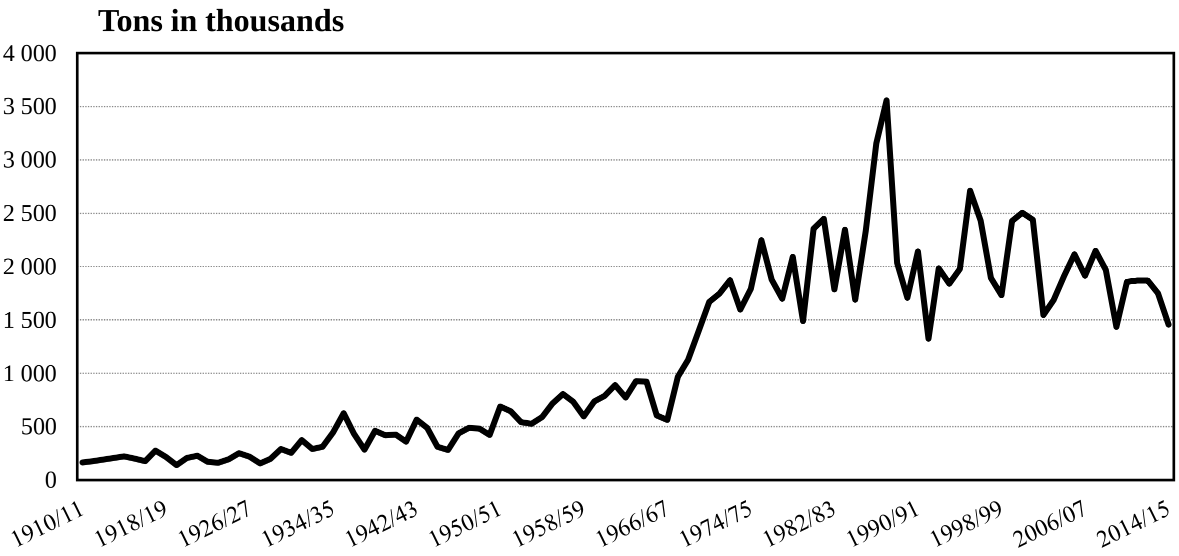


Figure 2.1: Total wheat production in the South African industry, 1910 to 2015
Source: DAFF (2015) and Liebenberg (2013)

Phase 1: 1910 to 1937

In 1910, during a time of low wheat production that did not satisfy local demand, the Union of South Africa was formed. The growth rate of wheat production from 1910 to 1937 was at 3.68 percent. Changes in production during this period were largely due to changes in land allocation, mainly in the then Cape Province and the Orange Free State (Tomlinson, 1935). Given that there was a high demand for wheat with low levels of local production, South Africa relied primarily on imports. The persistent low output led to government intervention through the development of the South African Wheat Control Scheme and the South African Wheat **B**oard in the 1930s. The Wheat Board coordinated buyers and sellers of wheat and its products.

This ultimately helped increase local production. Figure 2.1 further shows an increase in production from 1934 to 1935, during the time of the Wheat Board's development (Stander, 2012). The Board later on became the sole buyer and seller of wheat in South Africa and traded at fixed prices (WBR, 1964).

Phase 2: 1938 to 1967

Phase commenced right after the introduction of the single-channel marketing system in 1937 and concluded at the beginning of the wheat import ban of 1967. Phase 2 is identifiable by its slightly higher wheat production levels which show a gradual increase over time. The introduction of the single-channel fixed priced system granted the sole right to buy and sell wheat in South Africa to the Wheat Board. The period 1938 to 1967 had a wheat production growth rate of 2.84 percent. Although the growth rate was lower than that of the rate before the Wheat Board era, the wheat production level was higher.

Phase 3: 1967 to 1989

Phase 3 began in 1967 when the wheat import ban was introduced and ended shortly before the introduction of the Agricultural Product Standards Act in 1990. The growth rate of Phase 3 was found to be 6.00 percent. This was the highest of all the phases.

The increase in wheat production from 1967 to 1976 is largely explained by the adoption of mechanisation, intensive and wide spread fertiliser use, and wide spread use of improved seed (Hazell, 1985). Further, no wheat was imported during the period 1967 to 1970 (WBR, 1970). During this period the announcement of a ban on imports encouraged farmers to dedicate more land to the production of wheat. Popular ARC cultivars that were released during this period included T4 and Inia, which were released in 1964 and 1969 respectively. T4 became highly prevalent in national production from the 1969/70 season with a share of 0.84 percent while Inia only had a national share of 0.04 percent in the 1969/70 season (WBR, 1970).

The decline in wheat production from 1976 to 1978 may have been influenced by the amendment of the Plant Breeders' Rights Act in 1976, along with the introduction of the Plant Improvement Act in 1976. These two Acts limit the number of seed handlers and may have ultimately influenced production by limiting distribution and use of seed.

The increase in production from 1984/85 occurred at a time when there was a high adoption rate of ARC cultivars, being Scheepers 69, Betta, T4, and Inia. These cultivars had a national production share of 19.35 percent, 15.15 percent, 4.06 percent, and 2.89 percent respectively (Winter Cereal Statistics, 1985). The highest recorded levels of wheat production in South Africa were in 1987/88. This was largely due to favourable climatic conditions (DAFF, 2006).

Phase 4: 1990 to 2015

Phase 4 began in 1990 when there were structural changes in the South African agricultural sector. Phase 4 is identifiable by a decline in production of wheat, with the period 1990 to 2015 showing a decline rate of 0.64 percent.

After the introduction of the Agricultural Product Standards Act in 1990, there was a sharp decline in production from 1990/91 to 1991/92. This was a time of major structural change in farmer support systems, including a reduction of farmer subsidies and consideration of international wheat prices in fixing local wheat prices (Stander, 2012). The allocation of less land to wheat production in the following seasons demonstrates the extent of the influence these changes had on the decisions farmers were making at that time. Land dedicated to wheat production declined from 1.5 million hectares in 1990/91 to 1.4 million hectares in 1991/92 and to a further 740 000 hectares in the 1992/93 season (Liebenberg, 2013).

Legislation that had a major effect on the wheat industry in the 1990s include the Marketing of Agricultural Products Act (No.47 of 1996) and the Agricultural Product Standards Act (No. 119 of 1990).

Contributing to the increase of production from 1993 to 1996, as shown in Figure 2.1, is the release of the ARC's wheat cultivars Caledon and Gariep in 1991 and 1995 respectively. Gariep later became the third most sold wheat seed nationally by the 1998/99 season (SAGL, 2014).

The decrease in wheat production from 1996 to 1999 can be explained by market speculation following the abolition of the Wheat Board, followed by the immediate market response to the Wheat Board's elimination in 1996 (Stander, 2012). Farmers no longer had a guaranteed market for their harvest and suddenly wheat production was associated with financial risk, owing to uncertain prices. As a result, the land area planted with wheat sharply decreased during the period directly after the abolition of the Wheat Board (DAFF, 2012).

Figure 2.1 also shows an increase of production from the 1998/99 to the 2000/01 season. This is followed by the 1999 release of the Eland and Steenbras cultivars. With the fairly high adoption rate of ARC wheat seeds in the 1998/99 season of 31.77 percent, Caledon held a share of 2.08 percent of the national seed sold, which made it the ninth highest sold seed cultivar for that period (SAGL, 1999).

The large decrease in production from 2000/01 to 2002/03 coincided with the 2001 drought (Liebenberg, 2013).There has been a decline in land dedicated to wheat cultivation in the Free State province since the drought of 2001 (Dube *et al*., 2015). Despite the continual decrease in area planted to wheat in the Free State since 2000/01, total production recovered in 2002/03. This suggests gains in genetic improvements of the cultivated wheat breeds, which produced a higher tonnage per hectare in all three production regions: i.e. irrigation, summer, and winter regions. Other factors such as the development of better cultural methods and a greater knowledge of optimal planting dates may also have influenced the increase of production despite the decrease in land planted to wheat.

A decrease in wheat production can be seen from 2007/08 to 2009/10, coinciding with the global recession. Increased prices of farm implements and fertilisers may also have had an influence on the decline in production. The 2009/10 to 2010/11 wheat production increase can be explained as a response to the international commodity price spike.

The effects of the current drought conditions in South Africa are evident in the declining wheat production as seen during the 2013/14 season.

2.4. SUMMARY

In this chapter, government intervention was investigated through the discussion of various legislative Acts affecting the agricultural sector. The Agricultural Marketing Act of 1937 played a vital role in establishing a productive and quality-accountable wheat industry. It was through the price fixing action introduced by the Agricultural Marketing Act that farmers decided to dedicate more acreage to wheat, ultimately increasing wheat production. The Agricultural Marketing Act of 1937 also introduced uniform grading standards. This had a net positive effect as farmers aimed for higher quality yields in order to receive premiums associated with the higher grades of wheat. However, focussing on higher quality often leads to lower yields. One of the major influences on wheat quality has been brought about by the Agricultural Product Standard Act's grading of wheat.

There has been an overall increase in wheat production in line with government intervention through legislation and the public breeders' release of cultivars. Further analysis of the Agricultural Product Standards Act's quality parameters is done in Chapter five.

CHAPTER 3
SOUTH AFRICAN WHEAT PRODUCTION

3.1. INTRODUCTION

South Africa has been involved in commercial wheat seed production from as early as the 1940s. Prior to 1960, the main source of wheat seed was from importing seed and that of farmers' own storage from previous seasons (van Wyk, 1961a). According to Van Wyk (1961a), the seed production industry grew as a response to the farmers' raised awareness, both of the need for good quality seed and that South Africa could produce equally good or better seed for local conditions as compared to imported seed. The market conditions encouraged the then Department of Agricultural Technical Services to intervene in the development of the South African seed industry. In 1976 the Bethlehem Small Grain Centre was established in the Free State province for the purpose of seed improvement for the Highveld region. The agricultural research station where the Small Grain Centre was located was established in 1947. The Agricultural Research Council (ARC) was established in April 1992 and the Bethlehem Small Grain Centre was incorporated into the ARC (ARC-SGI, 1995).

Wheat breeding occurs in both the public and private sectors. According to Stander (2012), South Africa has three major players in the wheat breeding industry, those being SENSAKO, PANNAR, and the ARC. The former two organisations are private enterprises, leaving the ARC as the only public wheat breeder. Only a few South African universities are involved in wheat breeding. As with most universities involved in wheat breeding, the University of Stellenbosch is involved in pre-breeding and provides material to commercial breeders with the aim of developing advanced breeding lines (Botes, 2012).

Chapter 2 showed the long term historical wheat production trends and associated government interventions and public (i.e. ARC) breeding efforts. In this chapter, the production trends of the various production regions are analysed, with the purpose of identifying the productivity of the various regions as well as identifying the causes of the production trends in each region.

3.2. SOUTH AFRICAN WHEAT PRODUCTION REGIONS

According to Stander (2012), until 2002 South Africa was the largest wheat producer on the African continent. Wheat in South Africa is produced in all of its present nine provinces. The provinces make up three production regions, i.e. the summer rainfall region, the winter rainfall region, and irrigation region. Before the new geographic division of the country into nine provinces, the country was divided into four provinces which were known as Natal, Free State, Transvaal, and Cape (Stander, 2012). For the purpose of performance analysis, a province is assumed to resort exclusively to one production region based on the SAGL classification of provinces and production regions. However, provinces are not exclusive to one production region. The provinces that produce the most wheat in South Africa are the Western Cape, Free State, and Northern Cape (van der Vyver, 2013). These provinces form part of the summer rainfall, winter rainfall, and irrigation region respectively.

Figure 3.1 shows the production of the top three wheat producing provinces in South Africa from 1979 to 2015. During this period the Northern Cape produced the least amount of wheat, having also dedicated the least amount of land to wheat. It is further evident from Figure 3.1 that the Free State is the only one of the three provinces with a declining trend in wheat production, matching a decrease in hectares planted to wheat over the years. The Free State produced more wheat than the Western Cape until 2006. The shift in production from the Free State to the Western Cape can be attributed to the growing drought conditions in the Free State, which made it unfavourable for wheat production in the dryland areas (Dube *et al.*, 2015). The change in wheat production levels from the Free State to the Western Cape is in line with Stander's (2012) findings. Both the Northern Cape and the Western Cape show an increase in output. The increase of wheat production in the Western Cape can be explained by the enhanced yielding ability of new cultivars and the lack of alternative crops suitable to be planted in the region (van der Vyver, 2013).

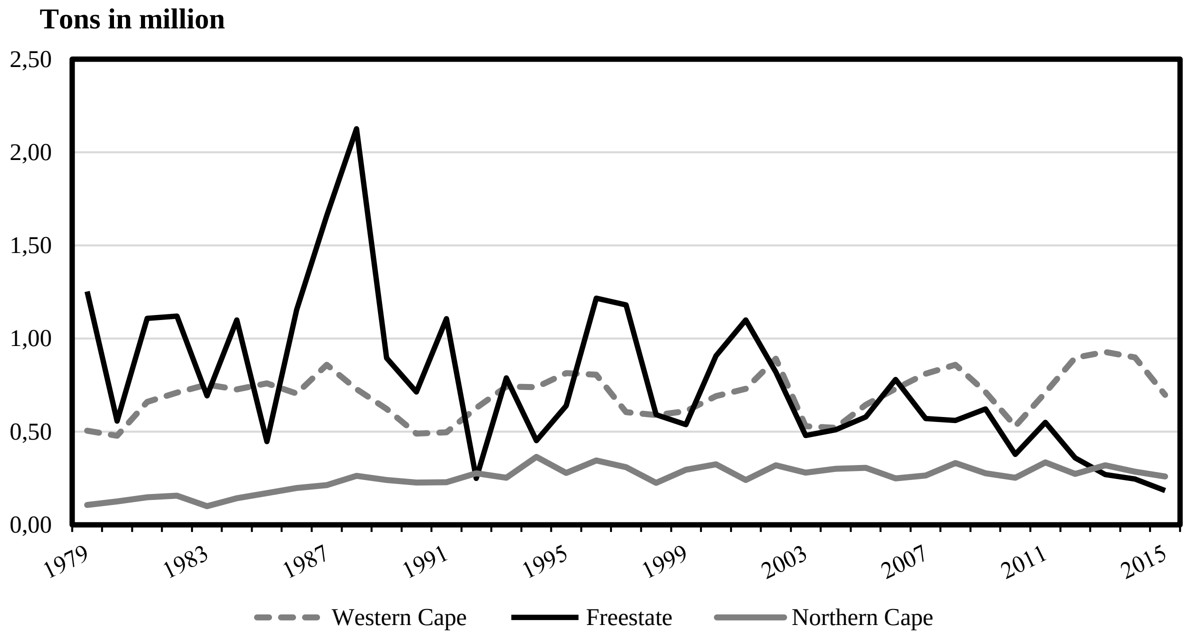


Figure 3.1: Wheat production in highest producing provinces in South Africa, 1979 to 2015
Source: DAFF (2016)

3.2.1. Summer rainfall region

Wheat in summer rainfall areas has largely been grown in the Free State province. However, both the area under cultivation and the output of wheat in the Free State have been on the decline from 1979 to 2015. Most of the Eastern Cape also forms part of the summer rainfall region (SAGL, 2014). According to Dube *et al.* (2015), farmers in the summer rainfall region have been experiencing drought conditions more often than other provinces over the years. As a result, they seek alternatives to producing wheat. The area under wheat cultivation has been reduced from 450 000 hectares in 2005 to 60 000 hectares in 2013 (Dube *et al.*, 2015). This is attributable to rising temperatures and the increased variability of rainfall.

Figure 3.2 shows the trends in production and hectares planted to wheat in the summer rainfall region from 1979 to 2015. Both production and area planted to wheat in the summer region are decreasing. Throughout the period 1979 to 2015, area planted (in hectares) decreased by 6.81 percent and production decreased by 5.05 percent. These figures suggest that production in the summer rainfall region declines at a lower rate than the reduction of hectares dedicated to planting.

The highest production occurred in 1988 which is also the year that had the highest area planted to wheat. The lowest production recorded was in 2015. It is of interest, however, that the least amount of land had been dedicated to wheat production in this region the previous year. The increase of production from 1994 to 1996 may be indicative of the move from farming in marginal areas to more productive lands.

In the summer rainfall region, farmers plant seed in the winter and rely on soil moisture for the seed to go through germination and the vegetative growth stage. Drought risk is said to be high in the periods of May to December, which means that most wheat is produced under drought conditions in this area (Dube *et al*., 2015). Dube *et al.* (2015) further states that the major challenge of breeders for drought resistant wheat is that of developing a cultivar that is drought resistant but still performs well under favourable weather conditions.

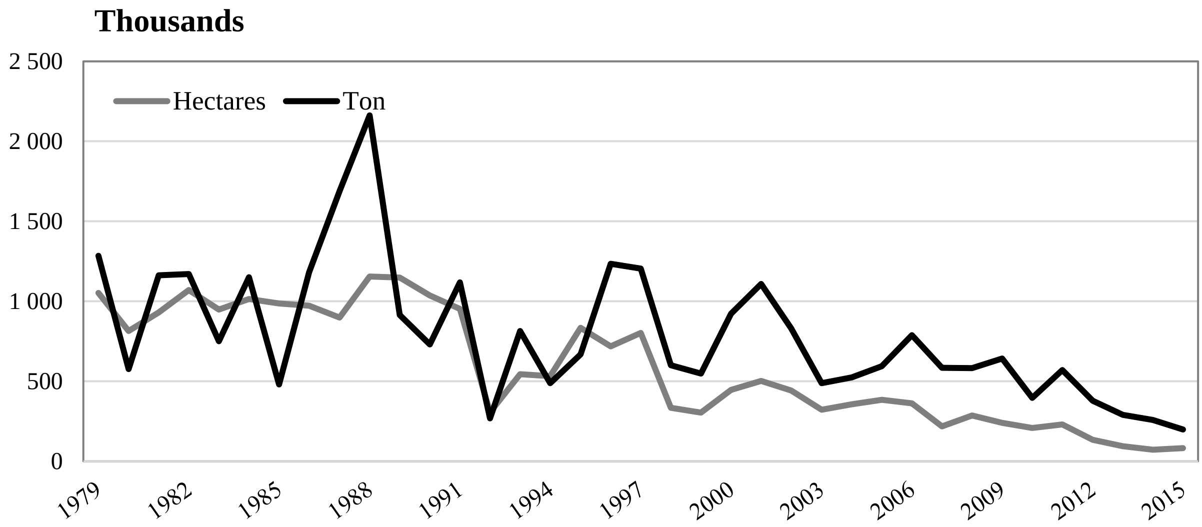


Figure 3.2: Wheat output and hectares planted to wheat in the summer rainfall region, 1979-2015

Source: DAFF (2016)

3.2.2. Winter rainfall region

Western Cape field crop growing conditions offer few alternatives to wheat, resulting in the province continuing to increase its production of the grain crop. The Western Cape produces more wheat than is required to meet local demand, with surplus wheat being exported inland (van der Vyver, 2013).

Figure 3.3 shows the trends in production and hectares planted to wheat in the winter rainfall region from 1979 to 2015. During this period, wheat production increases over time despite the decrease in land area being dedicated to its cultivation. This increase in tonnage, despite a decrease in land dedicated to growing wheat, may be attributable to, among other factors, the release of better cultivars that increase ton per hectare and the adoption of better farming practices.

The decrease in production from 1988 to 1991 coincides with the decrease in land dedicated to wheat production. This was a time of major structural changes in the agricultural industry, the withdrawal of farm subsidies being one example (Stander, 2012). During this period production decreased by 11.98 percent and hectares planted to wheat decreased by 20.54 percent.

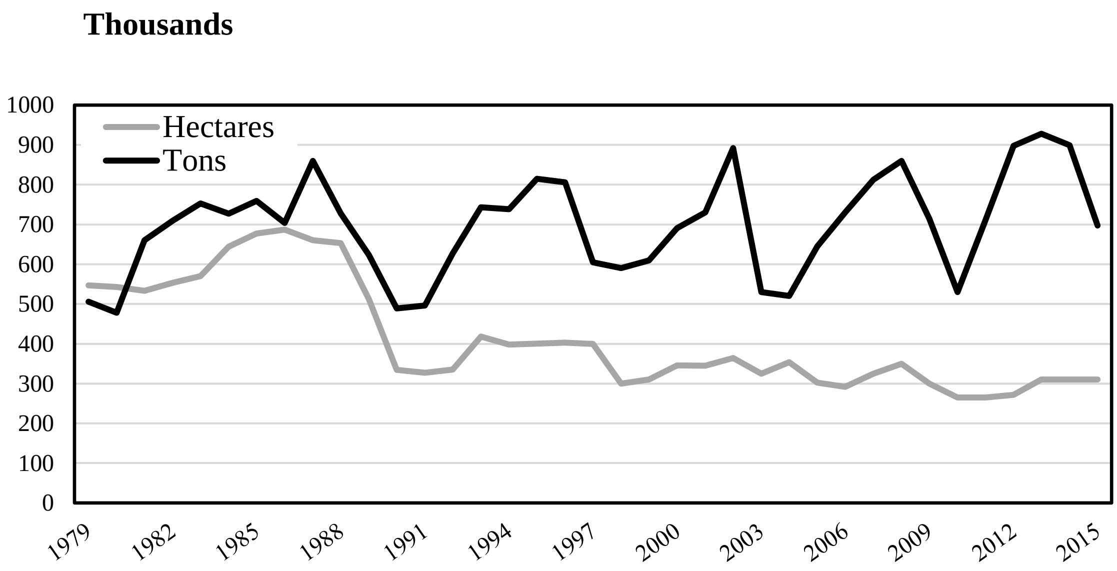


Figure 3.3: Wheat output and hectares planted to wheat in the winter rainfall region, 1979 to 2015

Source: DAFF (2016)

3.2.3. Irrigation region

Provinces producing wheat under irrigation are the Northern Cape, KwaZulu Natal, Mpumalanga, Limpopo, Gauteng, and the North West provinces. The irrigation region has dedicated the least hectares of land towards wheat production from 1979 to 2015.

Figure 3.4 shows trends in production and hectares planted to wheat in the irrigation regions from 1979 to 2015. As is the case with the summer and winter rainfall regions, hectares dedicated to wheat production have been on the decline. Arable land in the irrigation region is very competitive with other crops. Hectares planted to wheat decreased by 7.77 percent from 1979 to 1992. This was followed by a lower decreasing rate of 0.62 percent from 1993 to 2015. This decrease in land use coincides with a greater yield of wheat in the region over time (SAGIS, 2016b), suggesting that better cultivars with higher yielding potential were used. Further, there was a move from farming in marginal areas to more productive areas.

Production increased throughout the period 1979 to 2015. Production shows an increase from 1979 to 1997 of 4.84 percent. Production increases further from 1998 to 2015 at a lower rate of 0.71 percent. The lower rate of production from 1998 to 2015 follows the abolition of the Wheat Board and its supporting structures for wheat production in 1997.

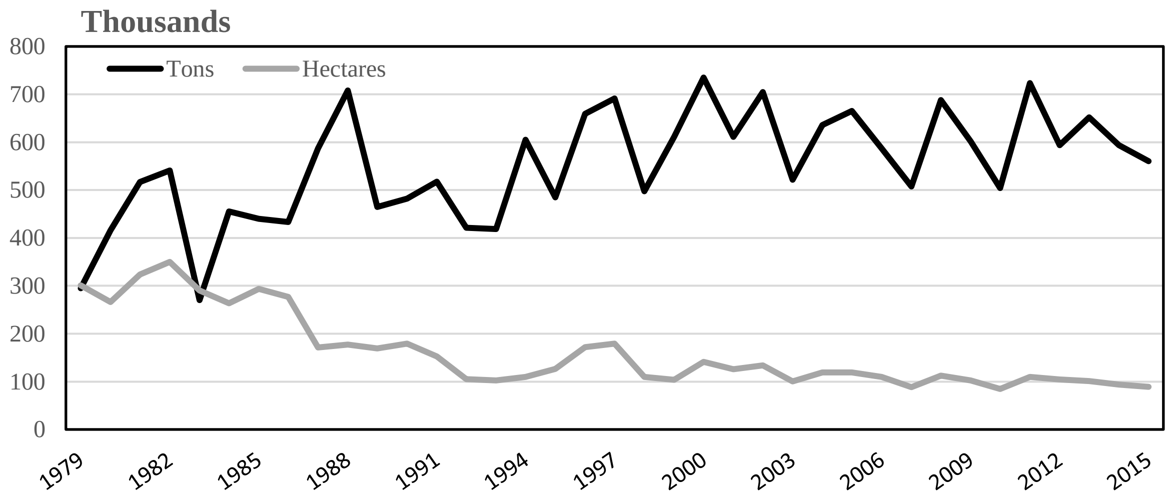


Figure 3.4: Wheat output and hectares planted to wheat in the irrigation region, 1979 to 2015
Source: DAFF (2016)

3.3. GROSS VALUE OF PRODUCTION

Wheat is the most important grain crop produced in South Africa, second only to maize. Figure 3.5 shows the gross value of wheat production in South Africa from 1980 to 2014. Historically there has been an increase in the gross value of wheat produced in South Africa. During the Wheat Board era (i.e. 1980 to 1996) there was a higher growth rate of 54.76 percent in the gross value of production than after the Wheat Board era (i.e. 6.07 percent from 1997 to 2014).

The much lower growth rate may be attributed to the high price volatility of wheat as a result of the supply and demand driven market structure following the abolishment of the Wheat Board.

As shown in figure 3.5, the value of production was below R1 billion from 1980 to 1995. It was only in 1996 that the industry passed the R1 billion mark on the value of production. This was followed, however, by a decline in the value of production to R940 million in 1997. Higher levels of gross value in the industry amounting to over R3.8 billion were reached in 2007 and 2008. The gross value of production dropped in 2009 to R3 billion; this occurred at the time of lower producer prices (DAFF, 2015). The value of production recovered to amounts over R5 billion in 2011 and reached the R6 billion mark in 2012. The high levels reached in 2012 were maintained until 2014.

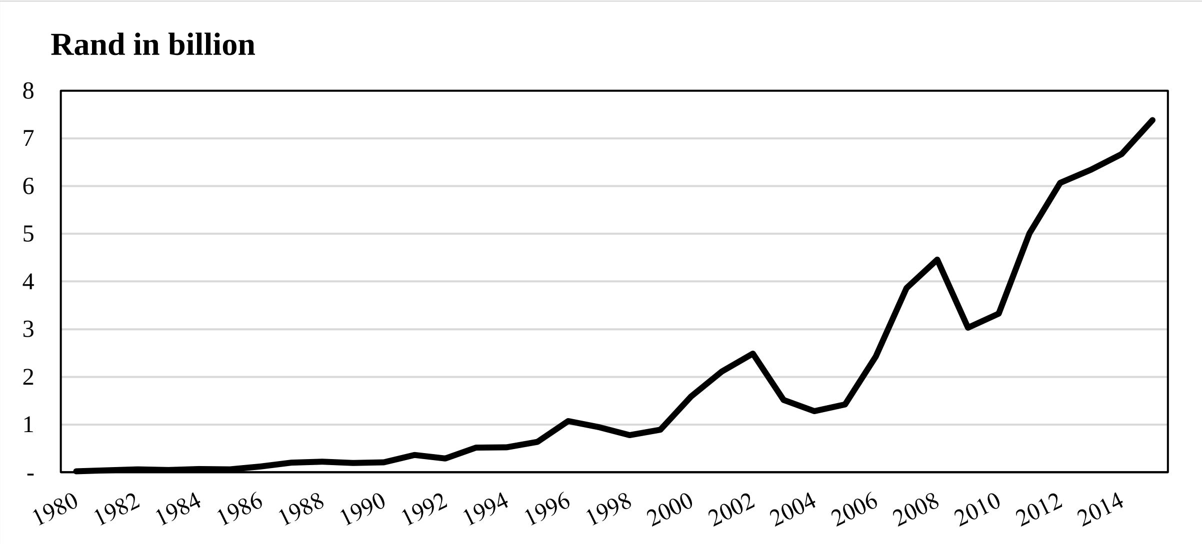


Figure 3.5: Gross value of production, 1980 to 2015

Source: DAFF (2016)

**Base Year: 2010*

3.4. SOUTH AFRICA IN THE INTERNATIONAL WHEAT MARKETS

South Africa is involved in both the import and export of wheat, overall being a net importer of wheat (van der Vyver, 2013). According to Stander (2012), since the 1990s the domestic supply of wheat has rarely satisfied domestic demand.. As stated by Meyer (2002), wheat is one of the top ten imports into the country. This is still the case, as wheat was reported in the 2015 *Abstract of Agricultural Statistics* to have been in the top three imported agricultural commodities by value since 2009. The import of the grain far exceeds the export thereof. Historically, South Africa has needed to import wheat in order to supplement the country's own inadequate supply (Meyer, 2002).

Further, Van Lill and Purchase (1995) suggest that South African produced bread-baking wheat during the 1950s and 1960s was of such poor quality that it needed to be supplemented by imports to make bread. Consequently, breeding programmes had to be established in order to develop cultivars suitable for the South African farmer.

Currently, the quality of South African wheat compares favourably to that of import supplements. The main countries of import over the past three years have been Argentina, the United States of America (USA) and Australia (van der Vyver, 2013). However, over the years, countries such as Canada, Brazil, Ukraine, Russia, Germany and Uruguay have been critical partners in providing South Africa with wheat to supplement its local production (SAGL, 2014; Van der Merwe, 2015).

The wheat industry can still be viewed as a growing industry in South Africa. However, operating in an open, global economy, it faces threats from international markets. During the Wheat Board era these threats were controlled by imported wheat being sold to millers at the same price as local wheat. These prices were adjusted based on local farmers' production costs (WBR, 1970). Another government intervention measure to level the playing field for farmers as against international markets included the Export Subsidy Act (No 49 of 1931). The Export Subsidy Act compensated farmers for the low prices they received when exporting wheat (van der Merwe, 2015). According to Meyer (2002), in 1985 government developed a policy in order to curb the inflation that was a direct consequence of its monetary policy. The policy devalued the Rand and made imported farm input such as machinery, dips and sprays more expensive. The General Agreements on Tariffs and Trade negotiations increased the pressure on South Africa to abandon quantitative import controls, instead using tariffs (Meyer, 2002), which left local farmers facing higher price risks. According to Van der Merwe (2015), the Agricultural Markets Division (commonly known as The South African Futures Exchange (SAFEX)), was established in 1995. It was formulated to help reduce the price risk farmers would now face in an open wheat industry market. Currently, the price of wheat is based on the lowest import parity price (van der Merwe, 2015), with the quality then being taken into account.

Figure 3.6 shows a 28-year period of wheat import and export, along with the trade deficit/surplus of South Africa. The Figure attests to the net import status of the South African wheat industry. For the most part of the 28-year period of analysis (i.e. 1987 to 2015), South Africa has been in deficit of the international wheat trade. This is attributed to the high demand for wheat in South Africa that is not met by local production (Stander, 2012; Meyer, 2002; Van der Merwe, 2015). It has only been in the 1987/88, 1988/89, 1989/90, 1991/92, and 1996/97 seasons that the country's export of wheat exceeded its import thereof. The three seasons 1987/88, 1988/89, and 1996/97 were extremely good production years wherein local production outweighed local consumption of wheat, leading to wheat not having to be imported (SAGIS, 2016a). Although local wheat supply did not meet local wheat demand in the 1989/90 and 1991/92 seasons, there was a trade surplus (SAGIS, 2016a). The decision to export while local wheat demand was not being met may have been influenced by the preference for international prices of wheat.

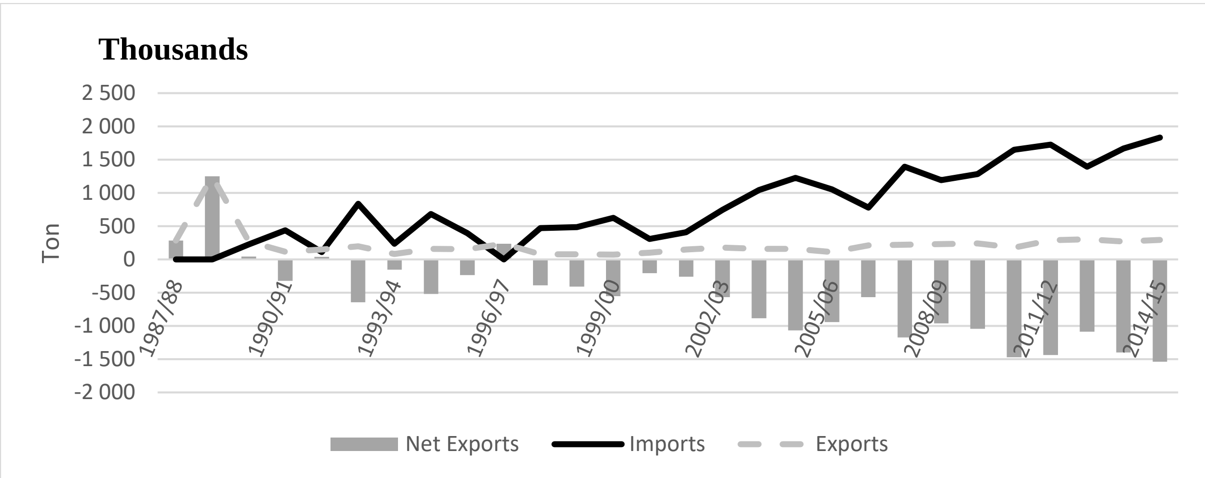


Figure 3.6: Wheat Imports vs Exports, 1987 to 2014

Source: SAGIS (2016a)

3.5. SUMMARY

This chapter compared the various wheat production regions of South Africa. It was found that there has been a significant change in land use in the Free State, mostly due to unfavourable climatic conditions over the years and the potential for alternative, higher value crops in the region. This change in land use has led to lower levels of wheat production in the country, specifically in the summer rainfall region. In contrast, it was found that more wheat is now produced in the local winter rainfall region and exported to other provinces. However, despite the growing trend of higher wheat production in the winter rainfall and irrigation regions, the country still fails to produce enough wheat to meet local demand and must instead depend on the import of wheat to satisfy demand.

The gross value of wheat production in South Africa was also discussed in chapter 3. It was found that the gross value of production has been increasing over the years. Despite the fact that wheat production if of such high value, South Africa was found to be a net importer of wheat, relying on the import of wheat to meet local demand.

CHAPTER 4
ACCOUNTING FOR QUALITY IN SOUTH AFRICAN WHEAT PRODUCTION

4.1. INTRODUCTION

This chapter discusses the main factors influencing wheat yields and quality of wheat, other than the intrinsic characteristics of wheat (quality parameters), which are also discussed in this chapter. South African quality standards are also compared to international standards. Furthermore, a brief history of seed breeding and seed quality testing is provided, explaining the events that led to the global need for seed testing, and thus grading, of wheat.

This chapter also discusses the wheat classes and grades that came about as a means of quality assurance during and after the Wheat Board era. Wheat output is investigated during the Wheat Board era according to bread-baking and non-bread-baking quality.

4.2. COMPONENTS OF WHEAT QUALITY: ANALYSIS OF PRIMARY QUALITY PARAMETERS

As mentioned in Chapter 1, the primary quality parameters of wheat are inflexible against the quality standards as set, thereby having great influence on the grading of wheat. The primary parameters are categorised according to grain, milling, baking and rheological character (Miles, 2010). Table 4.1 shows the primary quality parameters for wheat.

Grain characteristics include protein content, falling number and hectolitre mass:

- protein content is the most sought after quality parameter and is the parameter which traders give most consideration to (Loy *et al*., 2015). Protein content is correlated with a number of other quality parameters (Hruskova & Svec, 2009; Nebraska Wheat Board, 2009; SAGL, 2013). The protein content preference will depend on end use;
- hectolitre mass is one of the most widely used quality parameters in grading. It gives an indication of flour extraction (i.e. flour yield) and directly affects packing efficiency (Hollins *et al.*, 2004; SAGL, 2013); and

- falling number is an indication of enzyme activity in the flour (German, 2006). Enzymes balance sugar and starch in flour (WMC, undated). Starch is important as it provides the structure of the flour; weak flour structure results in bread that crumbles. Falling number is also a good indication of shelf life (German, 2006).

Miles (2010) further distinguishes the milling characteristics of wheat to include flour colour and flour yield. Flour colour preference depends on end use: generally, whiter flours are preferred. Flour yield differs between cultivars and soil fertility levels (Metho, 1999). The relationship between cultivar and flour yield is a result of the different genotypes of wheat (Van Lill & Smith, 1997; Bergman *et al.*, 1998).

Loaf volume is the primary parameter of baking characteristics. It is also the final quality test. Well-formed loaves are of higher market value than deformed loafs. Differences in cultivars result in different loaf volumes (Koen, 2006), implying that breeding has a significant effect on loaf volume.

The rheological characteristics include alveogram dough strength, alveogram stability/density (P/L)-values, mixogram peak time, and farinogram water absorption. The alveograph was one of the first instruments used in determining wheat quality (Koen, 2006) by testing for dough strength, stability and density. The ratio of stability (P-value) to distensibility (L-value) is commonly used in the wheat trade as it indicates suitability for end use (Miles, 2010, SAGL, 2015). Both mixogram peak time and farinogram water-absorption are indirect measures of protein content (Koen, 2006). High protein in grain results in flour with higher water absorption (van Lill & Smith, 1997), which is preferred as it gives desired loaf volumes (Kirby, 2007).

Table 4.1: Primary Quality Parameters for Wheat

Quality Category	Primary Parameter	Definition	Preferred levels/state	Economic Implications
Grain Characteristics	Protein Content	The percentage of protein available in a grain is measured on a 12 percent moisture basis	9 percent to 13 percent	Higher price premiums for wheat with higher protein content
	Falling Number	Falling number is measured in seconds and is the time it takes for a viscometer stirrer to fall through a hot aqueous flour gel after being stirred for 60 seconds	200 seconds to 350 seconds	Higher price premiums for wheat with wheat close to the optimal 220 seconds falling number
	Hectolitre Mass	Hectolitre mass is the mass in kilograms per hectolitre	70 kg/hl to 77kg/hl	Affects packing efficiency Higher hectolitre mass preferred to lower hectolitre mass
Milling Characteristics	Flour Colour	Flour colour is the determination of the flour's colour in accordance with its end use and depends on its yellowness and brightness. It is measured by its Kent Jones and Minolta-CM-5 colours	Generally, a low value of Kent Jones is preferred over a high value Minolta CM-5 values preferred are: L* value +92.5 whiteness, a* value –2.4 green colour, b* value +6.9 yellow colour	Higher price premiums for wheat producing whiter flour
	Flour Yield	Flour yield is the percentage of flour obtained from a given amount of wheat	70 percent	Wheat with higher flour yield (i.e. extraction rate) reduces loss during milling
Baking Characteristic	Loaf Volume	Loaf volume is the ability of a flour to produce large and well-shaped loaves	Well-formed loaves	Wheat producing larger and well-formed loaves with less dough reduce the cost of production
Rheological Characteristics	Alveogram dough strength	Alveogram dough strength measures the resistance of dough to stretching and its extensibility	Strong dough	Higher energy required to mix stronger doughs. Weaker doughs produce less bread per unit of flour

Quality Category	Primary Parameter	Definition	Preferred levels/state	Economic Implications
	Alveogram stability/density (P/L)-values	Alveogram stability/density (P/L)-values measures the time and pressure needed to burst a bubble formed by dough	The P/L value depends on end use. The preferred bread P/L ratio ranges from 0.40 to 0.80. The P/L values suitable for pasta range from 1.5 to 2.5	Flours showing P/L values suitable for bread may get higher premiums
	Mixogram peak time	Mixogram peak time measures the time it takes a dough to reach its maximum consistency	Two to three minutes	Too little mixing time results in weak structured bread. Such bread has lower value
	Farinogram water-absorptions	Farinogram water-absorptions measures the amount of water required for dough to reach a consistency of 500 Brabender units	60 percent	More costs associated with dough which needs more water to reach maximum consistency

Source: *Al-Dmoor (2013); Hadnadev et al. (2011); Hollins et al. (2004); Koekemoer (2003); Kirby (2007); Koen (2006); Loy et al. (2015); Miles, (2010); Perten (1964); Posner & Hibbs (1997); SAGL (2014); Van Lill & Purchase (1995); Wheat Marketing Center (undated)*

4.3. FACTORS INFLUENCING WHEAT QUALITY AND WHEAT YIELD

4.3.1. Factors influencing wheat yields

In the pursuit of better wheat quality, breeders face a trade-off between improvements in quality and yield. Yield is influenced by a number of factors. Nalley *et al.* (2008) explained wheat yields to depend on agronomic and genetic factors. According to Nalley *et al.* (2008), agronomic factors include fertilisers, fungicides and any other input that is outside of the seed that contributes towards the crop's growth. Nalley *et al.* (2008) further defines genetic factors as seed traits that are held within the seed itself. Carew *et al.* (2009) found that spatial diversity and proportion of land in wheat production influence yield, and the interaction of rising temperature and precipitation reduce yields. Carew *et al.* (2009) also found that higher soil quality and improved plant breeders' rights increased yields. The increase in yield by improvements in plant breeders' rights can be explained by the effect that increased security of intellectual property has on innovation. When greater benefits are awarded to plant breeders for their seeds, it becomes more profitable for breeders to develop and release more cultivars that are better suited to each region of production.

Acreage allotment is an institutional factor that has an effect on yield. The amount of land the government decides to allocate to farming key products in order to achieve food security goals will affect the amount of land available for the cultivation of wheat.

The Wheat Board had a significant effect on the production levels until its abolition in 1997. In order to promote local production, farmers received higher prices for their wheat than they would have at international prices (Tomlinson, 1935). This encouraged farmers to allocate more land and resources towards wheat farming. From 1938 to 1945, major influences on yields were weather conditions - with special reference to frost prevalence - and planting dates (van der Merwe & van Garderen, 1952). According to Van Der Merwe & Van Garderen's (1952) agronomic experiment in the Vaal-Hartz area, almost all wheat varieties tested had the potential of producing high yields when sown before the end of May. Varieties that had high yields when planted before May yielded less when planted after May. Further, varieties that had low yields when planted before May showed higher yields when planted after May. It was concluded that the date a specific variety was planted had a significant influence on its yield.

Fertilisers have long played a role in increasing wheat yields in South Africa. Although fertiliser prices doubled over the pre-war years, their use increased yields and nutritional content of winter crops, encouraging their application (van Garderen & Smuts, 1951).

Other factors that affect wheat yields include cultural practices, pests and diseases, technology, soil quality, genetic potential, etc.

4.3.2. Factors influencing wheat quality

Reimer (2011) defines wheat quality as a "particular wheat's ability to consistently produce a flour that will perform well in the production of a finished product". The ability of a particular wheat variety to consistently produce desired characteristics depends on a number of factors including the grain's genetic composition (genotype) and environmental conditions (environment). The interaction between genotype and environment is also critical to the quality of output (Kong *et al*., 2013).

Genotype expresses the genetic composition of the plant and can be manipulated through breeding. Zeceivic *et al.* (2005) claim that grain quality is mostly influenced by genotype. In contrast, Gwirtz *et al.* (undated) maintain that wheat quality depends on monitoring and controlling moisture content. Protein content is the most sought after parameter in wheat breeding and is the major determinant for selection of bakery flour by millers (Gwirtz *et al*., undated). Protein content is mostly affected by genotype, however environmental conditions such as temperature during the growing period, nitrogen and water access all play a vital role (Horvat *et al*., 2012).

Environmental conditions take into account controlled and uncontrolled conditions. Controlled conditions include management practices on tillage, irrigation schedule, fertilisation, sowing time, harvesting, storage, artificial drying, etc. (Van Lill & Purchase, 1995; Kong *et al.*, 2013). Uncontrollable conditions include precipitation, solar radiation, temperature, soil type, soil moisture regime, latitude disease outbreaks, etc. (Kong *et al*., 2013). According to Zeceivic *et al.* (2005), wheat harvested at full maturity is of lower quality than wheat harvested before it reaches full maturity.

Market regimes can also affect the quality of wheat produced. Protected markets keep inefficient producers active in the industry. Before the dismantling of the Wheat Board in 1997, South African wheat farmers were protected from international wheat price fluctuations. This protection reduced competition and, as such, may have reduced the incentives for some farmers to produce the best quality of wheat possible. The Wheat Board did, however, test for wheat quality. To encourage production of higher quality wheat, the Wheat Board gave higher fixed premiums for higher grades of wheat, which have a greater baking quality (WBR, 1939; RCAG, 1964).

4.4. HISTORY OF SEED BREEDING

Seed breeding is technologically driven. This implies that breeding can only advance as much as the available technology allows. Little attempt was made to improve winter cereals until the 19th century (Lupton, 1987). Early seed breeding was more focussed on increasing output per hectare as opposed to increasing the quality of the wheat produced. Modern day breeding faces a trade-off between improving yields and quality. According to Reif *et al.* (2005), extended plant breeding has led to a reduction in genetic diversity of wheat cultivars. However, wheat breeding does not necessarily lead to a loss of genetic diversity as the effects can be countered in the breeding process.

Wheat was first cultivated in South Africa in the Western Cape by Jan Van Riebeeck during the 1600s (Neethling, 1932). The settlement in the Cape was established for the purpose of providing fresh fruits, vegetables, meat and medical assistance to the Dutch East Indian Company's trading ships that passed the coast (SAHO, undated). At that time, seed breeding took place through selection. Through trial and error, various wheat cultivars from around the world were sown in the Cape. Difficulty existed in finding a cultivar suited to the windy regions of the Cape (Pooly, 2009; Neethling, 1932). Some cultivars only began producing satisfactory yields on venturing further inland, where there was less wind (Neethling, 1932). At that time, the ability of seed to produce high yields and withstand harsh weather conditions would have been sufficient to define seed as being of good quality.

From the early 1960s, good quality seed (including wheat) was defined as seed that is pure, of uniform size, free of weed seed, free of disease organisms, viable and uniform in growth, and true to type (van Wyk, 1961b). According to Van Wyk (1961b), pure seed is that which contains no waste matter such as broken seeds, small stones, plant remains or other worthless material. Uniformity of size relates to the grains, kernels and grading of the seed, which is noted to be important in relation to the practice of machine planting. Viability and uniformity in growth are also very important characteristics of good quality seed (van Wyk, 1961b), as steady yields are needed to maintain profit and to minimise the risk associated with the farmer's choice of land allocation. During the 1960s good quality seed was also defined as being true to type. This meant seed had to produce expected output in the regions for which it was bred. Seed that is true to type also means a farmer will reap the species and variety that they expected from the seed which they had sown (Powell, 2009). The abovementioned characteristics that constituted good quality wheat during the 1960s were mainly physiological. Today, the primary parameters defined by the SAGL that determine wheat quality are comprised of both physical and chemical characteristics.

Breeders have historically vacillated between yield improvements and quality improvements. These improvements have occurred alongside breeding objectives such as drought resistance, disease resistance, pest tolerance, etc. Simply breeding for higher yielding crops became less popular as farmers could receive higher prices for less output due to the price premium of wheat with preferable quality characteristics.

In South Africa, there are 10 primary parameters that determine wheat quality and can be attributed to the premium price of higher grade wheat (Miles, 2010). The most popular parameter to breed for, with a focus on price premium, is protein content (Loy *et al.*, 2015). Farmers can get the same, if not higher, revenue by producing lower yielding wheat with a higher protein content as opposed to higher yielding wheat with low protein content. The demand for high protein wheat is driven by the demand for bread flour, while the demand for low protein wheat is the result of the demand for pasta, cakes, biscuits, and livestock feed (Bale & Ryan, 1977). Although protein content is the most sought after parameter for receiving higher price premiums, it is not the only parameter that influences wheat market prices. Ozberk *et al.* (2006) showed there is a significant correlation between the market price and other parameters, such as hectolitre mass and Zeleny sedimentation values.

4.5. HISTORY OF SEED QUALITY TESTING

The trading of seed was already common in European markets from as early as the 19th century. Farmers would travel to sell and buy seed from other farmers and sellers, however the purity and potential yield was unknown to the buyer (Nobbe 1876 cited on Muschick 2009). This raised a need for a means to ascertain the truth of the claims of seed sellers. First efforts to test seed are attributable to Prof Nobbe, a botanist at the Royal Academy for Foresters and Agronomists in Germany, who tested the quality of seed being traded in the local markets. In one sample labelled "Tall Fescue", it was found that only thirty percent was true seed (Muschick, 2009). This showed a low level of quality in the seed traded at that time. The results were similar in many other samples tested. This was an unacceptable standard and encouraged Prof Nobbe to investigate the seed market further, leading to the 1869 publication entitled: *On the Necessity for Control of the Agricultural Seed Market* (Muschick, 2009). According to Muschick (2009), the publication suggested what to measure for in seed, when to measure it, and how it should be measured.

The ideology of testing seed quality quickly spread in Europe and led to the formation of the European Seed Testing Association which changed to the International Seed Testing Association, and was renamed Seed Science and Technology in 1973. Seed testing stations were established and a certification system used to regulate seed quality. The United States of America (USA) is amongst the world's top consumers and producers of wheat. The USA established its seed quality testing institute, the American Association of Cereal Chemists International (AACC), in 1915. The AACC sets standards and methods for seed quality testing. Organisations that comply with the AACC's methods and standards of seed quality testing get accreditation. Powell (2009) contends that the first two aspects of seed quality testing are variety and purity tests. These aspects ensure that the farmer plants the variety intended with no contamination by other varieties.

In South Africa, seed quality testing was introduced when the wheat control scheme began its operations in 1938 (WBR, 1983). It was thought that, in order to develop the wheat industry, quality standards had to be set and verified. The Wheat Board was responsible for wheat quality testing and grading upon delivery from producers.

The country's reform and the resulting affiliation with international committees led to the closure of the Wheat Board in 1997. As a result, seed traded in South Africa has been evaluated and tested by the Southern African Grain Laboratory (SAGL) since 1997. The SAGL is accredited by the AACC, the South African National Accreditation System, Agri Laboratory Association of Southern Africa and the *Bureau Interprofessionnel des Etudes Analytiques* (i.e. the International Bureau for Analytical Studies).

4.6. CHANGES IN SOUTH AFRICAN WHEAT QUALITY STANDARDS

4.6.1. Wheat Board era

The inception of the Wheat Board in 1937 brought about a controlled market environment for the wheat industry, as a result, formal grading systems were introduced. Growth in technology and demand of wheat defined by its different end use have all played a major role in contributing to the changes in wheat grading methods over the years.

The period 1938/39 was the first season recorded by the Wheat Board. There were five wheat classes (i.e. A, B, D, E, and under-grade wheat), each class having up to six grades with the exception of class A and under-grade wheat. Class A only had three grades, while under-grade wheat consisted of wheat that was below the standards of any of the grades set. The 1939/40 season saw the removal of class E. Thereafter, classes and grades remained unchanged until the 1955/56 season when class C was introduced. Class C had six grades but introduced two more grades for only one season (i.e. the 1957/58 season), after which only six grades remained until the 1970/71 season. Thereafter class C was reduced to only four grades, and reduced further to only two grades by the 1985/86 season.

When the Wheat Board grading system was introduced in 1938, class A was the highest quality grade, consisting of three grades i.e. A1, A2 and A3. In 1970 class A was redefined, maintaining three grades through the introduction of A-super grade and the removal of the A3 grade. A-super was of the highest quality on the market. Class A existed until the end of the 1990/91 season.

Class B had six grades (i.e. B1 to B6) until the 1955/56 season, when it was reduced to only having four grades (i.e. B1 to B4). Class B further dropped a grade in 1970/71 season to only remain with three grades until the 1985/86 season, when only two grades remained.

Class AP emerged in the 1985/86 season. Class AP became the highest quality of graded wheat and had three grades i.e. ASP, A1P, and A2P. It co-existed with Class A until both classes were discontinued in the 1990/91 season.

The discontinuation of class AP, class A, and class B in the 1990/91 season was succeeded by the introduction of three new classes (i.e. class BP, class BS, and class BL). Class BP had two grades i.e. BPS and BP1. Grade BPS was wheat of the highest quality on the market. Class BS had three grades which included BSS, BS1, and BS2. The class introduced in the 1990/91 season with the lowest quality was class BL, which had two grades (i.e. BL1 and BL2). Wheat that did not meet the standards of any of the grades was classified as under-grade wheat.

During the Wheat Board era, wheat of bread-baking quality were classes A, AP, AS, B, BP, BS, and BL. Class C, D and class "other wheat (COW)" were of non-bread-baking quality and generally used for biscuits, pastas and animal feed respectively.

4.6.2. Post Wheat Board era

Currently there is only one class of wheat in South Africa, i.e. Class B, which is of bread-baking quality. Table 4.2 shows the current primary parameter quality standards of wheat in South Africa. Wheat quality standards are set by DAFF while quality tests are done by the SAGL. Currently there are six grades of South African wheat i.e. grade 1 (B1), grade 2 (B2), grade 3 (B3), grade 4 (B4), utility grade, and "class other wheat". Utility grade and "class other wheat" are not suitable for human consumption and are often used for livestock feed. Of the primary parameters, hectolitre mass, falling number, and protein content are used in grading. The minimum requirements of class B wheat for hectolitre mass, falling number and protein content are 70kg/hl, 150 seconds, and 8 percent respectively. The highest requirements of class B for hectolitre mass, falling number, and protein content are 77kg/hl, 220 seconds, and 12 percent respectively.

Table 4.2: Current Primary Parameter Quality Standards of Wheat in South Africa

Grade	Minimum		
	Hectolitre mass, kg/hl	Falling number, seconds	Protein content, percentage
B1	77	220	12
B2	76	220	11
B3	74	220	10
B4	72	200	9
Utility grade	70	150	8
Class other wheat	< 70	<150	<8

Source: SAGL (2014)

4.7. SOUTH AFRICAN QUALITY STANDARDS VERSUS INTERNATIONAL QUALITY STANDARDS

Various stakeholders often argue that the wheat quality standards as set in South Africa are too high. Due to the inverse relationship between yield and quality, it is believed that these strict quality standards have a major influence on the low levels of wheat production in South Africa.

Wheat quality comparisons are conducted on imported wheat, as with South African wheat, by the SAGL. According to the SAGL (2014), in previous years of import, Canadian wheat has had the highest protein content. In the 2013/14 season, USA wheat had the lowest protein content compared to other wheat (including South African wheat). The USA wheat showed very poor quality on the farinograph and had the weakest quality on the alveograph. The farinogram development times of imported wheat (except imported from Australia and Canada) were much shorter than that of South African wheat. With the exception of Canada, imported wheat showed too long a mixogram mixing time.

South African wheat is of a higher quality than imported wheat, which causes losses to local farmers who have to meet local quality standards but still compete with lower international standards that yield more wheat. According to Van der Merwe (2015), if South African quality standards were relaxed to meet industry supply and demand, the economy stands to gain an additional R606 million in net farm income per annum and a 12.8 percent increase in wheat production.

Table 4.3 compares South African quality standards with those of its biggest import countries. The comparison of quality standards looks only at the two most important quality parameters that market traders look for in wheat, i.e. protein content and hectolitre mass (Loy *et al*., 2015). Only classes that are suitable for human consumption were used for this comparison.

It can be seen from Table 4.3 that Australia and the USA do not have minimum requirements of both protein content and hectolitre mass. The USA only has a hectolitre mass minimum requirement of 62.5kg/hl, which is lower than the minimum requirement of South African wheat of 70kg/hl (SAGL, 2014; USDA, 2014). Protein content in the USA is a quality parameter often negotiated between the producer and buyer (Bryant-Erdmann, 2016). Australia has a higher protein content minimum requirement (i.e. 9.5 percent) than South Africa's minimum requirement of 9 percent. However, the quality requirements are still stricter for South Africa as breeders have to counter breed for hectolitre mass as well, which is not a requirement in Australia (Blakeney *et al*., 2009).

Similar to South Africa, Canada has minimum quality requirements in respect of both hectolitre mass and protein content. Canada's minimum protein content requirement is higher than that of South Africa. However, South Africa's hectolitre mass minimum requirement is much higher than that of Canada.

Table 4.3: South African Primary Parameter Quality Standards versus International Primary Parameter Quality Standards

Quality Variable	Minimum Requirement by country			
	South Africa	United States of America (USA)	Australia	Canada
Hectolitre mass	70 kg/hl	62.5 kg/hl	-	65 kg/hl
Protein Content	9 %	-	9.5 %	9.5 %

Source: Blakeney et al. (2009); CGC (2016); SAGL (2014); USDA (2014)

As shown in Table 4.3, South Africa's quality standards are stricter than those countries from which it imports wheat. This attests to the argument that South African wheat quality standards are set too high which in turn hinders wheat production, ultimately causing a loss in economic benefits received from wheat production. The extent of this loss is investigated in Chapter 6.

4.8. CHANGES IN THE RELEASE CRITERIA OF WHEAT CULTIVARS

Before a new cultivar is released it has to meet certain quality standards. Due to the variations in production and quality caused by environmental conditions, the release criteria are set making provision for a variation tolerance. A well performing cultivar is selected and set as a biological standard. This means that any other cultivar tested for commercial release can only have lower (or even higher) quality parameter measurements within the determined tolerance ratio. This is common practice for many wheat producing countries. However, other countries with more than one wheat class, such as the USA, have different tolerances that apply to the different classes. The South African criteria accommodates both spring and winter varieties of the various production regions.

Prior to the re-evaluation of the release criteria of cultivars in 1995, South Africa had the relatively large number (over 2 000) of wheat cultivars available on the market. This number was reduced by more than 100 percent to only 708 cultivars available for commercial use after revision (ARC-SGI, 1995). After 1995, more revisions of the release criteria followed, including those done in 1999, 2002, 2004, 2005, 2007, 2008, 2010, and 2013.

Elands, Betta DN, Kariega, SST 806 are some of the more popular cultivars that have been used as biological standards. Selection of a biological standard depends on its general performance with regard to yields and quality in various environments. Thus, the interaction between its environment and genotype is vital. The earlier 1995 criteria had six standard cultivars which has since changed. There have been four standard cultivars since 2013. Betta was replaced in the 1999 revision by its improved cultivar Betta-DN, which is resistant to Russian Wheat Aphid. Betta-DN was dropped as a biological standard in 2005.

Mixograph peak time is the only quality parameter that varies in tolerance ratio by standard cultivar. The other quality parameters tested share the same tolerance ratio regardless of the standard cultivar of the region. Changes in the criteria affect the number of cultivars that can be released for commercialisation. Tolerance ratios are the primary quality regulator used to determine whether or not a cultivar of wheat can be produced for the South African market. Subjecting wheat cultivars to such quality restrictions in order to limit them to commercial use has had immense adverse effects on farm revenue and industry productivity (van der Merwe, 2015).

Appendix A details the changes in the standard cultivars and the tolerance ratios for the release of new cultivars.

4.9. TRENDS IN QUALITY OF PRODUCTION

In South Africa, wheat is mainly used for human consumption. Human consumption of wheat includes products such as bread, biscuits, cakes, and pasta. The highest quality classes have traditionally been used for bread-baking, while inferior classes have been used for biscuits, pasta, and cakes. Only wheat of very low quality with unsatisfactory protein content and consistency when baking is used for livestock feed (SAGL, 2014). Classes of bread-baking quality that have existed include: class BP, class BS, class BL, class AP, class AS, class A, and class B. Historically, wheat that has been of non-bread-baking quality while still being suitable for human consumption was classed as class C and class D. Currently there is only one main class of wheat, class B. Class B is of bread-baking quality, and wheat that does not meet the criteria of class B is classified as utility grade or "class other wheat".

4.9.1. Aggregate bread-baking quality wheat quantities vs aggregate non-bread-baking quality wheat

Figure 4.1 shows the historic production of wheat of bread-baking quality against wheat of non-bread-baking quality in South Africa. It can be seen from the figure that production of both bread-baking and non-bread-baking quality wheat had been increasing throughout the Wheat Board era of 1938 to 1993. This can be attributed to the increasing yield per hectare associated with the release of more adaptable cultivars and improvements in farming practices. The increase of wheat production from the 1966/77 season to the 1973/74 season was due mainly to the wheat import ban which encouraged farmers to dedicate more land to wheat production (WBR, 1970). Both bread-baking quality and non-bread-baking quality wheat production spiked in the 1988/89 season. This was mainly due to favourable climatic conditions (DAFF, 2006).

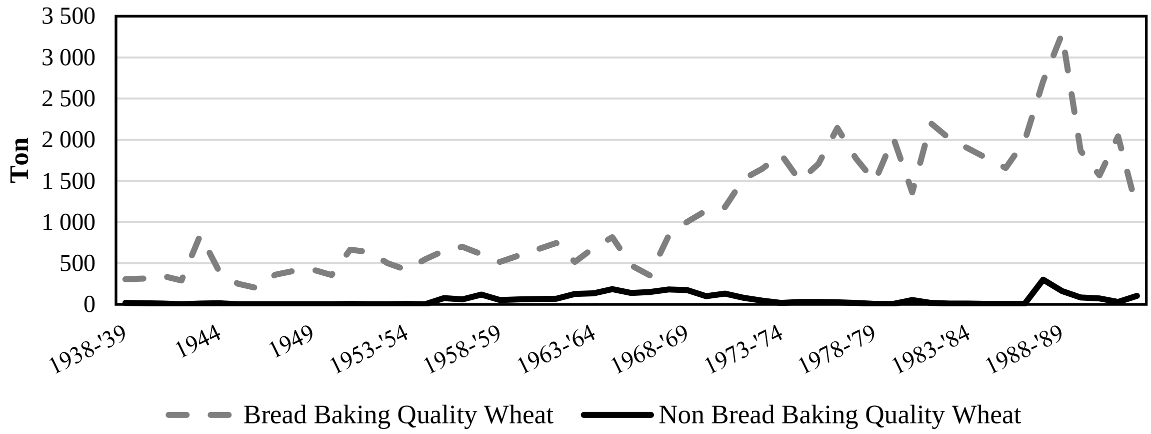


Figure 4.1: Production of bread-baking wheat and non-bread-baking wheat, 1938 to 1993

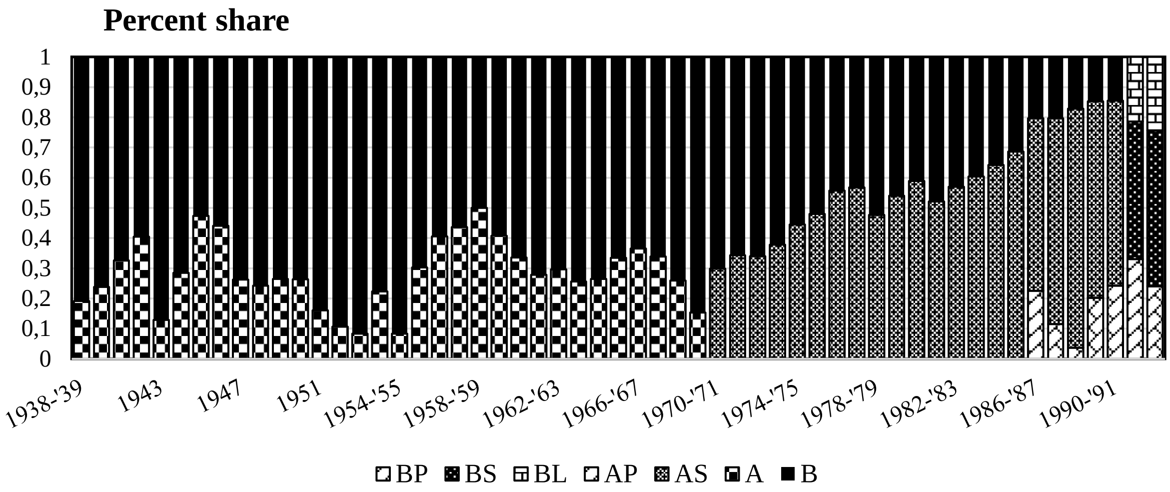
Source: Wheat Board reports from 1938 to 1993

4.9.2. Production by class of bread-baking quality wheat vs non-bread-baking quality wheat

This section illustrates the percentage share of the various wheat classes during the Wheat Board era. In Figure 4.2, Panel (a) and Panel (b) show the percentage share of the various wheat classes of bread-baking quality and non-bread-baking quality respectively. Class B has had a relatively high percentage share in bread-baking wheat quantities from 1938 to 1991 (see Panel (a)). However, its share reduced from 80.86 percent in 1938/39 to 14.48 percent in 1990/91. This is largely due to increased production of the higher quality class AS and class AP wheat. Class AS and class AP were introduced in 1970/71 and 1986/87 respectively. Class A was in existence from 1938/39 to 1969/70. Class A's percentage share dropped from 19.13 percent in 1938/39 to 15.32 percent in 1969/70. However, there was an overall increase in the share of production of class A wheat during its period of existence. This may be due to the higher premiums it earned over other wheat classes.

Class C and class D were of non-bread-baking quality but still suitable for human consumption. Although class C showed a greater percentage share than other non-bread-baking wheat classes, its share was in decline. Class C's percentage share of non-bread-baking quantities produced dropped from 97.43 percent in 1955/56 to 90.84 percent in 1986/87. The large share of class C quantities may have been influenced by the demand for its end product: biscuits and cakes (SAGL, 2002).

Panel (a): Percentage share of bread-baking wheat classes



Panel (b): Percentage share of non-bread-baking wheat classes

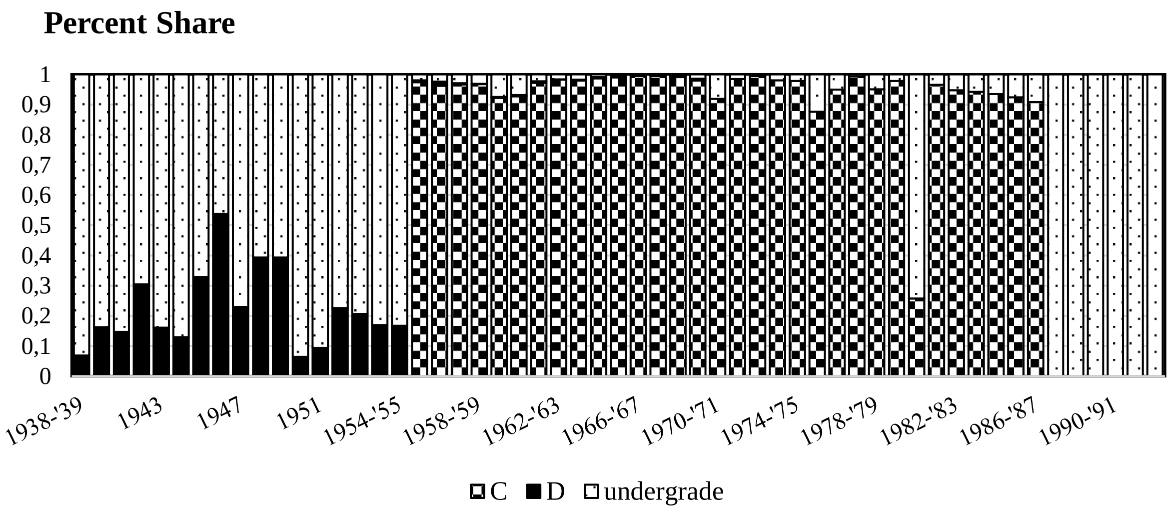


Figure 4.2: Percentage share of wheat classes under a controlled market, 1938 to 1993

Source: Wheat Board reports data from 1938 to 1993

In the comparisons made between the production of bread-baking classes and non-bread-baking classes, the bread-baking classes exhibited a higher level of production. This may be attributed to the demand for higher quality wheat that is of bread-baking quality. Further, the quality of seed approved for release had to display higher levels of quality parameters than existing cultivars in order to satisfy the Wheat Board (as shown in Appendix A). Wheat of higher quality would receive higher price premiums which may also have influenced the level of production of higher quality wheat positively (WBR, 1970).

4.10. SUMMARY

Chapter 4 looked at the history of wheat production in relation to quality. Historically, bread-baking wheat has had higher output than non-bread-baking wheat. It was found that the wheat produced in South Africa has dominated the global market in terms of quality, being of the highest quality class set at the time. This was attributed to the release criteria of new seeds that had to exhibit higher quality than cultivars that were already in the local market, as well as the level of demand for wheat of bread-baking quality.

A comparison of South African quality standards and international quality standards was done for the two most important quality parameters, i.e. protein content and hectolitre mass, and found that South Africa has stricter quality standards than its international trade partners.

CHAPTER 5
METHODS AND PROCEDURES

5.1. INTRODUCTION

This chapter presents the various data set used and methods considered for the three specific objectives of:

(i) determining the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry;

(ii) identifying high yielding and quality satisfactory ARC cultivars in the different production regions of South Africa; and

(iii) determining the returns from the current wheat quality standards.

The various economic tools of analysis considered are discussed for each objective.

5.2. DATA COLLECTION

This study relies on secondary data. To test whether there is a greater and positive output change in wheat of non-bread-baking quality, the analysis was done for wheat outputs in the Wheat Board era. The Wheat Board issued annual reports on market data for the wheat it handled during the Wheat Board era. Annual price data for wheat by grades was collected from the Wheat Board reports available from the South African Grain Information Service (SAGIS). The data in the Wheat Board reports covered the period from the 1938/39 season to the 1995/96 season. However, from 1992/93 quantity by quality data was unavailable, limiting analysis to the period when both quantity and price data were recorded. Missing data on quantity before 1993 was filled in by averaging between years. Only seven of the 55 years had data missing on quantities during the Wheat Board era. Price data was unavailable for nine inconsecutive periods and so averages were taken between years. It is worth noting that, due to price control, prices did not always change the following season.

The same data set was used to identify high yielding and quality satisfactory cultivars, and determine the returns from breeding under the current quality standards requirements. Data on wheat yields, hectolitre mass, and protein content were collected from the ARC-SGI and the

Agricultural Research Council Infruitec/Nietvoorbij. This data was collected as part of the ARC's annual National Cultivar Trials, which seek to measure the performance of both commercial and unreleased cultivars in various localities. The ARC-SGI has been in operation since the 1940s. However, given the limited available data, analysis was performed on a 15-year period (economic analysis) as well as a 17-year period (agronomic analysis), occurring between1998 and 2014. Although this may be considered a small period of analysis for this kind of study, it is well compensated for by the large number of observations recorded for each year.

Data on the total area planted to wheat was collected from DAFF and Liebenberg (2013). Wheat prices from 1999 to 2014 were also obtained from these two sources. Nominal prices are used and adjusted for, using the South African Reserve Bank's (SARB) CPI 2010 base year. Although South African wheat farmers are estimated to plant 60 percent of their annual production from seed retained from previous years, seed sales from silos to commercial farmers give an indication of the adoption rate of each seed company's cultivar. Hence SAGL estimates for seed sales were used as a proxy for the adoption rate of cultivars.

Data was collected from the three main wheat production regions of South Africa. A total of 316 localities were used in the final analysis. A cultivar was planted at the various localities in different years. However, some cultivars fall off the National Cultivar Trials over time as they become less popular with farmers of those localities, or a seed producer introduces another cultivar for the Trials. This, along with the varying number of localities within each region, has led to the hugely unbalanced nature of the panel data. The combined number of observations in all three wheat production regions for wheat yield, protein content and hectolitre mass was 32 574, 30 495, and 32 255 respectively.

In the winter rainfall region, 3 892 observations of protein content, 3 904 of hectolitre mass, and 4 084 of yield data were used. Three sub-regions were used as panels, along with 75 localities and two planting methods. Eleven ARC cultivars appeared within the region during the study period: AdamTas, Baviaans, Biedou, Duzi Kariega, Kwartel, Nantes, Palmiet, Ratel, Steenbras, and Tankwa.

The summer rainfall region analysis used 10 583 observations of yield, 9 285 observations of protein content and 10 685 observations of hectolitre mass. The region comprised five sub-regions: four belonging to the Free State province and one to Mpumalanga. There were 74 localities in total and 14 cultivars planted, namely: Betta-Dn, Caledon, Elands, Gariep, Hugenoot, Komati, Koonap, Limpopo, Molen, Matlabas, Nossob, Senqu, Tugela-DN, and Tarka.

In the irrigation region, the analysis used 17 907 observations of yield, 17 318 observations of protein content, and 17 666 observations of hectolitre mass data. This region comprised 167 localities and tested 15 cultivars: Baviaans, Biedou, Buffels, Duzi, Inia, Kariega, Krokodil, Marico, Olifants, Palmiet, Sabie, Steenbras, Tamboti, Timbavati, and Umlazi.

5.3. ANALYTICAL TECHNIQUES

In achieving the first objective of determining the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry, various indexing methods are discussed. Popular genotype x environment interaction models such as the Analysis of Variance (ANOVA) and Least Significant Difference (LSD) tests are considered when identifying high yielding cultivars of satisfactory quality. The methods of coefficient determination are explained below, as well as the calculation of the benefits and costs to estimate returns from breeding for quality under the current quality standards being discussed.

5.3.1. Evaluating the historic output changes of bread-baking wheat and non-bread-baking wheat

In fulfilling the first objective of determining the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry, various indexing methods were considered and are discussed below. Growth rates were later calculated for wheat of bread-baking quality and non-bread-baking quality.

The Laspeyre’s, Paasche, and Fisher ideal indexes are the most common methods used. The three indexes are weighted.. Laspeyre’s output index uses base year prices to weigh both current and base-period output, while Paasche’s output index uses present year prices to weigh both current and base-period quantities. The Fisher ideal index reduces the shortcoming of Laspeyre’s and Paasche’s index of overweighing goods. The Fisher ideal index is a multiplicative of Laspeyre’s and Paasche’s indexes (Liebenberg, 2013).

If the abovementioned indexes are used in forming quantity indexes, errors may occur in forming an aggregate quantity index over an extended time period. In order to minimise these errors, Divisia indexes are used (Liebenberg, 2013). According to Alston *et al.* (1998), Divisia indexes are used to minimise the impact of relative changes in output prices when real output aggregates are formed. An offset of the divisia is needed for continuous measurement of prices and quantities. Following Craig and Pardey (1990), Liebenberg (2013) defined the divisia of Laspeyre's, Paasche's, and the Fisher ideal indexes as shown below:

Laspeyre's Divisia index

$$Q_L = \frac{\sum_{i=1}^{N} q_{i,t}\ p_{i,t-1}}{\sum_{i=1}^{N} q_{i,t-1}\ p_{i,t-1}} \tag{5.1}$$

where:

Q_L =Laspeyre's divisia quantity index.

$P_{i,\, t-1}$ = Price of output item *i* in period before the current period.

$q_{i,t}$ = quantity of item *i* in current period.

$q_{i,t-1}$ = quantity item *i* in period before the current period.

Paasche's Divisia index

$$Q_p = \frac{\sum_{i=1}^{N} q_{i,t}\ p_{i,t}}{\sum_{i=1}^{N} q_{i,t-1}\ p_{i,t}} \tag{5.2}$$

where:

Q_P = Paasche's Divisia quantity index.

$P_{i,t}$ = Price of item *i* in current period.

$q_{i,t}$ = quantity of item *i* in current period.

$q_{i,t-1}$ = quantity item *i* in period before the current period.

Fisher Ideal Divisia index

The formulation of the Fisher ideal index will remain the same but depend on the Divisia indexes of Laspeyre and Paasche. It is then given by;

$$Q_F = \left(\frac{\sum_{i=1}^{N} q_{i,t}\ p_{i,t}}{\sum_{i=1}^{N} q_{i,t-1}\ p_{i,t}}\right)^{\frac{1}{2}} \left(\frac{\sum_{i=1}^{N} q_{i,t}\ p_{i,t-1}}{\sum_{i=1}^{N} q_{i,t-1}\ p_{i,t-1}}\right)^{\frac{1}{2}} \tag{5.3}$$

Other index numbers may include a value index and Tornqvist-Theil index. There is not much difference in the results when using Fisher's index versus Tornqvist-Theil's (Alston *et al*., 1998). Alston *et al.* (1998) further suggest that the decision as to which index to use depends on the systems used and data available. Liebenberg (2013) states that the Tornqvist-Theil index is another approximation of a Divisia index that uses both previous and current value shares in weighing quantity changes. Liebenberg (2013) further states that the Tornqvist-Theil index is undefinable for any current period with a quantity that equals zero. This can be problematic when attempting to form an aggregate estimate over a long sample period where there is missing data, resulting in having to omit the commodity with the missing data from the index. In this case, this would involve the omission of an entire wheat class. However, the Fisher ideal Divisia index can accommodate zero valued observations.

It was possible to calculate growth rates after the development of the Fisher divisia quantity index for bread-baking and non-bread-baking wheat quantities in the given periods, enabling comparison between them.

According to Beddow (2014), the log difference growth rate for variable *Z*, starting from year *s* and ending in year *t* is given by:

$$\frac{Ln(Z_t)-Ln(Z_s)}{(t-s)} \equiv \frac{Ln(Z_t/\,Z_s)}{(t-s)} \tag{5.4}$$

5.3.2. Identifying high yielding and quality satisfactory Agricultural Research Council's cultivars

A cultivar's performance relies heavily on the interaction between the environment and its genotype. Seeds have to be provided with the right environmental conditions in order to reach their expected yields and quality attributes. Genotype and environment interactive models such as the Additive Main Effects and Multiplicative Interaction (AMMI), Analysis of Variance (ANOVA), and Least Significant Difference (LSD) methods were considered in order to determine the effects of breeding on quality performance

ANOVA is a popular starting point to analyse genotype and environment in agronomy literature (Nalley, 2007). According to Nalley (2007), the ANOVA model's simplicity enables a mixed effect analysis of trial data, which allows for fixed and random effects. When evaluating a breeding programme, a mixed ANOVA is mostly used for its ability to handle complicated data sets. However, whilst ANOVA can indicate a significant difference within a group, it cannot tell us which groups are different; thus a LSD test usually follows it (William & Abdi, 2010).

It was found through a study by Nel *et al.* (1998) using AMMI model analyses that environment was the most influential parameter to variance in determining the effects of genotype, environment and their influence on kernel protein content, hectolitre mass and grain yield.

These methods establish variables of significance in performance variations, and also identify high yielding cultivars of satisfactory quality.

5.3.3. Estimating returns from the current wheat quality standards

To fulfil the third objective of determining the returns from the current wheat quality standards, the study followed three steps. Firstly, genetic gains and losses associated with breeding for quality alone were calculated on an annual basis. This was done through a coefficient determination for protein content and hectolitre mass. Secondly, inherent costs and benefits associated with the genetic gains and/or losses were calculated on an annual basis. Inherent costs and benefits are the costs and benefits that come as a result of quality improvement itself. Thirdly, the inherent benefits and costs for each year were used in the calculation of a benefit-cost ratio.

Step 1: Coefficient determination

Methods considered to calculate the effects of breeding for quality on yields were the Just-Pope method, Pearson's coefficient, and forward regression. The Just-Pope method simultaneously captures gains from wheat breeding programmes and the improvement in yield stability (Nalley, 2007). Pearson's coefficient shows the relationship between two variables on a range from -1 to +1, where values close to 0 show less correlation (University of Regina, undated). The nature of the relationship is informed by whether the sign is positive or negative. Two-part models (such as forward regression) improve the estimation abilities of the Ordinary Least Squares model (Kapitula, 2015). These methods are discussed below.

Just-Pope production function

The Just-Pope production function is a General Least Squares (GLS) procedure, which makes efficiency gains in parameter estimates possible (Traxler *et al*., 1995). This ability of the Just-Pope method would allow for the effective measure of the effects on yields that breeding for quality traits has had. According to Barkley *et al.* (2008), the significance of the Just-Pope production function used to evaluate wheat breeding is its ability to account for multiplicative heteroscedasticity. Accounting for this is of high value, as there is high variation not only between but within wheat species. The Just-Pope method can be viewed as a multiplicative heteroscedasticity model since its basis is that the error term depends on some or all of the regressors (Barkley & Chumley, 2011).

According to Nalley (2007), the unique attribute of the Just-Pope method, as used by Traxler *et al.* (1995), came with its ability to simultaneously test for an increasing yield hypothesis as well as a decrease in variance of the yield. In the case of Traxler *et al.* (1995), the variance represented yield stability, i.e. risk factors. According to Smale *et al.* (1998), the Just-Pope method allows for output enhancing input to have either positive or negative effects on variance by relating the variance of output to the independent variables in a multiplicative heteroscedastic model.

The model specification is as follows:

$$Y_i = f(X_i, \beta) + g(X_i, \alpha)\, \varepsilon_i \tag{5.5}$$

where::

Y_i = yield output of the i^{th} cultivar.

X_i = regressors.

β and α = parameter vectors.

ε_i = a random variable with zero mean.

The Just-Pope notably has two parts. The first part - $f(X_i, \beta)$ - relates the regressors to the mean output. The second part - $g(X_i, \alpha)\, \varepsilon_i$ - relates the independent variables to the variance in output.

Having recognised the Just-Pope method as a heteroscedastic model that relates regressors to the error term, if the variance is an exponential function of K variables, the model can be specified as below:

$$Y_i = X_i + e_i \text{, i=1, 2, 3... , N} \quad (5.6)$$

where X_i represents a row of vector observations till the K^{th} explanatory variables, i.e. $X_i‘ = (X_{1i}, X_{2i}, X_{3i}, \dots X_{Ki})$.

$$E(e_i^2) = \sigma^2_i = \exp[X_i‘\alpha] \quad (5.7)$$

where α is a vector that represents unknown coefficients i.e. $\alpha = (\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_k)$. If $E(e_i) = 0$ and $E(e_ie_s) = 0$, then (5.7) can be written as (5.8).

$$\ln \sigma_i^2 = X_i‘\alpha \quad (5.8)$$

Although σ_i^2 is unknown, the effects of the independent variables on the variance can be estimated by using the least squares residuals that we obtain (from 5.6).

$$\ln e_i^{\wedge 2} = X_i‘\alpha^{\wedge} + u_i \quad (5.9)$$

Predicted values from (5.9) are used to estimate the mean output for (5.6) as weights in the GLS model. The estimates from (5.6) become the measure of the risk factor.

$e_i^{\wedge}$ represents the predicted value of e_i with the error term now defined as

$$U_i = \ln (e_i / \sigma_i^{\wedge 2}) \quad (5.10)$$

If the multiplicative heteroscedasticity holds, the Just-Pope method represents an increased efficiency in the estimation of the mean function (Smale *et al*., 1998).

Pearson’s coefficient

This is a widely used method in estimating the linear relationship between two variables (e.g. X and Y) (University of Regina, undated). Literature on the agronomic and genetics of wheat suggest both positive and negative linear relationships between wheat yields and quality characteristics. The degree and nature of the relationship between wheat yields and quality parameters almost always differs with each different tool of analysis. Pearson’s coefficient range from -1 to +1 (University of Regina, undated). Values closer to zero show less correlation, whereas the sign informs on the relationship between the variables.

The Pearson's coefficient (r) is defined below:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}} \tag{5.11a}$$

or as

$$r = \frac{S_{XY}}{\sqrt{S_{XX} S_{YY}}} \tag{5.11b}$$

From equation (5.11a) we find the following, where X is a variable with n observations X_1, X_2, X_3,….,X_n and Y is a variable with n observations Y_1, Y_2, Y_3,…,Y_n:

- The numerator of the function $\sum(X_i - \bar{X})\,(Y_i - \bar{Y})$ represents the covariation of X and Y.
- In the denominator, $\sum(X_i - \bar{X})^2$ is the variation in X. This is to be separated from the variance as it is not divided by n-1.
- It then follows that $\sum(Y_i - \bar{Y})^2$ is the variation in Y.

Thus the denominator is the square root of the product of the variation of both X and Y (University of Regina, undated).

From equation (5.11b) we find the following:

$$S_{XX} = \sum X^2 - \frac{(\sum X)^2}{n} \tag{5.12}$$

Wherein $\sum X^2$ is the sum of the squares of the X variable. The second term represents the mean of the X variable.

$$S_{XY} = \sum Y^2 - \frac{(\sum Y)^2}{n} \tag{5.13}$$

Similarly, $\sum Y^2$ represents the sum of the squares of the Y variable and $\frac{(\sum Y)^2}{n}$ represents the mean of Y.

$$S_{XY} = \sum XY - \frac{(\sum X)(\sum Y)}{n} \tag{5.14}$$

Estimations of equations (5.12), (5.13), and (5.14) are then used to find the coefficient r in 5.11b. Pearson's coefficient offers a simple computation of the relationship between variables with a linear relationship. A significance test for r can also be computed (University of Regina, undated).

Forward regression

Forward regression is a best model selection procedure that relies on residuals for fitting the relevant regressors, based on significance to the model. Firstly, a regressor that is highly correlated to the dependent variable is chosen. Secondly, the regressor is fitted into the model (e.g. OLS) to calculate residuals. Thirdly, a variable most correlated with the residuals is added to the model (Thiebaut, 2011). The sequence is repeated until all significant regressors (i.e. those with a lower p-value than the critical value) are in the model (JHSPH, undated; SASinst, 2010). The forward selection model is illustrated in Figure 5.1.

Other selection models include backwards elimination and stepwise regression. In backward elimination, the OLS is first run with all the regressors. The regressor with the highest p-value greater than the critical value is then removed. Lastly, the OLS model is run again. Removal of regressors stops when all p-values are less than the critical value (JHSPH, undated). Stepwise regression is a combination of backward elimination and forward regression. The stepwise regression process starts like the forward regression. In stepwise regression, a regressor is removed when it is no longer significant and can be added or removed at any stage. The criterion for adding a regressor is less strict than that of removing it (Thiebaut, 2011).

According to Thiebaut (2011), there is not much difference between forward selection and other selection models. However, preference for the forward regression may occur because:

(i) it takes longer to reach minimum errors;

(ii) there is a lower variance with forward regression; and

(iii) it is applicable when the number of variables exceed the number of observations.

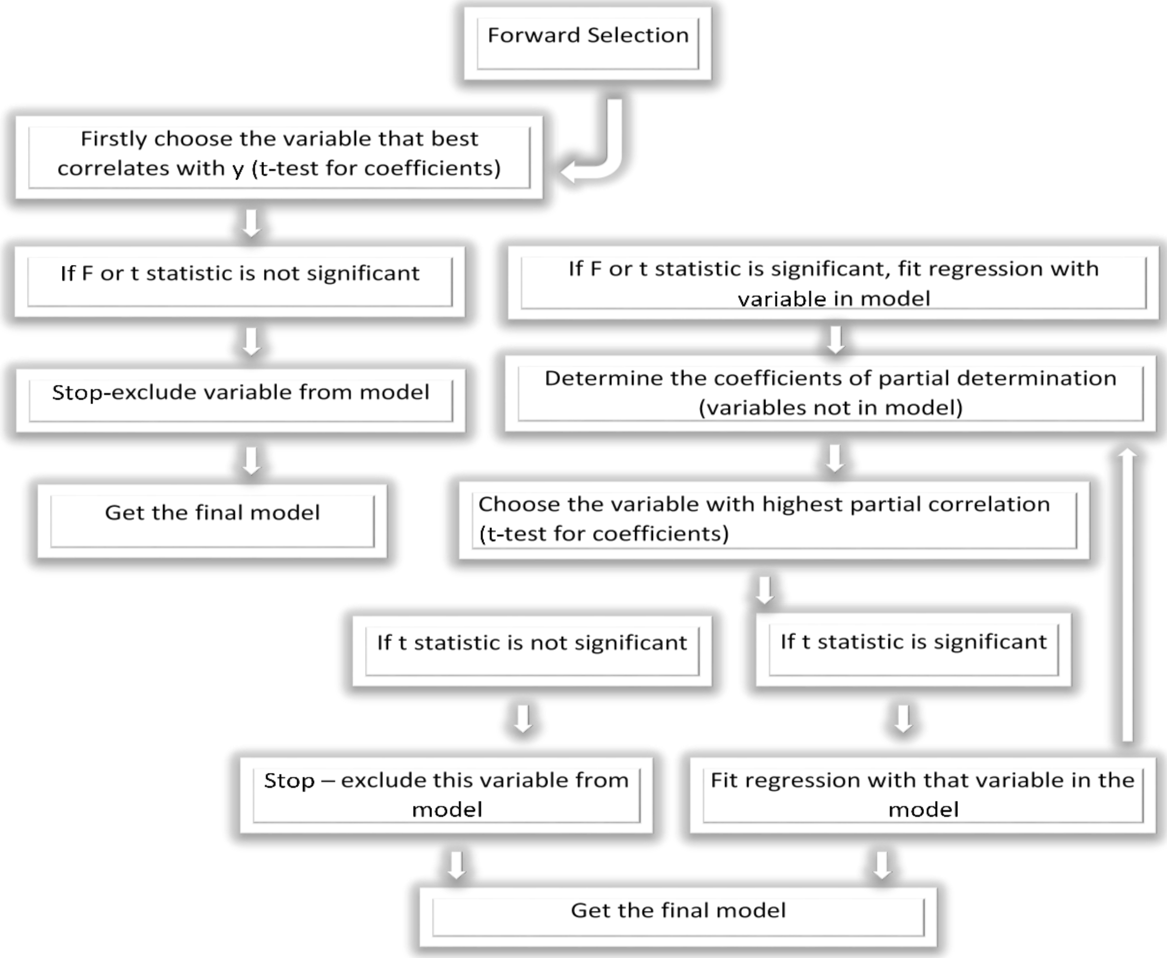


Figure 5.1: Forward selection procedure

Source: Thiebaut (2011)

Using OLS in both stages of the forward regression will lead to the below estimation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_k X_k + \mu \quad (5.14)$$

Where Y is the dependent variable, and X_1,X_2, to X_k are independent variables. β_0 is a constant, β_1, β_2, are estimates, and μ is the error.

Step 2: Inherent costs and benefits

Having estimated the genetic gain/losses associated with quality improvement, the inherent costs and benefits of these improvements can then be calculated. As mentioned above, inherent costs and benefits are the costs and benefits that come about as a result of quality improvement (i.e. gains and losses made from protein content and hectolitre mass improvement).

An estimation of inherent costs and benefits was performed adopting the methods used in Nalley *et al*. (2008) & Dlamini *et al*. (2017) to calculate benefits from genetic improvements.

The steps are shown below:

- Firstly, the number of hectares planted to ARC varieties was calculated. This was done by multiplying the total number of hectares under wheat production in the specific region by the estimated adoption rate of ARC cultivars.
- Secondly, the tonnage gains and losses were calculated. The tonnage gains and losses were calculated by multiplying the regression coefficients to the hectares planted to ARC cultivars. If the regression result of β_1 or β_2 is a positive coefficient then it adds to tonnage gains. If the result is a negative coefficient, it adds to tonnage losses.
- Thirdly, the inherent costs and benefits were calculated through multiplying tonnage losses and tonnage gains by wheat prices (discounted to 2010 prices) respectively.

Step 3: Benefits and costs

Having calculated the inherent costs and benefits, a cost-benefit ratio can be calculated. The benefit-cost ratio is mostly used as a quick way to determine if an investment is worthwhile. According to Barkley (2011), benefit-cost ratio gives a project's ratio of benefits - in monetary terms - to costs (also expressed in monetary terms).

The benefit-cost ratio formula is given below:

$$BCR = \sum_{t=0}^{T} \frac{B}{(1+r)^t} \Big/ \sum_{t=0}^{T} \frac{C}{(1+r)^t} \tag{5.15}$$

Where **B** is the benefits in Rands, **C** is the cost in Rands, **T** represents the ending year of analysis, $\boldsymbol{i}$ is the discount rate, and ***t*** is the year (time period).

A benefit-cost ratio above 1 indicates the profitability of a project while a value below 1 shows non-profitability/losses (Asaduzzaman *et al*., 2011). In this study, a benefit-cost ratio above 1 would indicate the gains from investment from pursuing the current quality standards; a benefit-cost ratio below 1 would indicate the losses on investment incurred in pursuing the current quality standards.

5.4. SUMMARY

This chapter discussed the various methods considered to fulfil the three study objectives. It was found that each objective would be best achieved by a different method. For the first objective, indexing methods were considered. The second objective considered ANOVA, AMMI and LSD. The third objective considered an econometric approach of coefficient determination followed by a benefit-cost ratio.

This chapter also described the data set used. The study used secondary data and relied on field trial data from the National Cultivar Trials for yield and quality data. Price and quantity data was obtained from various sources including SAGIS and DAFF.

CHAPTER 6
RESULTS AND DISCUSSION

6.1. INTRODUCTION

This chapter shows and discusses the results of the three hypotheses tested:

(i) government intervention in the wheat industry through quality standards has historically led to a greater and positive output change in wheat of non-bread-baking quality;

(ii) the ARC's high yielding cultivars are not quality satisfactory; and

(iii) the cost of breeding towards fulfilment of the current wheat quality standards exceed the benefits.

6.2. HISTORIC EFFECTS OF QUALITY STANDARDS ON OUTPUT CHANGE OF BREAD-BAKING AND NON-BREAD-BAKING WHEAT

In order to determine the effect of changes in output quality, the output quantity needs to be adjusted to reflect changes in the quality over time. This is done by deriving a quality adjusted index of quantity produced. This quality adjusted index is formed from the underlying data on price by grade and output by grade.

By forming an index on the underlying data on wheat price by grade and output by grade, the first hypothesis that government intervention in the wheat industry through quality standards has historically led to a greater and positive output change in wheat of non-bread-baking quality is tested.

6.2.1. Aggregate wheat quality adjusted index vs aggregate wheat quality unadjusted index

A quality adjusted index was developed against a quality unadjusted index for commercial wheat from 1939 to 1993 - Wheat Board era. Due to data limitations, largely caused by assigning some of the duties previously performed by the Wheat Board to other, ill-equipped organisations, the analysis is only limited to the years when data was available on both prices and quantities of different grades, i.e. 1939 to 1993.

Figure 6.1 shows a quality adjusted versus quality unadjusted index during the Wheat Board era. The Fisher Divisia index represents the quality adjusted aggregated output for wheat and is shown by the dotted line, while the quality unadjusted index is represented by the solid line. Both indexes move similarly until the mid-1960s, after which quality unadjusted index shows a sizable increase in output change as opposed to the decrease shown by the quality adjusted index. According to Van der Merwe (2015), the quality criteria became harsher with time; this could be the cause of a lower increase in aggregate output as shown by the quality adjusted index starting in the 1960s. A declining rate of 0.33 percent and a growth rate of 2.70 percent were found for the adjusted and unadjusted indexes respectively. The declining rate of the quality adjusted index attests to Van der Merwe's (2015) suggestion that losses in wheat output are being caused by adhering to the wheat quality standards.

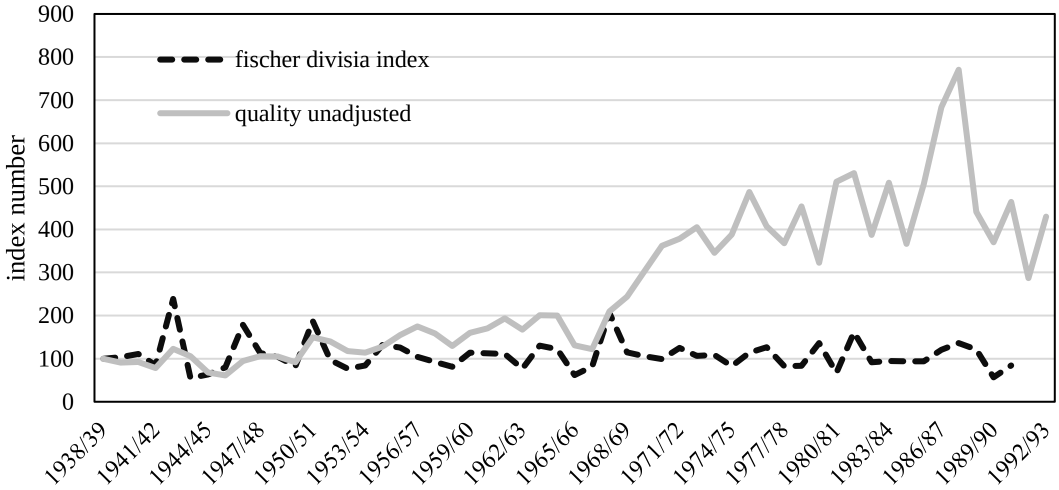


Figure 6.1: Quality adjusted vs quality unadjusted for South African wheat:1938/39 to 1992/93 season

Source: Wheat Board report

**Base year: 1938/39*

The sizable increase in output change from 1967 until 1972 can be explained by the government intervention measure of putting bans on imports from 1967 to 1970 (WBR, 1970). This encouraged farmers to dedicate more land to wheat production, which in turn led to higher output. After the import ban was lifted, a decline in output is shown in the unadjusted index from 1972. In the 1982/83 season, classes B and C were reduced to two grades from three and four grades respectively. This was followed by a decline in index number, as shown by both the quality adjusted and quality unadjusted index lines for the 1982/83 season.

This was also a time of drought (Liebenberg, 2013). The reduction in index numbers can be explained by the fact that a decline in grades led to more wheat output being classified as under-grade wheat than previously. This was not captured in either of the indexes as prices were not available for under-grade wheat. Prices for under-grade wheat were not fixed, instead being negotiated between the farmer and buyer by the Wheat Board.

The introduction of class C in 1955/56 coincides with an increase on aggregate output that reflects on the quality unadjusted index. However, the quality adjusted index shows a decline in output. Not taking quality into account, the quality unadjusted index shows an increase in output at the time that class C is introduced. The Fisher Divisia index takes quality into account; thus the introduction of class C does not add on to the output increase in quality adjusted index, as reflected by the Fisher Divisia index.

6.2.2. Aggregate bread-baking wheat quality adjusted index vs aggregate non-bread-baking wheat quality adjusted index

Wheat in South Africa is widely used for bread-baking. Figure 6.4 shows the historic output change of both wheat suitable for bread-baking and that not suitable for bread-baking.

The highest index number of wheat of bread-baking quality was in the 1970/71 season, followed by a decline until the 1977/78 season. This decline followed the termination of class A, which was the highest quality wheat class at that time. The termination of class A was followed by the introduction of class AS, which had higher quality standards. The highest and lowest index numbers for non-bread-baking quality wheat were in 1956/57 and 1972/73 respectively, with the highest index numbers appearing after the introduction of class C in 1955.

Wheat of bread-baking quality was found to have a declining rate of 0.23 percent, whereas wheat of non-bread-baking quality had a declining rate of 0.07 percent. This implies that the quality standards and the changing grades had less adverse effects on the production of non-bread-baking quality wheat.

Figure 6.2: Aggregate bread-baking quality wheat vs non-bread-baking quality wheat, 1943 to 1987

Source: Wheat Board data, 1938 to 1987

**Base year: 1943*

6.3. YIELDING AND QUALITY ATTRIBUTES OF ARC CULTIVARS

In order to identify high yielding and quality satisfactory ARC (i.e. public bred) cultivars, ANOVA and LSD tests were run using Statistical Analysis Software (SAS). Only commercial cultivars were used for this analysis.

By performing ANOVA and LSD tests, the second hypothesis that the ARC's high yielding cultivars are not of satisfactory quality was tested. These tests led to agronomic results of the winter rainfall, summer rainfall, and irrigation region.

6.3.1. Agronomic results for the winter rainfall region

The winter rainfall region has few alternatives in its wheat production sub-regions and localities (Dube *et al.*, 2015; Van der Vyver, 2013). Since 2006, the winter rainfall region has produced the highest quantity of wheat in South Africa. In the 2013/14 production season, 56 percent of the sampled wheat that did not achieve grade B1 (see Table 4.2, page 43) originated from the winter rainfall region. However, the regional hectolitre mass average was 78.6kg/hl, which is above the grade B1 requirement (as explained in page 43) of 77kg/hl (SAGL, 2014).

There has been a decline in the quality of wheat produced in the Western Cape, with average hectolitre mass changing from 81.7kg/hl in 2012/13 down to 78.6kg/hl in the 2013/14 season (SAGL, 2014). Wheat from this region has also exhibited a lower protein content reading as compared to that of other regions. Average protein content lowered to 10.7 percent in 2013/14, from 10.8 percent in 2012/13 (SAGL, 2014).

Table 6.1 shows the agronomic results of the winter rainfall region. Performance evaluations were based on three variables, i.e. yield, hectolitre mass and protein content. The top four yielding cultivars of satisfactory quality are identified for the region. Using the ANOVA model, variables of significance towards performance in the winter rainfall region were found to be; the cultivar (C) itself, locality (L), sub-region (SR), year (Y), cultivar and year interaction (CxY), cultivar and sub-region interaction (CxSR), cultivar and planting method interaction (CxPM), sub-region by year interaction (SRxY), and planting method by year interaction (PMxY).

Planting method only appears as a significant factor to cultivar performance in the winter rainfall region, as this is the only region which practices two planting methods: conservation and conventional.

Table 6.1: Agronomic Results of the ARC's cultivars in the winter rainfall region, 1998 to 2014

Rank	Winter Rainfall Region		
	Yield (ton/ha)	Hectolitre mass (kg/hl)	Protein Content (percent)
1 Mean	Ratel[A] 4.05	Steenras[A] 79.08	Palmiet[A] 12.75
2 Mean	Nantes[BA] 3.84	Biedou[BA] 78.33	Nantes[A] 12.75
3 Mean	Kwartel[BA] 3.79	Baviaans[BC] 78.01	AdamTas[BA] 12.7
4 Mean	AdamTas[BA] 3.77	Tankwa[BCD] 77.57	Tankwa[BA] 12.6
Variables Significant at 99% confidence interval (ANOVA)	Cultivar, Sub Region, Locality, CxY, CxSR, CxPM	Cultivar, Sub region, locality, year, PM, SRxY, CxPM, CxY, PMxY, CxSR	Cultivar, Sub region, locality, year, planting method, CxPM, CxY, CxSR
N-obs[1]	4 084	3 904	3 892
R-square	0.90	0.89	0.88
Mean	3.64	77.69	12.13

Source: Statistical Analysis Software (SAS)

Notes: Superscript letters show LSD groupings

[1]Number of observation

Discussed below are the performance variables (i.e. yield, hectolitre mass, and protein content) of the public bred varieties cultivated in the winter rainfall region.

Yield

As shown in Table 6.1, it was found that sub-regions (SR), locality, cultivar, planting method (PM), year, cultivar by year (CxY), cultivar by sub-region (CxSR), and cultivar and planting method interaction (CxPM) where all statistically significant towards wheat output at the 99 percent confidence interval. As previously mentioned, the effects of locality proxy the varying effects of climates within the different geographic spaces. The seasonal variation in climatic conditions is captured by the year-on-year analysis.

The cultivars Ratel, Nantes, Kwartel, and AdamTas were the top four yielding cultivars with mean yields of 4.05 ton/ha, 3.83 ton/ha, 3.79 ton/ha, and 3.77 ton/ha respectively. However, there is no statistical difference between the top four yielding cultivars and other lower performing cultivars, except for Duzi. Duzi was the least performing of all 11 cultivars. The four cultivars yielding the least were found to be Duzi, Steenbras, Biedou, and Tankwa with means of 3.38 ton/ha, 3.48 ton/ha, 3.57 ton/ha, and 3.59 ton/ha respectively. The least performing cultivars were also found to not be statistically different from each other nor to the higher yielding cultivars, except for Ratel which was the highest yielding cultivar. When cultivars have no statistical difference it implies that they have the same potential of reaching the same high or low yields.

Least Significant Difference tests revealed Elsenburg as the most productive locality with a mean yield of 6.47 ton/ha, and Ratelville as the least productive locality with a mean yield of 0.97 ton/ha. The winter rainfall region is the only production region to use both conventional and conservational planting methods. The LSD test revealed statistical differences between the two planting methods, with conventional planting methods having a slightly higher mean of 3.85 ton/ha while conservational methods had a mean of 3.37 ton/ha. The highest CxPM differentiation was found to be that of the Ratel cultivar under conventional planting method, averaging 4.14 ton/ha. The least satisfactory tonnage attributable to cultivar by planting method interaction was the Biedou cultivar under conservation planting method, averaging 3.04 ton/ha.

The high yielding performance of Ratel in the region is further attested to by its dominance in the Swartland and Ruens sub-regions with mean yields of 4.16 ton/ha and 3.91 ton/ha respectively. The Southern Cape however is dominated by AdamTas (3.85 ton/ha) as the highest yielding cultivar.

Hectolitre mass

Analysis of Variance revealed that variables which are of statistical significance at a 99 percent % confidence interval towards the amount of hectolitre mass include sub-region, locality, cultivar, planting method, year, sub-region by cultivar, cultivar by planting method, cultivar by year (CxY), and planting method by year (PMxY).

Cultivars displaying the highest mean hectolitre mass were found to be Steenbras (79.08 kg/hl), Biedou (78.33 kg/hl), Baviaans (78.01 kg/hl), and Tankwa (77.57 kg/hl). Steenbras was found to be statistically different from the lower nine performing cultivars, including Baviaans and Tankwa. AdamTas was found to be the lowest hectolitre mass producing cultivar and statistically different from the top seven hectolitre mass producing cultivars. Only Duzi, Nantes, and AdamTas did not meet the 77 kg/hl requirement to be classed as grade B1, achieving grade B2. Ratel, which displayed high levels of yield, had a mean yield of 77.10 kg/hl, which meets the highest grade of wheat requirement.

Of the 75 localities, LSD analysis showed Halfmanshof to be the locality with the highest hectolitre mass, with a mean yield of 80.48 kg/hl. This was statistically different from the lower 39 localities. Ratelville recorded the lowest mean hectolitre mass of 71.21 kg/hl. It was not statistically different from four other localities, forming part of the five lowest hectolitre mass mean recordings. The low mean hectolitre mass implies a very low quality of wheat (utility grade) that has been produced in Ratelville over the years. The second least hectolitre mass mean of 72.34 kg/hl in Hopefield also implies a low quality average.It does however meet the requirements to be classed as being of bread-baking quality (grade B4).

Of the three sub-regions, the highest hectolitre mass was recorded in the Swartland and found to be statistically different from Ruens and the Southern Cape, which implies a better quality attribute of hectolitre mass can be expected in the Swartland.

Cultivar and locality (CxL) interactions can be considered a representation of genotype and environment interaction (GxE). Cultivar by sub-region interaction (CxSR) is also genotype and environment interaction (GxE), but on a wider geographic space. AdamTas x Swartland produced the least hectolitre mass. This interaction was found to be statistically different from the top 17 interactions between cultivar and sub-region. The highest mean hectolitre mass of CxSR was that of Steenbras x Swartland, which was only statistically different from the bottom seven of the other 25 interactions.

In the Swartland sub-region, the top performing cultivars with no statistical difference were Steenbras, Biedou, and Baviaans. This implies that any of the three cultivars in the sub-region can produce high hectolitre mass. In the Southern Cape sub-region, however, Steenbras and Biedou were high performing cultivars with no statistical different. Selection between the two on the basis of hectolitre mass is impartial in this sub-region. In the Ruens sub-region, Baviaans was the highest performing cultivar with a mean hectolitre mass of 78.47 kg/hl, followed by Kariega with a mean hectolitre mass of 78.03 kg/hl. There was no statistical difference between the Baviaans and Kariega in Ruens sub-region. For the pursuit of higher hectolitre mass in Ruens sub-region, similar results can be expected from the two cultivars.

Protein Content

From the ANOVA, it can be said within a 99 percent confidence interval that the factors influencing the protein content of winter rainfall wheat include sub-regions, locality, cultivar, year, planting method, cultivar and planting method interaction (CxPM), cultivar and year interaction (CxY), and CxSR.

The highest performing cultivars in respect to protein content where found to be Palmiet, Nantes, AdamTas, and Tankwa with mean protein contents of 12.75 percent, 12.75percent, 12.70 percent, and 12.60 percent respectively. There was no statistical difference found between the top cultivars which implies that any of these cultivars are able to produce as high or as low protein content as the other. The choice of which cultivar to plant for higher protein content between the four cultivars is indifferent. In terms of protein content, all these cultivars meet the requirement of the highest grade of wheat, i.e. grade B1

On average, the two sub-regions that produced the highest protein content without being statistically different from each other were the Swartland and Ruens. The Southern Cape was found to produce the lowest protein content and could be statistically differentiated from the Swartland, but not from the Ruens.

The CxSR revealed AdamTas to yield the highest protein content in the Swartland sub-region, Duzi to yield the highest protein content in the Southern Cape sub-region, and Tankwa to yield the highest protein content in the Ruens sub-region. Cultivar and sub-region interaction in Ruens with Tankwa showed no statistical difference from the second highest performing cultivar in the sub-region, i.e. Kwartel. Therefore, either one of the two would be recommended in that sub-region in the pursuit of higher protein content. In the Swartland, no statistical difference was drawn from AdamTas, Nantes, and Palmiet and so any of these three cultivars may be cultivated in the pursuit of higher protein content in thissub-region. In the Southern Cape, Duzi was the highest performing cultivar with statistical difference to other cultivars in this sub-region. Thus, in terms of protein content, Duzi can be considered the superior cultivar and most advisable to plant in this sub-region.

Adowa was found to be the locality with the highest mean protein content of 16.86 percent Adowa was followed by Koperfontein, Heidelberg, and Langgewens with mean protein contents of 15.36 percent, 14.52 percent, and 14.44 percent respectively. The protein content in Adowa was not found to be statistically different from Koperfontein but differed from the remaining localities. A farmer therefore has equal probabilities of harvesting wheat with a higher protein content in both the Adowa and Koperfontein localities. The locality with the lowest mean protein content was found to be Boontjieskraal with 9.61 percent. It can be said that, on average, even localities which produce wheat with the lowest protein content still produce wheat meeting the protein content requirements to be used for bread-baking, i.e. grade B4 (see table 4.2 on page 43).

The two highest CxPM appear with the conservation planting method, with Duzi and Tankwa having mean protein contents of 12.94 percent and 12.77 percent respectively. While this is statistically no different from the conventional planting of Tankwa, it is statistically different from the conventional planting of Duzi. Hence no deduction can be made on the direct effect of planting method on the protein content produced by a certain cultivar.

6.3.2. Agronomic results for the summer rainfall region

The summer rainfall region comprises mainly the different production sub-regions of the Free State Province. There has been a decline in the land allocated to wheat production in these parts, which has led to a dramatic decline in production. The decline in land allocation has mainly been due to persistent drought conditions and availability of better performing alternative crops in the region (Dube *et al.*, 2015)

In the 2013/14 season, the average hectolitre mass was 79.2 kg/hl, which is worthy of a grade B1 rating. The average protein content in the same season was 11.7 percent which does, however, not qualify it for a grade B1 wheat rating (SAGL, 2014). However, this is still of relatively good uality and implies that wheat of satisfactory quality can be produced in the summer rainfall region.

Table 6.2 shows the agronomic results of the summer rainfall region. Similar to the winter rainfall region, ANOVA and LSD tests were used to identify the summer rainfall region's top four performing cultivars. In the summer rainfall region, variables of significance towards a cultivar's performance were found to be the cultivar (C) itself, locality (L), sub-region (SR), year (Y), cultivar and year interaction (CxY), cultivar and sub-region interaction (CxSR), and sub-region by year interaction (SRxY). The superscripts show the LSD grouping.

Table 6.2: Agronomic Results of the ARC's cultivars in the summer rainfall region, 1998 to 2014

Rank	Summer Rainfall Region		
	Yield (ton/ha)	Hectolitre mass (kg/hl)	Protein Content (percent)
1 Mean	Matlabas^{A} 2.89	Koonap^{A} 78.78	Koonap^{A} 14.07
2 Mean	Tugela-DN^{A} 2.85	Komati^{A} 78.48	Nossob^{BA} 13.71
3 Mean	Elands^{BA} 2.79	Elands^{A} 78.48	Matlabas^{BC} 13.41
4 Mean	Gariep^{BAC} 2.71	Gariep^{A} 78.16	Senqu^{BC} 13.39
Variables Significant at 99% confidence interval (ANOVA)	Cultivar, Sub Region, Locality, year, CxSR, SRxY, CxY	Cultivar, Sub Region, Locality, Year, CxSR, CxY	Cultivar, Sub Region, Locality, Year, SRxY, CxY
N-obs[1]	10 583	10 685	9 285
R-square	0.93	0.94	0.91
Mean	2.64	77.84	13.01

Source: Statistical Analysis Software (SAS)

Notes: Superscript letters show LSD groupings

[1]Number of observations

Discussed below are the performance variables (i.e. yield, hectolitre mass, and protein content) of the public bred varieties cultivated in the winter rainfall region.

Yield

As shown in Table 6.2, ANOVA testing has revealed the factors of significance at a 99 percent confidence interval towards determining the ton per hectare produced to be cultivar, sub-region, locality, year, CxSR, SRxY, and CxY.

The top four performing cultivars in terms of yield in the summer rainfall region were found to not statistically differ from each other. These were Matlabas, Tugela-DN, Elands, and Gariep, with mean yields of 2.89 ton/ha, 2.85 ton/ha, 2.79 ton/ha, and 2.71 ton/ha respectively.

This suggests that there is no differentiation when making the choice between the top four cultivars of which cultivar to plant in pursuit of higher yield within the greater summer rainfall region, since they all have equal probabilities of yielding high or low yields.

The summer rainfall sub-regions consist of a small part of Mpumalanga and the Free State's north-western, eastern, central, and southern parts. The sub-region with the highest and lowest average yields was found to be the north-western and southern parts of the Free State province, with mean yields of 3.09 ton/ha and 1.81 ton/ha respectively. The LSD test revealed statistical difference between the highest yielding sub-region and lowest yielding sub-region. However, no statistical difference was found between the north-western Free State and eastern Free State, and no statistical difference between the central Free State and southern Free State.

The highest yielding cultivars in the north western Free State, eastern Free State, Mpumalanga, central Free State , and southern Free State were Tugela-DN (3.72 ton/ha), Senqu (3.60 ton/ha), Caledon (2.71 ton/ha), Matlabas (2.39 ton/ha), and Matlabas (1.93 ton/ha). The lowest yielding CxSR was found to be Tarka in the Central Free State sub-region with a mean yield of 1.18 ton/ha. The highest yielding CxSR was statistically different from the lowest yielding CxSR.

Harrismith was the highest yielding locality with a mean yield of 4.10 ton/ha. This locality was found to be statistically different from Senekal, the lowest yielding locality with a mean output of 0.74 ton/ha.

Hectolitre mass

Analysis of Variance revealed the factors of influence at a 99 percent confidence interval towards the level of hectolitre mass in wheat in the summer rainfall region to be cultivar, sub-region, locality, CxSR, and CxY.

It can be seen from Table 6.2 that the cultivars with the highest hectolitre mass output in the summer rainfall region were found to be Koonap (78.78 kg/hl), Komati (78.48 kg/hl), Elands (78.48 kg/hl), and Gariep (78.16 kg/hl). These cultivars were not statistically different from each other, implying that planting any of these cultivars for greater hectolitre mass output in the greater summer rainfall region would yield similar results. All of these cultivars had hectolitre mass above the minimum requirement for grade B1 wheat, suggesting good quality wheat can be expected in terms of hectolitre mass in the summer rainfall region.

The LSD test revealed Mpumalanga as the lowest performing and only statistically different sub-region in regard to achieving higher hectolitre mass. It was the only sub-region with a mean hectolitre mass output less than the grade B1 requirement, i.e. 73.35 kg/hl. Of the 74 tested localities in the summer region, Bothaville had the highest mean hectolitre mass output of 81.02 kg/hl, a statistical difference from the lowest 28 hectolitre mass producing localities.

The highest CxSR was Koonap x southern Free State with a mean hectolitre mass output of 79.56 kg/hl, statistically different from the lowest CxSR between Limpopo x Mpumalanga with a mean hectolitre mass output of 72.21 kg/hl. However, of the 63 CxSR analysed, Koonap x southern Free State was only statistically different from the bottom 11 CxSR, and Mpumalanga's interaction with any cultivar only appeared in the bottom 11 CxSR. This implies that the highest quality wheat in terms of hectolitre mass output can be associated with all sub-regions except for Mpumalanga.

Protein content

From the ANOVA, it can be said within a 99 percent confidence interval that the factors influencing the protein content of summer rainfall wheat include cultivar, sub-region, locality, year, SRxY, CxSR, and CxY.

The regional top four performing cultivars in terms of protein content were found to be Koonap, Nossob, Matlabas and Senqu, with means of 14.07 percent, 13.71 percent, 13.41 percent, and 13.39 percent respectively. As shown in Table 6.2, there is no statistical difference between the highest performing cultivar Koonap and the second highest performing cultivar Nossob. However, Nossob is also not statistically different from Matlabas and Senqu which suggests that Koonap and Nossob can give similar outputs in terms of protein content. However, Senqu and Matlabas can equally produce as high a protein content as Nossob but not reach Koonap's protein content potential.

As already mentioned in the winter rainfall agronomic results, the cultivar by sub-region interaction (CxSR) is representative of the genotype by environment interaction (GxE).

Cultivar by sub-region interactions show how well a particular cultivar performs in different environments. The top performing cultivars in the eastern Free State, Mpumalanga, central Free State, north western Free State, and southern Free State were Koonap (15.21 percent), Limpopo (14.43 percent), Nossob (14.32 percent), Koonap (13.83 percent), and Nossob (13.19 percent) Nossob and Koonap show good adaptation in terms of protein content performance in the various sub-regions. It is therefore evident from the CxSR above that, in terms of protein content, ARC cultivars have the potential to produce grade B1 quality wheat in all sub-regions.

6.3.3. Agronomic results for the irrigation region

In the 2013/14 season, the irrigation region had the highest average hectolitre mass output of 80.9 kg/hl and the highest average protein content of 12.0 percent. This region showed the highest averages of the two quality parameters (SAGL, 2014). Both protein content and hectolitre mass averages meet the requirements for the wheat from this region to be classed as grade B1.

Similar to cultivars in the summer and winter rainfall regions, performance analysis was based on yield, hectolitre mass, and protein content. Table 6.3 shows the agronomic results for the irrigation region. Analysis of Variance revealed variables of significance towards cultivar performance in the irrigation region to be the cultivar (C) itself, locality (L), sub-region (SR), year (Y), cultivar and year interaction (CxY), cultivar and sub-region interaction (CxSR), and sub-region by year interaction (SRxY).

Table 6.3: Agronomic Results of the ARC's cultivars in the irrigation region, 1998 to 2014

Rank	*Irrigation Region*		
	Yield (ton/ha)	*Hectolitre mass (kg/hl)*	*Protein Content (percent)*
1 Mean	$Tamboti^{A}$ 8.10	$Tamboti^{A}$ 80.17	$Inia^{A}$ 13.36
2 Mean	$Palmiet^{A}$ 8.03	$Umlazi^{BA}$ 79.53	$Olifants^{BA}$ 12.99
3 Mean	$Umlazi^{A}$ 7.96	$Sabie^{BC}$ 79.38	$Marico^{BC}$ 12.71
4 Mean	$Timbavati^{A}$ 7.83	$Buffels^{BCD}$ 79.28	$Kariega^{DC}$ 12.49
Variables Significant at 99% confidence interval (ANOVA)	Cultivar, Sub Region, Locality, Year, CxY, CxSR, SRxY	Cultivar, Sub Region, Locality, Year,CxSR, SRxY, CxY	Cultivar, Sub Region, Locality, Year, CxY, CxSR, SRxY
N-obs[1]	17 907	17 666	17 318
R-square	0.88	0.93	0.97
Mean	6.64	78.26	12.44

Source: Statistical Analysis Software (SAS)

Notes: Superscript letters show LSD groupings

[1]*Number of observations*

The performance variables (i.e. yield, hectolitre mass and protein content) for the irrigation region are discussed below.

Yield

As shown in table 6.3, variables of significance at 99 percent confidence interval towards yield output were found to be; cultivar, sub-region, locality, year, CxY, CxSR, and SRxY.

The top four yielding cultivars in the entire irrigation region were found to be Tamboti, Palmiet, Umlazi, and Timbavati with means of 8.10 ton/ha, 8.03 ton/ha, 7.96 ton/ha, and 7.83 ton/ha respectively. The LSD tests revealed the top four yielding cultivars to not be statistically difference from each other. This implies that any one of the four cultivars can yield the high ton per hectare achieved by Tamboti.

The locality yielding the highest tonnage per hectare was found to be Remhoogte with a high mean of 12.03 ton/ha. This locality was statistically different from the second highest yielding and the lowest yielding localities which were Hartswater and Taung with means of 11.15 ton/ha and 1.78 ton/ha respectively.

Hectolitre mass

The major influences towards the hectolitre mass of cultivars sown in the irrigation region were; the cultivar itself, sub-region, locality, year, cultivar and year interaction, cultivar and sub-region interaction, and sub-region and year interaction.

The LSD revealed the top four performing cultivars in terms of hectolitre mass in the irrigation region to be Tamboti, Umlazi, Sadie, and Buffels with mean hectolitre mass of 80.17 kg/hl, 79.53 kg/hl, 79.38kg/hl, and 79.28 kg/hl respectively. All top four cultivars satisfy grade B1 requirement for hectolitre mass. Tamboti was found to be statistically different from Sabie and Buffels and would be a choice favourite to attain higher hectolitre mass.

Protein Content

As shown in table 6.3, the variation of protein content in the irrigation region was found to be influenced at 99 percent confidence interval by cultivar selection, sub-region, locality, year, cultivar and year interaction, cultivar and sub-region interaction, and sub-region and year interaction.

In terms of protein content, it was found that the top four performing cultivars were Inia, Olifants, Marico, and Kariega. Of these cultivars, Inia showed the highest average protein content of 13.36 percent, which was found to be statistically different from Marico and Kariega with a means 12.71 percent and 12.49 percent respectively. However, Inia was not statistically different from Olifants. This implies that Inia and Olifants can produce equally as high or as low protein content in the irrigation region. Both LSD groups in the top four cultivars displayed grade B1 satisfaction.

6.4. BENEFITS AND COSTS OF THE CURRENT WHEAT QUALITY STANDARDS

In order to determine the returns from the current wheat quality standards, the study followed the procedure discussed in section 5.3.3. For coefficient determination i.e. determining genetic gains and losses, forward regressions were run in the Statistical Analysis System (SAS) on a yearly basis. The regressions were run for each year in order to relax the assumption of cumulative genetic gains made in similar studies (Brennan, 1989; Traxler *et al.*, 1995; Nalley *et al.*, 2008; Dlamini *et al.*, 2017). By so doing, the influence of genetic improvement on yields was calculated for each year. Effects of genetic improvement varied between increasing effects and decreasing effects.

In the Nalley *et al.* (2008) impact study of the Kansas wheat breeding programme, the dependent variable used for the OLS regression was yield for variety *i*, in station *j*, at period *t*. The Regression was given by;

$$\mathrm{Y}_i = \alpha + \beta_1 white_i + \beta_2 soft_i + \beta_1 RLYR_i + \beta_1 Private_i + \beta_1 Blend_i + \beta_1 KAES_i + \lambda_i + \theta_i + \mathrm{e}_{ijt} \qquad (5.15)$$

Where:

$Yield_{ijt}$ = yield for variety i, in station j, at period t,

α = intercept,

$White_i$ = dummy variable of whether wheat is white or not,

$Soft_i$ = dummy variable of whether wheat was soft or hard,

$RLYR_i$ = cultivar release year,

$Private_i$ = dummy variable for whether a cultivar was released by a private breeder,

$Blend_i$ = dummy variable of whether the cultivar was a blend of two or more cultivars or not,

$KAES_i$ = dummy variable for whether a cultivar was breed by a public research university (e.g. University of Nebraska, Kansas State University, etc.) or private research company.

This cultivars were distinguished from other public bred varieties,

λ_i = vector of time,

θ_i = vector of location,

and e_{itj} = error term.

Nalley *et al.* (2008) used release year as a measure of genetic gains and assumed cumulative gains of these genetic improvement over the years. A similar assumption on genetic gains is also found in Brennan (1989) where it is assumed genetic gains are constant throughout the useful life of a cultivar.

In this study, the assumption of cumulative genetic gains is relaxed, along with that of constant gains. Actual genetic gains (i.e. protein content and hectolitre mass) are regressed for each year within the study period. Due to data limitations and more so, correlations between various quality parameters, only protein content and hectolitre mass were regressed. These are the most important quality parameters that market traders look for (Loy *et al*., 2015). Changes in each parameter reflect changes in quality. Only ARC cultivars were included in the regression, eliminating the need for a dummy of ARC cultivars or private cultivars. Effects of location were determined by an ANOVA while the need for a qualitative variable of time was eliminated due to the fact that multiple regressions were run each year.

The resulting OLS model for this study is given below by:

$$Y_i = \beta_0 + \beta_1 HLM + \beta_2 PC + \mu \qquad (5.16)$$

Where:

Y_i = wheat yields of cultivar *i*,

β_0 = constant,

β_1 = genetic gain/loss from hectolitre mass improvement,

β_0 = genetic gain/loss from protein content improvement,

and μ is the error term.

6.4.1. Economic results for the winter rainfall region

Table 6.4 shows the economic results of the quality breeding objective in the winter rainfall region. Using methods explained in section 5.3.3, the coefficients of protein content and hectolitre mass were calculated and used for the benefit-cost ratio calculations.

As expected, the regression results mainly found hectolitre mass to show a positive relationship with yields while protein content mainly showed a negative relationship with yields. The highest correlation between hectolitre mass and yield was in the 1999/00 season when an increase in one kg/hl led to a 0.21 ton increase in yields. The highest correlation of protein content to yields was found to be in the 2012/13 season. It was found that a one percentage increase in protein content (12 percent moisture basis) led to a 0.35 ton decrease in yields.

Table 6.4: Economic Results for the Winter Rainfall Region, 1999 to 2014

Year	Hectares	Adoption Rate (National)	Wheat Prices (R/t) 2010=100	HLM Coefficient	PC Coefficient	HLM Benefits (2010 Rands)	PC Benefits (2010 Rands)	Total Benefits (2010 Rands)	HLM Costs (2010 Rands)	PC Costs (2010 Rands)	Total Absolute costs (2010 Rands)
1999/00	345 500	0.12	1 708.16	0.21***	-0.18***	15 093 705		15 093 705		(13 375 675)	13 375 675
2000/01	345 000	0.02	1 961.52								
2001/02	364 000	0.09	2 192.06	0.10***	0.05***	7 512 005	3 419 714.81	10 931 719			
2002/03	325 000	0.09	2 291.82								
2003/04	354 000	0.07	2 051.50								
2004/05	302 000	0.11	1 518.36	0.07***		3 575 857					
2005/06	292 000	0.19	1 373.46	-0.04***	-0.25***				-3 206 333	(18 929 111)	22 135 445
2006/07	325 000	0.19	1 890.77		0.27***	32 079 683		32 079 683			
2007/08	350 000	0.17	2 786.79	0.08***	-0.23***	12 942 590		12 942 590		(37 828 054)	37 828 054
2008/09	300 000	0.18	2 405.65	0.10***		13 605 591		13 605 591			
2009/10	265 000	0.18	1 607.67	0.12***	-0.14***	8 967 183		8 967 183		(10 514 921)	10 514 921
2010/11	265 000	0.17	2 194.22	0.06***	-0.23***	6 308 590		6 308 590		(22 979 046)	22 979 046
2011/12	272 000	0.15	2 136.53		-0.10***					(8 637 294)	8 637 294
2012/13	310 000	0.11	2 486.11	0.16***	-0.35***	14 339 344		14 339 344		(31 080 357)	31 080 357
2013/14	310 000	0.07	2 315.80	0.06***	-0.20***	2 698 475		2 698 475		(9 437 962)	9 437 962
TOTAL								116 966 884			155 988 756
MEAN								12 996 320			19 498 594
Benefit Cost Ratio (Total)			0.75								
Benefit Cost Ratio (Mean)			**0.67**								

Source: DAFF, SAGL, SAGIS, and SAS

*Notes: *, **, *** Statistically significant at 90 percent, 95 percent, and 99 percent confidence interval respectively*

While the average benefits of wheat breeding under the quality standards that existed from 1999 to 2014 amount to R13 million, the average costs covering the same period exceed those benefits by R6.5 million amounting to R19.5 million. The costs are attributed to attaining a certain level of quality over the 15 years, thus this is the cost of quality and is seen to outweigh the benefits of attaining the same level of quality. These costs and benefits arise from the public breeding efforts of the ARC in the winter rainfall region.

The calculated benefit-cost ratio from the sum costs and benefits in the study period is 0.75. This is below 1 and can be said that breeding for quality in the winter rainfall has led to more losses than gains. The benefit-cost ratio calculated from the mean benefits and costs is also below 1 and was found to be 0.67. As in Nalley *et al.* (2008), this study will report on the mean benefit-cost ratio. A benefit-cost ratio of 0.67 implies that for every rand invested towards attaining the satisfactory quality standards, 33 cents is lost. A benefit cost ratio below one implies that there are negative returns from breeding for quality improvement. Also, this implies that the quality standards are too high.

6.4.2. Economic results for the summer rainfall region

Table 6.5 shows the economic results of the quality breeding objective in the summer rainfall region. In the summer rainfall region, hectolitre mass only displayed a positive relationship with yields. This implies an increase in hectolitre mass leads to an increase in yields as well.

As shown in table 6.5, the highest hectolitre mass and yield relationship was found to be in the 2009/10 season with a coefficient of 0.27. This implies that a one kg/hl increase in grain quality led to a 0.27 ton per hectare increase in yield. Protein content was found to mainly have a negative relationship with yields, attesting to Terman *et al.* (1969) of the inverse relationship between yields and protein content. The highest yield to protein content relationship was in the 2006/07 season at negative 0.55. This implies that a protein content one percentage increase (12 percent moisture basis) led to a decline of 0.55 ton/ha. The costs and benefits associated with wheat quality were calculated similarly to those in the winter region.

Table 6.5: Economic Results for the Summer Rainfall Region, 1999 to 2014

YEAR	Hectares	Adoption Rate (National)	Wheat prices (R/t) 2010=100	HLM Coefficient	PC Coefficient	HLM Benefits (2010 Rands)	PC Benefits (2010 Rands)	Total Benefits (2010 Rands)	PC Costs (2010 Rands)	Total Absolute Costs (2010 Costs)
1999/00	447 300	0.12	1 708.16	0.23***	-0.12***	21 265 397	-	21 265 397	(11 316 789)	11 316 789
2000/01	502 900	0.02	1 961.52	0.05 **	0.10***	1 094 352	2 303 103	3 397 456	-	-
2001/02	443 500	0.09	2 192.06	-	0.22***	-	19 392 061	19 392 061	-	-
2002/03	322 500	0.09	2 291.82	0.09***	-	6 360 041	-	6 360 041	-	-
2003/04	356 600	0.07	2 051.50	0.03***	-0.09***	1 525 405	-	1 525 405	(4 718 077)	4 718 077
2004/05	384 000	0.11	1 518.36	0.03*	-0.16***	1 845 216	-	1 845 216	(10 148 068)	10 148 068
2005/06	362 800	0.19	1 373.46	0.04***	-0.35***	3 552 580	-	3 552 580	(32 949 885)	32 949 885
2006/07	218 800	0.19	1 890.77	0.26***	-0.55***	21 074 443	-	21 074 443	(43 885 248)	43 885 248
2007/08	285 500	0.17	2 786.79	0.09***	-0.11***	12 367 722	-	12 367 722	(14 759 719)	14 759 719
2008/09	240 000	0.18	2 405.65	0.09***	-0.17***	9 328 939	-	9 328 939	(18 655 744)	18 655 744
2009/10	208 500	0.18	1 607.67	0.27***	-	15 796 105	-	15 796 105	-	-
2010/11	230 000	0.17	2 194.22	0.16***	-	14 025 985	-	14 025 985	-	-
2011/12	134 500	0.15	2 136.53	0.05**	-0.05*	2 082 136	-	2 082 136	(2 254 429)	2 254 429
2012/13	94 500	0.11	2 486.11	0.11***	-0.25***	2 896 712	-	2 896 712	(6 649 676)	6 649 676
2013/14	72 500	0.07	2 315.80	0.20***	0.19***	2 269 501	2 097 456	4 366 957	-	-
TOTAL								139 277 163	-	145 337 638
MEAN								9 285 144		16 148 626
Benefit Cost Ratio (Total)				0.96						
Benefit Cost Ratio (Mean)				**0.57**						

Source: DAFF, SAGL, SAGIS, and SAS

*Notes: *, **, *** Statistically significant at 90 percent, 95 percent, and 99 percent confidence interval respectively*

As shown in table 6.5, the mean benefits associated with public wheat quality breeding accumulated from the summer rainfall region from 1999 to 2014 amount to a value of R9.3 million. As with the winter rainfall region, the cost of quality in the summer rainfall region exceeded the benefits. The costs exceed the benefits by R6.9 million amounting to an average of R16.1 million within the 15-year study period.

The benefit-cost ratio of the mean benefits and costs was found to be 0.57. The results suggest a 43 cent loss from every rand invested towards quality breeding alone. A benefit cost ratio below one implies that there are negative returns from breeding for quality improvement. Also, this implies that the quality standards are too high.

6.4.3. Economic results for the irrigation region

Table 6.6 shows the economic results of the quality breeding objective in the irrigation region. Similar to the summer rainfall region, hectolitre mass in the irrigation region only displayed a positive relationship with yields. As was found in both summer and winter rainfall regions, protein content in the irrigation region mainly had an inverse relationship with yields. The highest hectolitre mass to yield relationship was in the 2005/06 season with an estimated coefficient of 0.33. This implies that an increase in hectolitre mass by one kg/hl led to a 0.33 ton/ha increase of wheat yields. The highest protein content and yield relationship was in the 1999/00 season with a coefficient of 0.63. This implies that a percentage decrease in protein content (12% moisture basis) led to 0.63 ton\ha decrease in wheat yields.

Table 6.6: Economic Results for the Irrigation region, 1999 to 2014

YEAR	Hectares	Adoption Rate (National)	Wheat prices (R/t) 2010=100	HLM Coefficient	PC Coefficient	HLM Benefits (2010 Rands)	PC Benefits (2010 Rands)	Total Benefits (2010 Rands)	PC Costs (2010 Rands)	Total Absolute Costs (2010 Costs)
1999/00	141 200	0.12	1 708.16	-	-0.63***	-	-		(18 883 535)	18 883 535
2000/01	125 600	0.02	1 961.52	0.14***	0.29***	796 556	1 710 132	2 506 688	-	-
2001/02	133 600	0.09	2 192.06	0.04***	-	1 185 610	-	1 185 610	-	-
2002/03	100 500	0.09	2 291.82	0.23***	-0.60***	4 792 800	-	4 792 800	(12 626 466)	12 626 466
2003/04	119 400	0.07	2 051.50	0.11***	-0.37***	2 077 111	-	2 077 111	(6 768 124)	6 768 124
2004/05	119 000	0.11	1 518.36	0.26***	-0.54***	4 912 895	-	4 912 895	(10 384 951)	10 384 951
2005/06	110 000	0.19	1 373.46	0.33***	-0.47***	9 356 378	-	9 356 378	(13 185 935)	13 185 935
2006/07	88 200	0.19	1 890.77	0.12***	0.13***	3 785 412	4 231 209	8 016 621	-	-
2007/08	112 500	0.17	2 786.79	0.24***	-0.20***	12 429 589	-	12 429 589	(10 551 806)	10 551 806
2008/09	102 500	0.18	2 405.65	0.30***	-0.22***	13 595 334	-	13 595 334	(10 134 645)	10 134 645
2009/10	84 600	0.18	1 607.67	0.24***	-0.22***	5 725 461	-	5 725 461	(5 133 008)	5 133 008
2010/11	109 700	0.17	2 194.22	0.14***	-0.13***	5 723 846	-	5 723 846	(5 264 175)	5 264 175
2011/12	104 700	0.15	2 136.53	0.16***	-0.22***	5 463 399	-	5 463 399	(7 725 162)	7 725 162
2012/13	101 000	0.11	2 486.11	0.12***	-0.32***	3 550 077	-	3 550 077	(9 335 068)	9 335 068
2013/14	94 070	0.07	2 315.80	0.24***	-	3 552 396	-	3 552 396	-	-
TOTAL								82 888 214		109 992 881
MEAN								5 920 586		9 999 352
Benefit Cost Ratio (Total)				0.75						
Benefit Cost Ratio (mean)				**0.59**						

Source: DAFF, SAGL, SAGIS, and SAS

*Notes: *, **, *** Statistically significant at 90 percent, 95 percent, and 99 percent confidence interval respectively*

As shown in table 6.6, the average benefits of public quality breeding under the set quality standards from 1999 to 2014 only amounted to R5.9 million, while the associated costs amounted to R10 million. This exceeded the benefits by R4 million. The resulting mean benefit-cost ratio was 0.59. This implies that for every rand invested towards wheat quality improvement in the irrigation region, 41 cents had been lost. A benefit cost ratio below one implies that there are negative returns from breeding for quality improvement. Also, this implies that the quality standards are too high.

6.5. SUMMARY

The Fisher divisia index was used in fulfilling the first objective of determining the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry. Although the production of bread-baking quality wheat was found to be higher than that of non-bread-baking quality, the difference in growth trends of the quality adjusted index for bread-baking quality wheat and non-bread-baking quality wheat showed more favourable conditions for continual production of the non-bread-baking quality wheat. This was shown by a lower declining rate of 0.07 percent for the non-bread-baking quality wheat index and a higher declining rate of 0.23 percent for the bread-baking quality wheat index. The observation is attributable to the high quality standards for bread-baking wheat. However, other factors (such as management practises, seed availability, climate, etc.) could have also played a role in the growth trends exhibited between the indexes of wheat of bread-baking quality and indexes of non-bread-baking quality wheat.

An ANOVA and LSD tests were used to fulfil the second objective of identifying high yielding and quality satisfactory ARC cultivars in the different production regions of South Africa. The top four yielding and top four quality performing cultivars were identified for each production region. Table 6.7 summarises the agronomic results. It was found that in the winter rainfall region, Nantes and Adamtas were the only two cultivars that had both satisfactory yields and quality. In the summer rainfall region, Elands, Gariep, and Matlabas showed high yields and satisfactory quality. In the irrigation region, only Tamboti and Umlazi showed both high yields with satisfactory quality. The satisfactory quality and yields of the seven cultivars is owing to the better genotype and environment interaction (they are simply better adapted). Cultivars showing high yields along with satisfactory quality would receive first planting preference in their respective regions.

Table 6.7: Summary of Agronomic Results, 1998 to 2014

	Region		
	Winter rainfall region	Summer rainfall region	Irrigation region
Cultivars showing both high yields and high quality parameters	Nantes AdamTas	Elands Gariep Matlabas	Tamboti Umlazi

This chapter also fulfilled the third objective of determining the returns from the current wheat quality standards. It was found that breeding for quality under the current strict quality standards has resulted in losses for all three wheat production regions of South Africa. Table 6.8 shows a summary of the economic results. The total average benefits for South Africa from quality improvements were found to be R28.2 million. The total average costs for South Africa from quality improvements were found to be R45.6 million. The benefit-cost ratio of public wheat breeding in South Africa was found to be 0.62. A benefit cost ratio below one implies that there are negative returns from breeding for quality improvement. Also, this implies that the quality standards are too high.

Table 6.8: Summary of Economic Results, 1999 to 2014

	Region			
	Winter rainfall region	Summer rainfall region	Irrigation region	South Africa
Benefits	R12,996,320	R9,285,144	R5,920,586	R28,202,051
Costs	R19,498,594	R16,148,626	R9,999,352	R45,646,573
Benefit cost Ratio	0.67	0.57	0.75	0.62

CHAPTER 7
SUMMARY AND CONCLUSIONS

7.1. INTRODUCTION

The aim of the study was to evaluate the economic implications of government intervention in the wheat industry through quality standards. Thus, the main objective was to determine the economic implications of adhering to the wheat quality standards in South Africa. From the main objective, three specific objectives were formed. The first objective looked at how government intervention, through quality standards, had historically affected wheat output. The focus was on output changes of bread-baking and non-bread-baking wheat.

The second objective continued to evaluate the implications of government intervention in wheat quality. However, this focused on government's direct breeding efforts to maintain quality through the ARC. Public cultivars were evaluated on their yielding and quality attributes (i.e. hectolitre mass and protein content).

Lastly, in the continual assessment of the economic implications of the wheat quality standards, the study's third objective estimated the returns from breeding under the current quality standards. In pursuing the third objective, benefits and costs associated with breeding for the current quality standards were estimated. These estimates were ultimately used in calculating a benefit-cost ratio. As such, this became the first study to determine societal benefits and costs associated with public wheat breeding for quality.

7.2. SUMMARY OF RESULTS

In fulfilling the first objective of determining the historic output changes of bread-baking wheat and non-bread-baking wheat in the South African wheat industry, the first step was to construct a quality adjusted index and a quality unadjusted index for the total wheat production. Secondly a quality adjusted index of bread-baking wheat was contrasted against a quality adjusted index for non-bread-baking wheat. The output changes of both wheat of bread-baking and non-bread-baking quality had a declining rate. However, wheat of bread-baking quality had a higher declining rate of decrease.

Within the periods of analysis for the various grades, the bread-baking quality wheat always maintained a higher output than the non-bread-baking quality wheat. The higher output of bread-baking quality wheat can be explained by the criteria of releasing wheat seed that favours seed displaying higher quality attributes. The declining output change in bread-baking and non-bread-baking wheat suggests that the industry will not be able to continuously produce wheat of such high standards.

In achieving the second objective of identifying high yielding and quality satisfactory ARC cultivars in the different production regions of South Africa, a combination of ANOVA and LSD tests was used. In the winter rainfall region, Nantes and AdamTas were identified as both high yielding and quality performing cultivars. In the summer rainfall region, Elands, Gariep and Matlabas were found to be high yielding with satisfactory quality attributes. In the irrigation region, Tamboti and Umlazi showed both high yielding and high quality attributes. These cultivars showed favourable performance due to a better genotype and environment interaction.

The third and final objective of determining the returns from breeding under the current wheat quality standards was realised through a benefit-cost ratio. A benefit-cost ratio was performed for all three production regions to determine the feasibility of quality breeding in each region from 1999 to 2014.

In the winter rainfall region, it was found that the average financial gains from quality improvements (R13 million) were less than the associated average losses (R19.4 million). The benefit-cost ratio for the winter region was found to be 0.67. This implies losses for quality breeding in the winter region. Also, in the summer rainfall region, there were more costs (R16.1 million) associated with achieving high quality wheat than there were gains (R9.3 million). The benefit-cost ratio for the summer region was found to be 0.57. This also implies losses for quality breeding in the summer rainfall region.

The irrigation region showed similar results to the winter and summer rainfall region in terms of gains and losses associated with public breeding for quality, it was found that the average gains were lower at R5.9 million than the average costs at R10 million. The benefit-cost ratio of this region was below one, indicating losses for the quality breeding objective in this region.

The total average costs of public quality breeding in South Africa from 1999 to 2014 amount to R45.6 million, while the benefits only amount to R28.2 million. This gives a benefit-cost ratio of 0.62, implying that for every rand invested into quality breeding alone, 38 cents is lost. A benefit-cost ratio below one implies that there are negative returns from breeding for quality improvement. Also, this implies that the quality standards are too high.

7.3. CONCLUSIONS AND RECOMMENDATIONS

Despite the various organisations with data monitoring and capturing responsibilities on different grains, collecting data on the South African wheat grain proved a tedious process, this may be caused by the sharing of similar functions by the various organisations. This led to discrepancies in price values reported by the various organisations on a single commodity and in some cases data not being available. Although sharing of similar functions by the various organisations leads to a wider data base, it is causing confusion on which organisation captures which information. It is therefore recommended that similar data capturing responsibilities need not be shared amongst the various organisations dealing with grains. It is further recommended that the capturing of market prices by grade be reintroduced and put in the public domain for ease of analysing the long-run effects of current grading systems in future.

To test the first hypothesis that government intervention has historically led to a greater and positive output change in wheat of non-bread-baking quality, the growth rates of the quality adjusted index for wheat of bread-baking quality was compared to the quality adjusted index of wheat of non-bread-baking quality. It was found that both wheat of non-bread-baking and bread-baking quality had a declining rate. Therefore, we reject the null hypothesis.

The study rejects the second hypothesis that the ARC's high yielding cultivars are not of satisfactory quality. However, only seven of the thirty-three cultivars (21 percent) showed well adaptation under the quality standards. In the winter rainfall region, cultivars Nantes and AdamTas appeared in the top four yielding cultivars and appeared in the top four performing cultivars in the region in terms of protein content. In the summer rainfall region, Elands, Gariep and Matlabas appeared among the top four yielding ARC cultivars and the top four quality performing cultivars in terms of hectolitre mass for Elands and Gariep, and protein content for Matlabas. In the irrigation region, Tamboti and Umlazi appeared among the top four yielding cultivars and top four quality performing cultivars in terms of hectolitre mass for both cultivars.

It is therefore recommended that the cultivars appearing in both top four yielding and top four quality performance be first planting preference in their respective regions.

Since government is involved in breeding and setting of quality standards, it would be expected that public breeding efforts would result in more benefits than costs from the quality standards it sets, meaning that current quality standards are not too strict. This would then suggest inefficiency in the breeding technics of the private sector. However, from the benefit-cost analysis of all production regions, it was found that public breeding for quality alone results in more costs than benefits. This implies negative returns from quality improvement. Therefore, we fail to reject the third hypothesis that the costs of breeding towards fulfillment of the current wheat quality standards exceed the benefits.

This study then supports Van der Merwe (2015) advocating less strict quality standards in the wheat industry. Based on the results, it is recommended that current wheat standards be revised. The new quality standards should be demand driven. It is further suggested that these new standards be set such that the benefits of quality improvement, at the very least, cover the costs (i.e. the benefit-cost ratio of quality improvement should be greater or equal to one).

7.4. LIMITATIONS OF STUDY

In the computation of quality indexes, data unavailability after the Wheat Board era became a major restriction. Thus, no post Wheat Board analysis could be performed with regard to the influence of the grading systems on the output changes and growth rates of the various qualities of wheat.

There was a large set of data recovered from the National Cultivar Trials on the yield, protein content and hectolitre mass performance of the various public and private sector cultivars. This study only focused on the public breeder (ARC) cultivars' performance. As such, there still remains a need to analyse both public and private cultivar performance. Also, the benefit-cost ratio for quality was only performed for public breeding efforts, this does not tell the story of whether the whole wheat breeding industry generates more loses from the current wheat quality standards. However, it does show that the standards are too high for public breeding efforts to generate more societal gains than losses.

The study took an intentionally narrow focus on the economics of quality to investigate whether there was any justification for the current quality standards. The benefit-cost ratio reported indicates a lack of justification for the currently high quality standards. However, the benefit-cost ratio reported does not tell a story of the total impact of the ARC’s wheat breeding programme for other objectives such as drought resistance, disease resistance, etc.

7.5. IMPLICATIONS FOR FUTURE RESEARCH

The study was able to put together a quality adjusted index for bread-baking wheat and non-bread-baking wheat during the Wheat Board era. Difficulties in sourcing data arose dealing with the post-Wheat Board era. The challenges were mainly due to the recording functions that fell with the Wheat board. Collection of data on wheat prices and quantity by grade will allow for more extensive quality-adjusted index.

In formulating a benefit-cost ratio, a broader picture can be drawn on the effects of the quality standards on the whole of the South African wheat industry by including privately bred cultivars in analyses. Also, the study period could be back-dated to get a more historic outlook on returns from quality improvement.

The narrow focus on the gains and losses associated with quality breeding leaves a question as to whether the entire public wheat breeding programme constitute more losses than gains or the loses in quality are offset by other breeding objectives such as yields gains, disease resistance, drought resistance, etc. There exists a need for a more elaborate study taking these factors into account.

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APPENDIX A

Table A1: 1995 wheat quality tolerance ratio

1995		
Mixograph Peak time	Karee	+0 to- 25%
	Betta	+ 5 to -20%
	Kariega	+ 5 to -20%
	Nantes	+ 10 to -15%
	SST66	+ 15 to -10%
	Molen	+20 to -5%
Kg / hl	-1.5 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.2%	
Colour (KJ)	+0.5	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2%	
-Development time	+- 20%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-10 to +20%	
-distensibility	-10 to +20%	
-P/L	+-20%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural Research Council's Small Grains Institute

Table A2: 1999 wheat quality tolerance ratio

1999		
Mixograph Peak time	Betta DN	+ 5 to – 20%
	Betta	+ 5 to -20%
	Kariega	+ 10 to -20%
	SST66	+ 20 to -10%
	SST65	+25 to -10%
Kg / hl	-1.5 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.2%	
Colour (KJ)	+0.5	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2%	
-Dev time	+- 20%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-10 to +20%	
-distensibility	-10 to +20%	
-P/L	+-20%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A3: 2002 wheat quality tolerance ratio

2002		
Mixograph Peak time	Betta DN	+ 5 to – 20%
	Elands	+ 5 to -20%
	Kariega	+ 10 to -20%
	SST806	+ 20 to -10%
	SST65	+25 to -10%
Kg / hl	-1.5 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.2%	
Colour (KJ)	+0.5	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2%	
-Development time	+- 20%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-10 to +20%	
-distensibility	-10 to +20%	
-P/L	+-20%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A4: 2004 wheat quality tolerance ratio

2004		
Mixograph Peak time	Betta DN	+ 10 to – 15%
	Elands	+ 5 to -20%
	Kariega	+ 10 to -20%
	SST806	+ 20 to -10%
	SST65	+25 to -10%
Kg / hl	-1.5 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.2%	
Colour (KJ)	+0.5	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2%	
-Development time	+- 20%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-10 to +20%	
-distensibility	-10 to +20%	
-P/L	+-20%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A5: 2005 wheat quality tolerance ratio

2005		
Mixograph Peak time	Kariega (South)	+5 to -25%
	Elands	+ 5 to -20%
	Kariega(Irrig)	+ 20 to -20%
	SST806	+ 20 to -10%
	SST65	+25 to -10%
Kg / hl	-1.5 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.2%	
Colour (KJ)	+0.5	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2%	
-Dev time	+- 20%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-10 to +20%	
-distensibility	-10 to +20%	
-P/L	+-20%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A6: 2007 wheat quality tolerance ratio

2007		
Mixograph Peak time	Kariega (South)	+15 to -25%
	Elands	+ 15 to -25%
	Kariega (Irrig)	+ 20 to -20%
	SST806	+ 20 to -20%
	SST65	+30 to -5%
Kg / hl	-1.8 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.5%	
Colour (KJ)	+1.0	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2.5%	
-Dev time	+- 25%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-+20%	
-distensibility	-10 to +20%	
-P/L	+-25%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A7: 2008 wheat quality tolerance ratio

2008		
Mixograph Peak time	Kariega (South)	+15 to -25%
	Elands	+ 15 to -25%
	Kariega (Irrig)	+ 20 to -20%
	SST806	+ 20 to -10%
	SST65	+30 to -5%
Kg / hl	-1.8 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.5%	
Colour (KJ)	+1.0	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2.5%	
-Dev time	+- 25%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-+20%	
-distensibility	-10 to +20%	
-P/L	+-25%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A8: 2010 wheat quality tolerance ratio

2010		
Mixograph Peak time	Kariega (South)	+15 to -25%
	Elands	+ 15 to -25%
	SST806	+ 20 to -10%
Kg / hl	-1.8 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.5%	
Colour (KJ)	+1.0	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2.5%	
-Dev time	+- 25%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	
-stability	-+20%	
-distensibility	-10 to +20%	
-P/L	+-25%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute

Table A9: 2013 wheat quality tolerance ratio

2013		
Mixograph Peak time	Kariega (South)	+15 to -25%
	Elands	+ 15 to -25%
	SST806	+ 35 to -10%
	SST027	+45 to -5%
Kg / hl	-1.8 unit	
1000 kernel mass	+- 4g	
Falling number	-15%	
Protein (12%mb)	-1%	
Extraction	-1.5%	
Colour (KJ)	+1.0	
Break Flour Yield	+-5%	
Farinograph		
-Absorption	+-2.5%	
-Dev time	+- 25%	
-Stability	+10 to -30%	
Alveograph		
-strength	+-20%	SST027 (+25%)
-stability	-+20%	
-distensibility	-10 to +20%	
-P/L	+-25%	
Bake test		
-Corrected volume	-10%	

Source: Agricultural research Council's Small Grains Institute