# TRADE AND WELFARE IMPLICATIONS OF GENETICALLY MODIFIED MAIZE ON SOUTH AFRICA

**By**

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November 2007

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## ABSTRACT

During the last century, human life and the quality of living have been impacted significantly through continuous developments in science and technology. Man has evolved himself from a hunter and gatherer to the modern man whose lives are enriched with products that relate to information and communication technology, biotechnology and info-space technology. The domestication of biotechnology may dominate our lives during the next fifty years at least as much as the domestication of computers has dominated our lives during the previous fifty years.

The advent of genetically modified organisms (GMOs) has brought rapid change to world agricultural production and trade. Evidence shows that Genetically Modified (GM) crops can have a yield advantage over conventional crops. Currently 46% of the total area utilised in maize production in South Africa is planted with GM maize.

South Africa's main trading partners in maize have differing GMO regimes, and many of them may well change their current stances and regulations as the international

conventions and agreements on GMOs further evolve. Over and above this regulatory framework, consumer attitudes to GM foods are also changing.

The objective of the study is to calculate and quantify the potential impacts of GM maize on the South African maize trade, by applying the GTAP model. This will provide scientific input to South African policy makers on GM maize related regulations in the domestic market, as well as on their stances in the international conventions. The GTAP model is generally accepted by trade researchers as the most suitable tool to analyse the impact of trade policy decisions on trade flows and national welfare on a global level due to its regional and sectoral coverage as well as its theoretical compliance.

The results suggest that the South African policy to allow the domestic production of approved GM maize events was to the benefit of the country. Policy measures that will restrict the country's access to new GM maize events will gradually disadvantage both the domestic producers and consumers of maize. The consumers will suffer a decrease in total welfare whilst the producers will be disadvantaged in terms of imported competition. For this reason, commodity clearance before general release should be the exception rather than the rule.

In terms of future studies on this issue to further refine the results of this study specific effort should be afforded to improve the changes made to disaggregate the maize sector from other grain sectors, nationally and internationally, in the GTAP model. In addition, it is recommended that trade flows between countries as included in the GTAP model should be scrutinised in detail to check for the correctness of actual flows. This would entail a proper evaluation of the base data of the GTAP model specific to countries playing a relatively smaller role in the international trade of agricultural products. Neglecting to do the aforementioned could result in incorrect policy recommendations.

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**Deur**

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## UITTREKSEL

Gedurende die afgelope eeu het die voortdurende ontwikkleing in wetenskap en tegnologie 'n betekenisvolle invloed op die menslike lewe en die gehalte daarvan uitgeoefen. Die mens het van jagter en versamelaar gevorder tot moderne wesens wie se lewens verryk word met produkte wat verband hou met kommunikasie-tegnologie, bio-tegnologie en info-ruimte-tegnologie. Bio-tegnologie kan dalk die volgende vyftig jaar ons lewens in dieselfde mate oorheers as wat rekenaars ons lewens die afgelope vyftig jaar oorheers het.

Die koms van geneties gemodifiseerde organismes (GMOs) het 'n vinnige ommekeer in wêreld-landbouproduksie en –handel teweeggebring. Daar is bewys dat geneties gemodifiseerde (GM)-gewasse 'n oes-voordeel bo konvensionele gewasse het. Tans is 46% van die totale gebied wat vir mielieproduksie aangewend word in Suid-Afrika, met GM-mielies beplant.

Suid-Afrika se belangrikste handelsvennote in mielies het uiteenlopende GMO-stelsels en namate die internasionale konvensies en ooreenkomste oor GMO's verder op die voorgrond tree, sal baie van hulle heel waarskynlik hulle huidige standpunte en regulasies wysig. Bo en behalwe hierdie regulatoriese raamwerk, is die houding van verbruikers jeens GM-voedsel ook aan die verander.

Die doel van die studie is om die potensiële impak van GM-mielies op die Suid-Afrikaanse mieliehandel te bereken en te bepaal deur toepassing van die GTAP-model. Dit sal Suid-Afrikaanse beleidmakers van wetenskaplike insette oor verwante regulasies op die plaaslike mark ten opsigte van GM-mielies voorsien en dit kan ook hulle standpunte beïnvloed wat hulle op internasionale konvensies kan inneem. Weens die streeks- en sektorale strekking en die teoretiese meegaandheid daarvan, word die GTAP-model algemeen deur navorsers wat spesialiseer in internasionale handel aanvaar as die toepaslikste middel ter ontleding van die impak van handelsbeleidsbesluite op handelsvloei en nasionale welvaart op wêreldvlak.

Die resultate dui daarop dat die Suid-Afrikaanse beleid om plaaslike produksie van goedgekeurde GM-mielies toe te laat, die land tot voordeel strek. Beleidsmaatreëls wat die land se toegang tot nuwe GM-mielie-gewasse beperk, sal uiteindelik tot nadeel van plaaslike produsente, sowel as mielieverbruikers lei. Die verbruikers se welvaart sal negatief beinvloed word, terwyl die produsente ten opsigte van invoer-mededinging benadeel sal word. Daarom moet kommoditiet-goedkeuring voor algemene vrystelling eerder die uitsondering wees as die reël. Sover dit toekomstige studie oor hierdie onderwerp aangaan om die resultate van hierdie studie verder te verfyn, moet daar veral gepoog word om die veranderings (nasionaal en internasionaal) wat gemaak is om die mieliesektor van ander graansektore af te sonder in the GTAP-model, te verbeter. Daar word ook aanbeveel dat handelsvloei tussen lande soos huidiglik in die GTAP-model ingesluit is deeglik nagegaan behoort te word om die korrektheid daarvan te bepaal. Dit sal 'n deeglike ontleding inhou van die basisdata van die GTAP-model, veral vir lande wat 'n relatiewe klein rol speel in die internasionale handel van landbouprodukte. Indien nagelaat word om dit te doen, kan dit tot foutiewe beleidsaanbevelings lei.

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| | |
|---|---|
| ABE | Agricultural Biotechnology in Europe |
| AFAA | Agrifood Awareness Australia |
| AGE | Applied General Equilibrium |
| ANZ | Australia and New Zealand |
| ARC | Agricultural Research Council |
| Bt | *Bacilllus thuringiensis* |
| CBD | Convention on Biodiversity |
| CES | Constant Elasticity of Substitution |
| CGE | Computable General Equilibrium |
| cif | cost, insurance and freight |
| CPB | Cartagena Protocol on Biosafety |
| DACST | Department of Arts, Culture, Science and Technology |
| DNA | Deoxyribonucleic Acid |
| DTI | Department of Trade and Industry |
| EC | European Council |
| EU | European Union |
| FAO | Food and Agricultural Organisation |
| FGIS | Federal Grain Inspection Service |
| fob | free on board |
| GM | Genetically Modified |
| GMO | Genetically Modified Organism |

| | |
|---|---|
| GTAP | Global Trade Analysis Project |
| IMPACT | International Model for Policy Analysis of Agricultural Commodities and Trade |
| LEI | Landbouw Ekonomisch Instituut |
| LMO | Living Modified Organism |
| NDA | National Department of Agriculture |
| NTB | Non-Tariff Barrier |
| OECD | Organisation for Economic Co-operation and Development |
| R&D | Research and Development |
| SA | South Africa |
| SADC | South African Development Community |
| SAGIS | South African Grain Information Service |
| SIP | Segregation and Identity Preservation |
| SPS | Sanitary and Phytosanitary |
| SSA | Sub-Saharan Africa |
| TBT | Technical Barriers to Trade |
| UN | United Nations |
| USDA | United States Department of Agriculture |
| USFDA | United States Food and Drug Administration |
| US/USA | United States of America |
| WHO | World Health Organisation |
| WTO | World Trade Organisation |

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

During the last century, human life and the quality of living have seen an amazing impact from science and technology. Man has evolved from a hunter and gatherer to modern man whose life is enriched with the knowledge products of information and communication technology, biotechnology and info-space technology (Abdul Kalam, 2002).

According to Dyson (2007), the twentieth century was the century of physics and the twenty-first century will be the century of biology. Biology is now bigger than physics, as measured by the size of budgets, the size of the workforce and the output of major discoveries. Dyson (2007) is of the opinion that biology is also more important than physics, as measured by its economic consequences, its ethical implications, or its effects on human welfare.

Dyson (2007) predicts that the domestication of biotechnology will dominate our lives during the next fifty years at least as much as the domestication of computers has dominated our lives during the previous fifty years.

Thomson (2002) defines biotechnology as the utilisation of biological processes in order to produce products and processes with commercial value. Nef (1998) reports that modern biotechnology, which started in the 1980s, is generally based on molecular biology and the utilisation of genetic engineering principles to produce organisms with new genetic combinations. The United States Food and Drug Administration (USFDA) defines modern biotechnology as the techniques used by scientists to deliberately modify deoxyribonucleic acid (DNA) or the genetic material of a bacterium, plant or animal in order to produce a desired trait (USFDA, 2001). Genetic modification, genetic engineering and bioengineering are synonymous with modern biotechnology. When reviewing modern biotechnology, a number of acronyms are frequently encountered. The most common of these include GM (genetically modified), GE (genetically engineered), GI (genetically improved) and GMO (genetically modified organism) (Vermeulen, 2004). A GMO is an organism that contains a new or altered gene (AfricaBio, 2002).

Since the introduction of crops produced through modern biotechnology in the 1990s, the cultivation of GM crops has become a worldwide phenomenon (ISAAA, 2004). According to literature reviewed by Engel, Frenzel and Miller (2002), there are numerous applications of modern biotechnology including, amongst others, crops with herbicide tolerance; insect resistance; virus, fungi and bacteria resistance; drought resistance; frost tolerance; higher yields; and greater crop stability.

The advent of genetically modified organisms has brought rapid change to world agricultural production and trade. The ability to transfer genes between unrelated species provides a mechanism for the creation of various benefits, as mentioned above, but also raises concerns about the safety and acceptance of the new genetically modified products. The developments of GM technology led to several international agreements and various domestic regulations by countries on GMOs (Gruère, 2006). Examples of these regulations include, amongst others, the Cartagena Protocol on Biosafety (CPB), the Codex Alimentarius, non-tariff barriers (NTBs) to trade linked to the Sanitary and Phytosanitary (SPS) agreement ruling under the World Trade Organisation (WTO), and SA's own GMO act. However, while these agreements and regulations are aimed at the biosafety aspects of GMOs, they may have a distinct impact on international trade in GM products.

Due to the concerns mentioned above, research efforts have shifted towards determining the trade impacts of GMOs. See, for example, three papers by Anderson and Jackson (2004), Huang, Hu, Van Meijl and Van Tongeren (2002), and Stone, Matysek and Dolling (2002), and two papers by Nielsen and Anderson (2000) and Nielsen, Anderson and Robinson (2000). These studies resulted from concerns and uncertainty linked to the safety and acceptance of GMO crops as well as their impact on food security and possible impact on biodiversity.

South Africa (SA) operates in a liberalised trade environment which already impacts on maize trade and the economy through increased global competition. This study focuses on the SA situation by contextualising the SA maize trade within the GM environment.

## 1.2 Problem statement and motivation

SA operates in a liberalised trade environment which means, by definition, the action of making a trade regime less restrictive (Krueger, 1998). This implies that other countries must enjoy improved market access in SA. It also implies the removal of trade-distorting (or trade-limiting) regulations by lowering import tariffs and subsidies or producer support. All of these factors impact on supply and demand internationally.

From a demand point of view, consumers may develop resistance to consuming GM products. Through this, governments might be inclined to increase regulation in order to protect domestic consumers.

On the supply side, the abovementioned factors can influence the extent to which farmers adopt this new technology. GM varieties are developed to achieve higher yields through incurring less damage from insects or to be tolerant to herbicides, which will lower the competition of the plant, also resulting in higher yields. According to Brookes (2002), the yield advantage of GM maize in Spain is between 10 and 15 percent. Gouse *et al.* (2005) found a yield advantage of 11.03 percent and 10.6 percent for GM maize in SA on irrigated farms and dry land, respectively. Other traits which can enhance production that is in the developmental stages include drought resistance. This yield advantage is linked to productivity increases, enabling the adopter of GM crops to reach higher levels of outputs with the same amount of inputs or to stay on the same level of output while needing fewer inputs to produce this level of output. Thus GM technology can increase the global productivity of maize production, and hence supply.

Within the liberalised environment, a regulatory environment linked to the momentum of liberalisation and globalisation operates. This regulatory environment facilitates the process and provides guidelines of future targets involved in liberalisation.

Taking all of the above into consideration, cognisance should also be taken of the fact that SA's main trading partners in maize have differing GMO regimes, and many of them may well change their current stances and regulations as the international conventions and agreements on GMOs further evolve. Over and above this regulatory framework, consumer attitudes to GM foods are also changing.

Policy towards GMOs and the trade thereof in SA should be based on evidence that can predict the best possible outcome of the policy or regime. Jooste *et al*. (2003) had reviewed studies in the international arena on the possible impact of GMO commercialisation (see for example Nielsen and Anderson, 2000; Stone *et al*. 2002; Anderson and Jackson, 2004) and concluded that, apart from some generalisations, no specific conclusions could be drawn from them specific to the SA situation. The result is a lack of policy direction pertaining to GMO trade, in this case with specific emphasis on maize trade. Moreover, current policies might not necessarily be to the best benefit of the maize industry or the country as a whole.

## 1.3 Objectives

The overall objective of the study is to calculate and quantify the potential impacts of GM maize on the SA maize trade. This will provide scientific input to SA policy makers on GM maize related regulations in the domestic market, as well as on their stances in international conventions.

Within this overall objective, the study will specifically address the following objectives:

(a) To investigate and describe the GM regulatory environment;

(b) To investigate and describe the international and domestic situation for GM maize;

(c) To adapt the modelling framework to represent SA circumstances;

(d) To model the potential impact of GM maize production and regulations on the SA maize trade and economy.

## 1.4 Methodology

Many different models and methodologies exist to quantify the impact of different policy changes. Within the context of this study, the Global Trade Analysis Project (GTAP) model is used to quantify the effects of policy measures, technology adoption, productivity increases and Segregation and Identity Preservation (SIP) costs. GTAP is a multi-regional, computable general equilibrium (CGE) model. It is a comparative static model that allows for a base period scenario to which trade "shocks" could be applied to simulate the outcomes of specific trade policy measures. The GTAP model is generally accepted by trade researchers as the most suitable tool to analyse the impact of trade policy decisions on trade flows and national welfare on a global level due to its regional and sectoral coverage as well as its theoretical compliance. The GTAP model not only estimates changes in trade flows due to trade policy decisions but also estimates the effect of such changes on the economic welfare of the community (Jooste, Le Clus, Van Wyk and Van der Walt, 2007). The GTAP model has been widely used over the last number of years to investigate GMO trade mainly due to its suitability to the analysis of international trade within the general equilibrium framework and to provide answers on relative welfare changes (see, for example, Nielsen and Anderson, 2000; Nielsen, Anderson and Robinson, 2000; Huang *et al*. 2002; Stone *et al*. 2002; and Anderson and Jackson, 2004).[1]

The methodology of this study followed 4 steps:

i. Numerous role players in the SA maize industry were interviewed on a wide range of issues in order to understand the complexity and dynamics of GMO issues in the industry. Information gained through interviews is reflected throughout this entire document;

ii. Changes to the applied model for the SA situation;

iii. Projections of the future adoption of GM maize; and

iv. Construction of different scenarios in order to quantify the impacts of GM maize on SA's maize trade and welfare.

## 1.5 Chapter outline

Chapter 2 represents an overview of the international and domestic GM governing environment with specific reference to countries that are important from an SA point of view. Perspective on global and domestic production, consumption and trade in GM and non GM maize is provided in chapter 3. Chapter 4 describes the quantitative approach to determine the trade and welfare impacts of GM maize on SA. The development of the different scenarios and accompanying model results is reported in chapter 5, while chapter 6 concludes with a summary of the findings with conclusions, policy recommendations and recommendations for further studies.

[1] Refer to section 4.2 for a more elaborate description of the GTAP model.

# CHAPTER 2

## THE GM GOVERNING ENVIRONMENT

### 2.1 Introduction

The insertion of foreign genes into plants has raised various questions on the human, animal and environmental safety of these "new" species and caused many countries to adopt stringent regulations on the production and marketing of GM derived food and feed products. Many of these regulations have a definite trade impact. Unlike conventional (non GM) products, GM products are subject to specific import procedures or import bans in many countries, labelling requirements in an increasing number of countries, and even traceability requirements in some countries. These regulations could be abused to protect domestic producers as a new type of NTB.

Kennett (2003) reports that national regulators have responded to GMOs in a variety of ways. On the one hand, the responses may reflect relevant regional and multilateral agreements, while, on the other, they may not. US policy makers are generally in favour of GMOs, while those in Western Europe are against them. Runge, Bagnara, Ford and Jackson (2001) concluded that the difference in approach is historical and cultural. The Europeans take a precautionary approach towards GMOs and treat them as new goods and therefore will not approve GM products for release before they have been proved safe. The US sees GMOs as a natural extension of conventional products. This means that GMOs must simply pass the same safety tests as their conventional counterparts.

This chapter consists of three sections: first, international regulations regarding GMOs are covered; second, the GM regimes of the main maize importing countries, from a SA point of view, are briefly discussed; third, SA domestic regulations regarding GMOs are discussed.

## 2.2 International regulations

It is important to keep in mind the concerns of consumers, producers and environmentalists pertaining to the adoption of GMOs. Consumers are concerned about food security and food safety. Producers are concerned about protectionism and trade issues, while environmentalists are concerned about global biodiversity and the impact that GMOs might have on the environment.

All these concerns led to the need for international regulations on GMOs in order to protect consumers, producers and the environment. For the purposes of this study, no judgement is made regarding GMO safety and biodiversity issues. However, in setting up different scenarios that relate to policy measures with a potential impact on GMO trade, these issues are kept in mind.

Three international organisations are directly involved in setting up harmonised rules, standards and recommendations related to the international trade in GM crops: the Codex Alimentarius, the Cartagena Protocol on Biosafety, and the World Trade Organisation (WTO), all of which have a direct effect on the trade of GM maize (Gruère, 2006).

### 2.2.1 Codex Alimentarius

The Codex Alimentarius is an intergovernmental organisation jointly managed by the United Nations (UN) Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO). Its main purposes are to protect the health of consumers and to promote fair practices in international trade (Kimbrell, 2000). It provides recommendations and standards based on consensus amongst members.

The draft Codex GM food-labelling guidelines were published in May 2002 (ALINORM 03/22, Appendix IV). The draft guidelines cover food and food ingredients obtained through certain techniques of genetic modification. This is defined as ‘food and food ingredients composed of or containing GMOs obtained through modern biotechnology, or food and food ingredients produced from, but not containing GMOs obtained through modern biotechnology' (Van der Walt, 2001).

The guidelines apply to the labelling of food and food ingredients with altered composition, nutrition, intended use or allergens composed of GMOs or containing proteins or DNA from gene technology or that are produced by gene technology but do not contain GM material (Van der Walt, 2001).

While the last point could be extended to include meat from animals fed on GM grain and the numerous foods processed with enzymes produced by GMOs, no examples are provided in the guidance documents to cover these extensions. The examples provided in the text all cover food and food ingredients that are direct products of GMOs. Clarity will need to be obtained while this draft is debated and finalised. In general, the proposals appear to be moving away from detection levels to a system of identify preservation that will determine the GM content or origin of foods regardless of whether or not GM components can be detected in food (Van der Walt, 2001).

To date, the members have failed to reach any agreement on the issue of GM food labelling, which leaves member countries free to institute labelling regulations at their own discretion (Gruère, 2006). Regarding food safety, the Codex Commission reached an official agreement in 2003. There is international consensus on the risk assessment of GM food, and this is similar to existing approval procedures across the major trading countries (Gruère, 2006).

### 2.2.2 Cartagena Protocol on Biosafety

The Cartagena Protocol on Biosafety (CPB) flows from Articles 8(g), 17 and paragraphs 3 and 4 of article 19 of the Convention on Biological Diversity (CBD) and was introduced in January 2000. The Protocol entered into force in September 2003, 90 days after the receipt of the 50th instrument of ratification. By January 2006, 130 instruments of ratification or accession had been deposited with the United Nations Secretary General. SA gave accession in November 2003 (Jooste *et al.* 2007).

The Cartagena Protocol governs the transfer of living GMOs across national borders. The objective of the Protocol is to ensure an adequate level of protection in the field of safe transfer, handling and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity. Human health is also taken into consideration by the protocol (Kennett, 2003).

According to Gruère (2006), the CPB allows importers of LMOs intended to be planted ("released into the environment") in the importing country to request information on the food and environmental risk of GM crops and allows the importing country to ban imports of specific events (i.e. genetic modifications) as a precautionary measure (i.e. for a limited period until a satisfactory risk assessment is provided, although this raises the question of what a fair limited period is). LMOs not intended to be planted but only to be used as food, feed or processing are not subjected to full biosafety procedures as they are not intended to be released into the environment, but importing countries may request information from exporters on the presence and identification of LMOs in every shipment (this raises questions on the degree of detail and on a threshold level for the adventitious presence of LMOs not specified in the information). The members of the BSP have not yet reached agreement on most of the regulations mentioned (Gruère, 2006). A study conducted for the International Food and Agricultural Trade Policy Council (Kalaitzandonakes, 2004) showed that these regulations could impose a substantial cost on exporters and importers of the main GM and non GM crops.

The CPB contains several articles with the potential to impact negatively on international trade in agricultural products as a result of variable interpretations and manipulations. Van der Walt (2001) reports that the Precautionary Principle and the Substantial Equivalence concept have not been clarified sufficiently and mean different things to different people, giving regulators leeway to make decisions in the absence of complete scientific data, which may make the Protocol subject to abuse. Van der Walt (2001) also highlights Article 9 (Acknowledgement of Notification), Article 10 (Decision Procedure), Article 12 (Review of Decisions), Article 18 (Handling, Transport, Packaging and Identification), Article 26 (Socio-economic Considerations) and Article 14 (Compliance), which may be interpreted and manipulated in such a way as to constitute impediments or barriers to international trade.

### 2.2.3 World Trade Organisation

The WTO does not have a mandate on GM food regulations, but the rules of the WTO may be brought into question when GM regulations act as barriers to trade (Gruère, 2006). Also, the WTO trade agreement does not provide well-defined guidance on the regulation of products according to their process and production methods (Josling, Roberts and Orden, 2004). However, two WTO agreements are important regarding the legality of GM food regulations, namely the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and the Agreement on Technical Barriers to Trade (TBT Agreement).

The main objectives of the SPS agreement are to recognise the right of nations to set up their own regimes regarding health and to ensure that these measures are not pointless barriers to trade (Gruère, 2006). This means that WTO members may not ban imports of products they consider hazardous for a long period of time unless they can scientifically prove the hazard or risk associated with the product or provide evidence that they are in the process of gathering this scientific evidence (Gruère, 2006). The SPS agreement would rule in a dispute on the validity of GM food safety regulations (including bans), and the TBT agreement would rule in a dispute on GM food standards and regulations (such as labelling) regarded as more than necessary for safety and potentially trade distortive (Gruère, 2006). If a WTO dispute settlement panel concludes against a particular country on any such issue, the country may decide to change its regulations to comply or decide to maintain its regulations and suffer the consequences of any possible retaliatory measures that may be instituted against it (Jooste *et al.* 2007).

Considerable divergence in the GM rules and regulations of different countries remains. The GMO environment is rapidly changing, and countries are amending their stances and regulations as new developments evolve. An analysis of the impact of GMOs on trade must therefore account for GM regulations in the more important countries and of possible changes therein.

## 2.3 The GM regimes of the main maize importing countries

Trade-related GM food regulations include import-approval measures and marketing regulations (Kennett, 2003). GM regimes could differ quite substantially between different countries. In this section, the important maize-importing countries (from an SA point of view) are discussed briefly.

**Japan** has, to date, approved 21 GM maize events (traits) for animal feed purposes. These include virtually all the events approved for general release in the USA and all the events approved in SA for general release (AGBIOS, 2006).

According to Gruère (2006), Japan introduced regulations regarding the authorisation procedure of GMOs in 2000. During 2001, Japan's mandatory labelling scheme was introduced, while the feed safety assessment became mandatory in 2003.

Gruère (2006) reports that Japan increased the frequency of food safety inspections (from 5%, to 50%) for all maize shipments arriving in the country. For food, there is 0% tolerance[2] for unapproved GM food material. For feed, this tolerance is 1% for GM material unapproved in Japan. Labelling is required for all GM food if DNA can be

[2] Some shipments of food, feed and commodities are allowed to be labeled as "non GM" even though a small amount of GMs might be detected. This amount is referred to as the tolerance level.

detected in the finished product and if the GM ingredient is one of the three main ingredients and accounts for more than 5% of the total weight.

Food processors and retailers in Japan tend to avoid products with GM labels. Many highly processed products that are derived from GM ingredients, such as soy oil, are sold without labels (Gruère, 2006).

The **European Union (EU)** has, to date, approved 8 GM maize events for general release, which include those approved in SA (AGBIOS, 2006). The EU's approach to GMOs is preventative, process related and includes mandatory labelling and traceability requirements. These requirements apply to all food and feed crops whether processed or not. The only exception to the requirements applies to non-food GM products, such as textiles (Gruère, 2006).

Gruère (2006) reports that the European Council adopted a directive regarding the release of GMOs into the environment in 1990. The directive regulated the approval of GM crops and GM food, while no specific labelling regulations were stipulated. In 1997, approval procedures were defined requiring proof that any GM food is safe for human consumption. Labelling of food products containing GM soybeans and GM maize became mandatory in 1998. In 2000, this was extended to apply to all GM food and GM ingredients at a 1% tolerance level. During the same year, the labelling requirements were extended to apply to food ingredients containing GM additives. According to Gruère (2006), the most recent laws regarding GM food came into effect in 2004.

Gruère (2006) reports that, since 2004, all shipments of GM foods and feeds are tested on arrival in the EU. The EU's regulatory system for GM demands mandatory labelling of GM food and food additives and flavouring at the 0.9% tolerance level in the case of GMs that have been approved in the EU. In the case of GMs that have been assessed as safe but have not formally been approved, the threshold for labelling is at the 0.5% level. This applies to animal feed, food sold by caterers, and food derived from GM ingredients. Zero tolerance applies to GM products or ingredients that have not been assessed for safety and have not been approved. The GM material has to be traced from the farm to the consumer. No labelling is required for meat, eggs, milk and other products from animals fed with GM feed. These regulations caused all food processors and retailers to avoid GM ingredients entirely, and it is almost impossible to find food products derived from GMOs in the EU (Gruère, 2006). A study conducted by Knight, Mather, and Holdsworth (2005) concluded that it is unlikely that the positions of retailers and food processors will change unless there is a significant shift in consumer acceptance of GM food in the EU.

In countries like **Brazil** and **China**, labelling regulations target the production process and are mandatory. This means that any product derived from GM crops will have to be labelled, whether it contains any traces of GM material or not. Brazil introduced labelling laws in 2003 (but has yet to actually implement these laws) and China followed with its own laws in 2004 (which are implemented). China provides a list of products that need to be labelled and exemptions apply to anything outside the list. China operates under a 0% tolerance threshold. Brazil's coverage of labelling applies to all food and feed products derived from GM material; this also includes meat and animal products. Brazil has a 1% tolerance threshold level (Gruère, 2006).

**Kenya's** Biosafety Act has not yet been approved by Parliament but the regulations for both seeds and grain are in place (Jaffe, 2006). Imports of GM maize seed are allowed only for research purposes and all tests are conducted in containment. Import documents must state the GM status of the grain or product consignments by the countries where the GM crops are grown. When maize meal and breakfast cereals are considered, GM status must be declared on the import documents and on product labels (Kephis, 2007). All shipments of maize from SA to Kenya have to be tested in SA before shipment.

The biosafety law of **Zambia** has recently been enacted. The new Minister of Agriculture in Zambia is not against GM crops, but the draft Bill was submitted by the previous anti-GM Minister. Zambia is a net exporter of maize seed and realises the potential competitive trade advantage of its maize production (Van der Walt, 2007).

The rest of the **SADC** (South African Development Community) countries, other than SA, apply the SADC policy which is non GM and requires all GM maize imports to be milled in the country of export. These countries do not test shipments on arrival and depend on tests and certification of the exporting countries.

## 2.4 Domestic regulations

SA has a GMO Act which provides for a GMO Executive Council, a GMO Advisory Committee, and various regulations. The Act is administered by the Directorate of Genetic Resources of the National Department of Agriculture (NDA). The Executive Council comprises the chairperson of the Advisory Committee plus a senior representative from each of eight government departments, namely Agriculture, Health, Environment and Tourism, Labour, Science and Technology, Water Affairs and Forestry, Trade and Industry, and Arts and Culture.

The GMO Act is the key biosafety law in SA. The Act regulates the use of GMOs as well as imports and exports of living GMOs. When GMOs are imported or exported (for contained use, field trials or general commercial release), approval must be obtained in the form of a permit issued by the Directorate: Genetic Resources. On application for a permit, the relevant competent authority in the exporting country must declare which GM maize events, if any, have been approved for general release in that country. If any such events have not been approved in SA for general release or commodity approval, the Directorate requires a test from a competent institution that the consignment does not contain any such events. The SA authorities do not test the maize again on arrival in SA despite the fact that imported maize certified as non GM by the exporting country may prove to be GM positive if tested on delivery (Jooste *et al.* 2007).

Three considerations must be taken into account when permits are issued or refused. These are environmental impact, food and feed safety, and socio-economic impact. Decisions regarding the issuing of permits are made by the GMO Executive Council, an inter-ministerial decision-making body. Expert information is provided by scientists within government as well as biosafety assessment data obtained from regulatory authorities in other countries. A representative of the Department of Trade and Industry (DTI) on the Executive Council ensures that the impact on economics and trade is taken into account when decisions regarding the commercialisation of GMOs are made (Jooste *et al.* 2007).

The fact that SA has only one deciding body when it comes to GMOs, namely the GMO Executive Council, can improve the efficiency of the Act. The US, for instance, has three bodies, which complicates decision-making processes (Jooste *et al.* 2007).

The SA GMO Executive Council recently placed a temporary moratorium on the importation of GM events that have not yet been approved for general release or commodity clearance in SA. The moratorium will most likely stay in place until the impact of new events on trade in maize and the benefits to the domestic farmers and consumers are determined. However, given the WTO Dispute Settlement Panel's conclusions in the dispute between the USA, Canada and Argentina on the one hand and the EU[3] on the other, the moratorium is most likely in contravention of the SPS Agreement of the WTO and will thus not indefinitely be sustainable (Jooste *et al.* 2007).

[3] •In 1998, the EU decided to ban the imports of new GM varieties for precautionary reasons while waiting for information on the biosafety of the varieties. In 2003, the USA, Canada and Argentina filed a WTO dispute over this de facto moratorium. The EU had lifted the ban in 2004 and replaced it with more stringent labelling and traceability regulations. Six EU member countries (Austria, France, Germany, Greece, Italy and Luxemburg), however, maintained the moratorium on maize and rapeseed varieties. On 7 February 2006, the Dispute Settlement Panel eventually sent its findings in a confidential report to the four countries involved for their evaluation and rejoinders. The final report of nearly 1100 pages was released to the general public on 29 September 2006. The Panel concluded that the EU had indeed applied a general de facto moratorium on a number of rapeseed, sugar beet, fodder beet, maize and cotton varieties and that the moratorium was inconsistent with the EU's obligations in terms of the SPS Agreement. The Panel also concluded that the ban by the six member countries on a number of maize and rapeseed varieties was not consistent with the safeguard measures provided for in the SPS Agreement. In the light of these conclusions, the Panel recommended that the Dispute Settlement Body request the European Communities to bring the relevant member State safeguard measures into conformity with its obligations under the SPS Agreement (Gruère, 2006).

## 2.5 Conclusion

This chapter provided more information regarding the international and domestic GM regimes. It can be concluded from this chapter that there are stringent rules and regulations regarding GMOs worldwide. It is also important to know the GM regimes of all of SA's maize trading partners because the developments in the GM regimes of the countries involved can have a definitive impact on the trade of maize. The underlying issue of the debate regarding GMOs is food security on the one hand versus food safety on the other.

# CHAPTER 3

## PERSPECTIVE ON GLOBAL AND DOMESTIC GM MAIZE

### 3.1 Introduction

This chapter provides global and domestic perspective on GM maize. Firstly, global GM crop production is discussed. Second, the focus shifts towards global production, yield, consumption and ending stocks of maize. Third, the focus falls on the SA cultivation of GM crops, especially GM maize. Next, the domestic production, yield, consumption and ending stocks of SA maize are discussed. Last, more information regarding the trade in maize from a SA perspective is discussed. The difficulties linked to the procurement of non GM maize from global exporters are also focused on.

### 3.2 Global cultivation of GM crops

According to James (2006), GM crops were grown by 10.3 million farmers in 22 countries and covered a global area of 102 million hectares in 2006 (Figure 3.1). The increase from 2005 was 12 million hectares or 13%. James (2006) indicates that 2006 marked the first year of the second decade of the commercialisation of GM crops and that the global GM crop area has increased more than sixty-fold since 1996. The 22 countries that grow GM crops include 11 developing countries and 11 industrial countries.

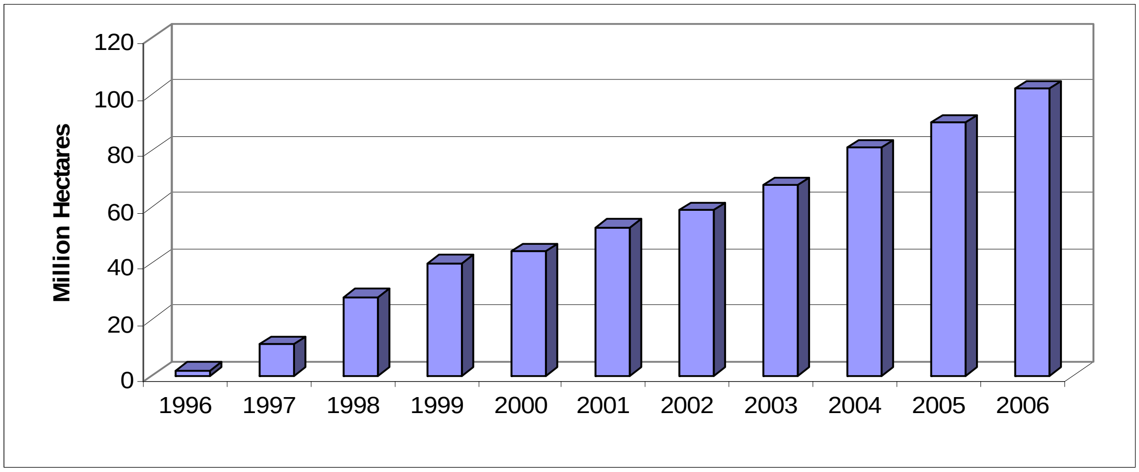


Figure 3.1: The global area under GM crops for the period 1996 to 2006

Source: James, 2006

During 2006, the USA was still the country with the largest area planted with GM crops, namely 54.6 million hectares, followed by Argentina and Brazil. SA is currently ranked number eight, with a total GM crop hectarage of 1.4 million hectares (this constitutes a 180% increase over 2005), while India has moved up to the 5th position (Figure 3.2).

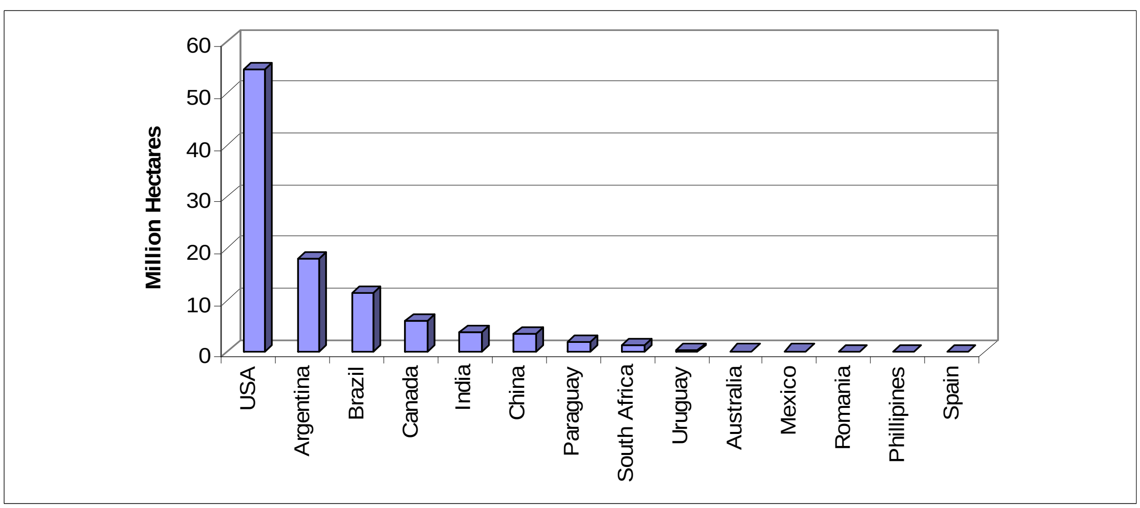


Figure 3.2: Cultivation of GM crops in countries planting 50 000 hectares or more during 2006

Source: James, 2006

James (2006) reports that the global area of GM crops is dominated by soybeans, using 57% of the total area planted to GM crops (Figure 3.3). Soybeans are followed by maize, cotton and canola, using 25%, 13% and 5% of the global GM crop area, respectively.

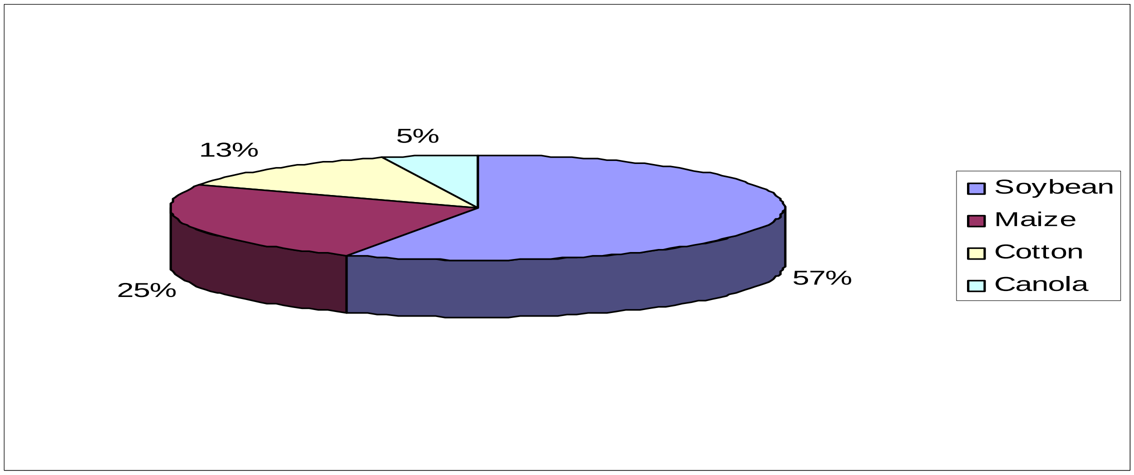


Figure 3.3: The distribution of the global GM area among the commercially grown GM crops

Source: James, 2006

## 3.3 Global supply and demand of maize

Figure 3.4 shows production, consumption, ending stocks and yield of global maize since 1996. The figure shows how declining world ending stocks of maize are caused by the fact that since 1995, the world consumption of maize has increased by 36%, while world production only increased by 34%. Yield only increased by 23% for the same period of time. If production of maize continues to be smaller than consumption, ending stocks will diminish.

James (2006) reports that GM maize already occupies 17% of the 148 million hectares cultivated with maize globally. This constitutes a 19% increase in area over 2005 resulting in 5 consecutive years with significant growth of GM maize globally. Most of the increase during 2006 occurred in 5 countries: the USA, with an increase of 2.5

million hectares, SA, with 0.9 million hectares, Argentina, with 240 000 hectares, the Philippines, with 125 000 hectares, and Canada, with 70 000 hectares. The major increases are driven by high popularity in the stacked trait events. Single trait GM maize showed smaller increases even though insect resistant maize still occupies the top position in hectarage, occupying 11.1 million hectares in 2006; stacked traits occupy 9 million hectares; and last, herbicide-tolerant maize occupies 5 million hectares globally.

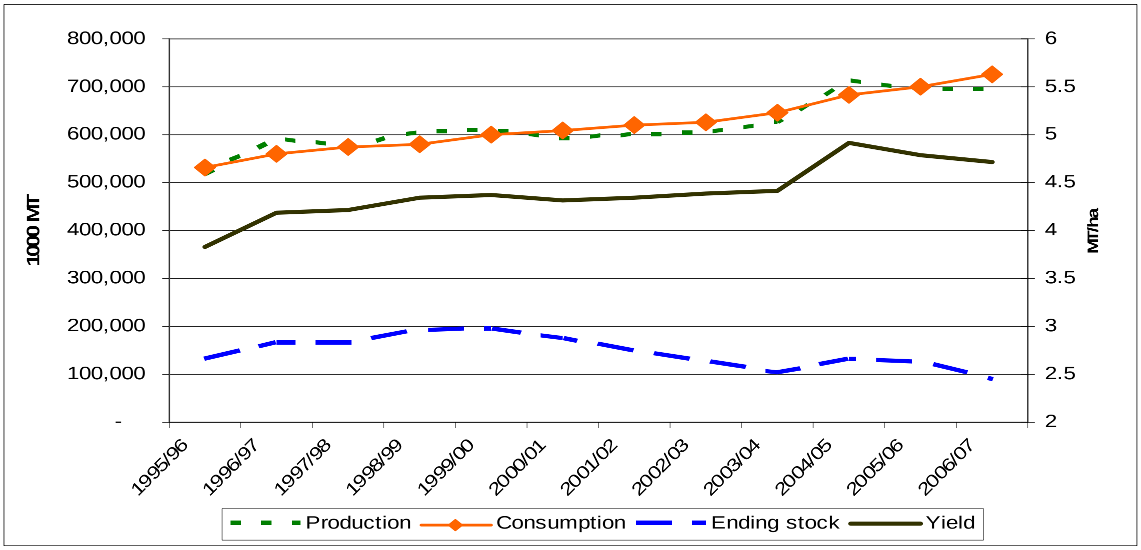


Figure 3.4: The world production, consumption, yield and ending stocks of maize since 1995

Source: USDA, 2007

Table A1 in appendix A shows the world exporters of maize in 2005. A total of 89 935 255 tons of maize was exported in 2005 The US has the biggest market share in world maize exports (44%), followed by France, Argentina and China with respective market shares of 13%, 12% and 9%. Hungary, Ukraine and SA each contribute 2% to world maize exports.

Table A2 in appendix A shows the world importers of maize for 2005. During 2005, a total of 88 901 494 tons of maize were imported globally. Japan is the biggest importer of maize with 19% of all maize imports, followed by Korea with 9%. Taiwan, Mexico and Spain each represent 5% of maize imports.

Due to high GM maize adoption rates in the major maize exporters in the world, it becomes increasingly difficult and costly to procure non GM maize internationally. James (2006) reports that the current adoption rates of GM maize in Argentina and the USA are 66% and 61%, respectively. To date, China has not commercially planted any GM maize. This could result in changes in the current GM regimes of countries, which may become less stringent due to the increasingly difficult procedures and higher cost of procuring non GM maize.

The **USA**'s Federal Grain Inspection Service (FGIS) is no longer prepared to issue non GM certificates. Exporters have to rely on private testing institutions and accept the risk that the maize may be tested positive and rejected by the importing countries.

It is as difficult to procure non GM maize from **Argentina** due to its high adoption rate of GM maize. The advent of silo bags alleviates the problem somewhat by ensuring segregation from GM maize, but the risk of contamination during transport and shipping still remains.

**China** is at this stage probably the largest supplier of non GM maize to the world market. **Brazil** can also supply non GM maize, but much of the maize planted there is GM seed brought in from Argentina. **France** also exports some non GM maize.

## 3.4 SA cultivation of GM crops

James (2006) mentions that the 1.4 million hectares of GM crops grown in SA are distributed as follows: GM maize covers 87% of this area, followed by soybeans and cotton covering 12% and 1% of this area, respectively (Figure 3.5).

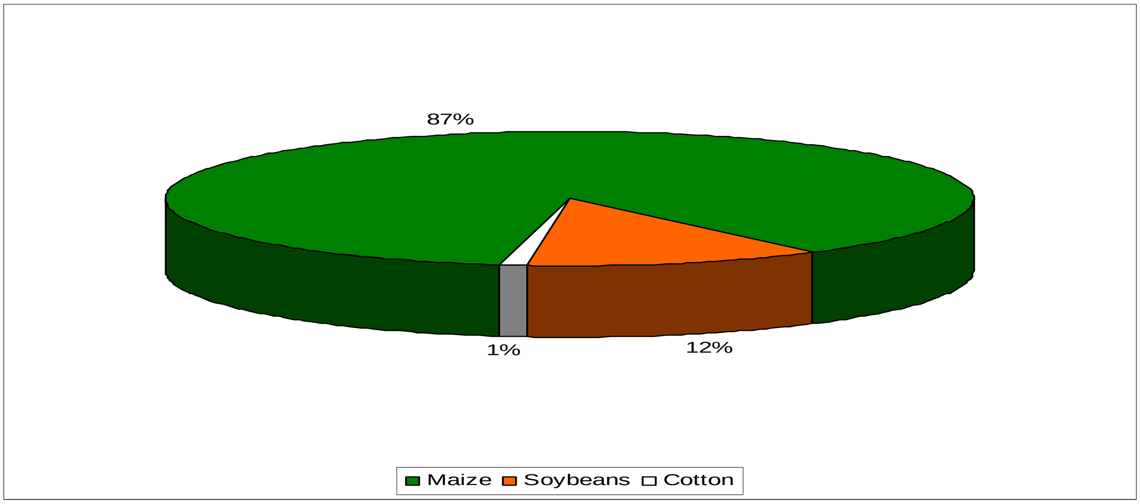


Figure 3.5: The distribution of the SA GM area among commercially grown GM crops

Source: James, 2006

James (2006) reports that 92% of the area planted with cotton in SA in 2006 was GM, followed by 75% GM adoption in the soybean hectarage and 46% adoption of the maize hectarage (Figure 3.6).

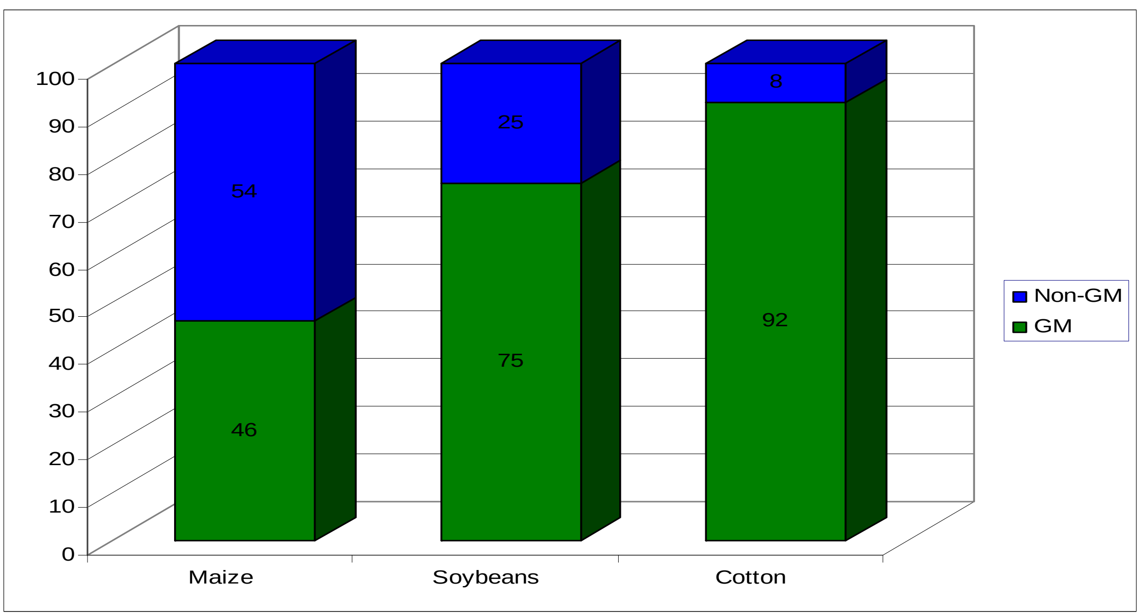


Figure 3.6: The adoption rates of GM crops in SA in 2006

Source: James, 2006

### 3.5 Domestic maize production

Figure 3.7 shows the instability of SA's maize production and yield. Since 2005, maize ending stocks have been on the decrease due to lower yields and the fact that consumption is greater than local production. During the 2006/2007 production season, 2.6 million ha was utilised for maize production. Dry land production is the practice for 93% of this area, while maize under irrigation only amounts to 7%. The instability of maize production and yield can mostly be attributed to below-average rainfall in the maize production areas, since only 7% of the SA maize area is irrigated.

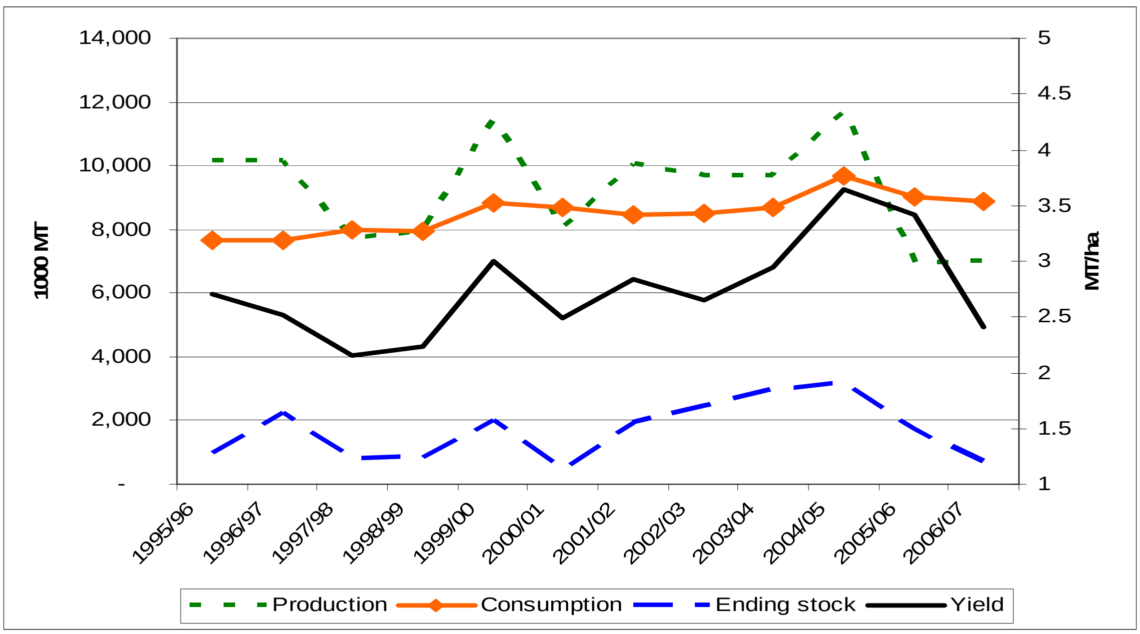


Figure 3.7: SA production, consumption, yield and ending stocks of maize since 1995
Source: USDA, 2007

Maize yield in SA is much lower than in countries like the USA and China, while SA's maize yield is also significantly lower than the world average (Figure 3.8).

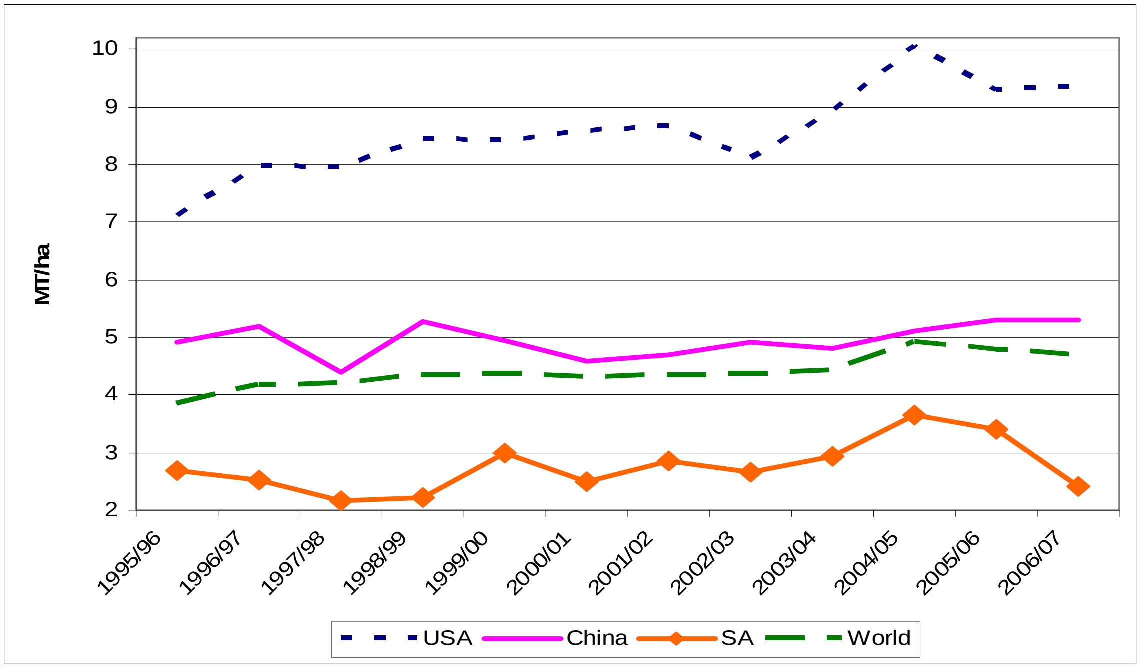


Figure 3.8: The World, USA, China and SA yield of maize since 1995

Source: USDA, 2007

Van der Walt (2006) reports that the adoption rates[4] of GM white and yellow maize in SA are 44% and 50%, respectively. This amounts to 1.2 million hectares of GM maize planted in SA during 2006. Insect-resistant traits dominate this area with 77%, with 23% being herbicide tolerant. Figure 3.9 shows the adoption rate of SA GM maize since 2000. It is evident that since 2003, the adoption of SA GM maize has grown at an increasing rate.

[4] The adoption rate refers to the percentage of the total area that is planted with GM crops

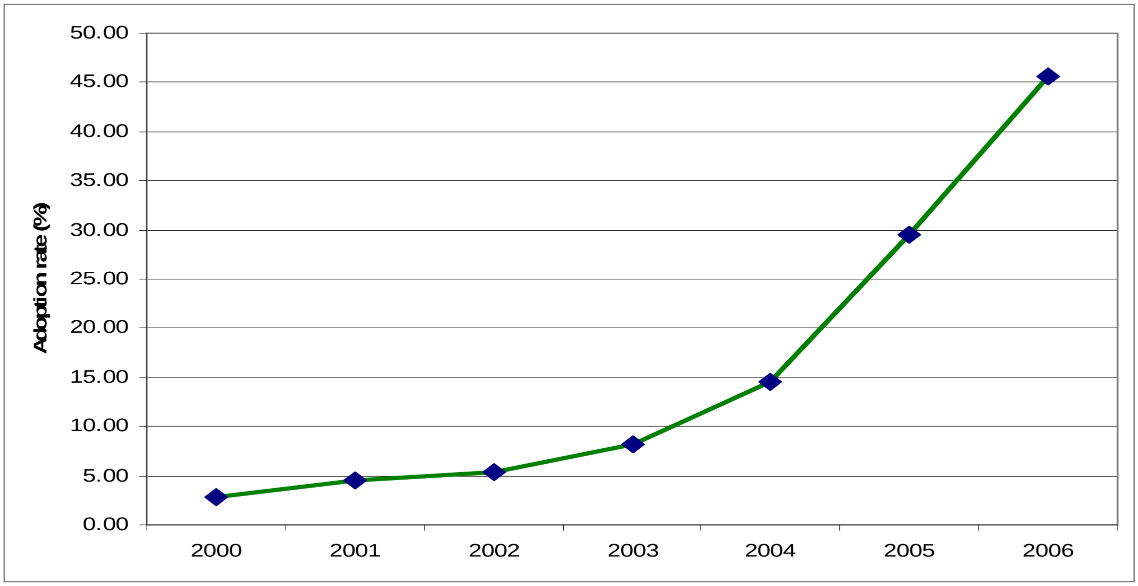


Figure 3.9: The adoption rate of SA GM maize since 2000

Source: Van der Walt, 2007

To date, four GM maize events have been approved for general release and another seven events have been approved for commodity clearance (See Appendix B for a full list of events). The next-in-line GM maize event from the USA controls rootworm. Rootworm is not a significant pest in SA. Currently, it is uncertain to what extent Argentina will adopt this event. Should Argentina fully adopt this event while it is not approved for commodity clearance[5], imports of maize from Argentina could drop significantly. Further investigation into this matter may be necessary but falls beyond the scope of this study.

New GM maize developments that may be released during the next 10 years include, amongst others, drought-tolerant traits. Drought-tolerant events will undoubtedly have a huge commercial impact in SA and could lead to virtually 100% adoption by farmers.

[5] If a GM event has commodity clearance, it means that it may be used but not planted.

### 3.6 Domestic maize consumption

The consumption of maize in SA shows a slow but steady increase since 1995 (see Figure 3.7). Since 2005, consumption of maize in SA has been greater than production, leading to depletion in maize ending stocks even though imports have drastically increased in the 2006/2007 production year (see Table 3.1). White maize in SA is usually consumed by humans, and yellow maize is utilised in animal feeds. According to SAGIS (2006), the ratio between animal and human consumption of maize in SA is 48% and 52%, respectively. Thus 48% of maize consumption in SA is exposed (sensitive) to the debate around the safety of GMOs because concerns focus on human GMO consumption.

The demand for non GM maize in SA is relatively small, namely about 780 000 tons of white maize for the starch and beer industries and 140 000 tons for the cereal food industry. The bulk of demand for white maize products (maize meal and stamp) and the feed demand for maize is not GM sensitive.

### 3.7 SA maize imports

Table 3.1 shows the countries of origin of SA maize imports, and it is evident that Argentina is the main source of SA maize imports. No maize was imported from the USA during the last two marketing years.

**Table 3.1: SA maize imports since 2003**

| | **2003/2004** | **2004/2005** | **2005/2006** | **2006/2007** |
|---|---|---|---|---|
| **Country** | **Metric tonnes** | | | |
| Argentina | 387,924 | 205,856 | 360,542 | 915,142 |
| China | 8,158 | - | - | - |
| USA | 41,294 | 15,508 | - | - |
| Malawi | - | 724 | - | - |
| **Total** | **437,376** | **222,088** | **360,542** | **915,142** |

Source: SAGIS, 2007

Figure 3.10 shows the competitiveness of suppliers of maize to SA. Maize imports by SA have declined at an annual rate of 15% during the period of 2001 to 2005. During the same period, total world exports of maize increased by more than 7% annually.

Figure 3.10 also shows that both the US and Argentina have positive growth in maize exports to the world, while only Argentina shows positive growth in maize exports to SA during the period of 2001 to 2005, which means that Argentina is gaining in a declining market. The US has a declining market share in SA but still a growing market share in world maize exports.

It must be noted that the area of the circles in figure 3.10 corresponds to the share in world exports of supplying markets for maize.

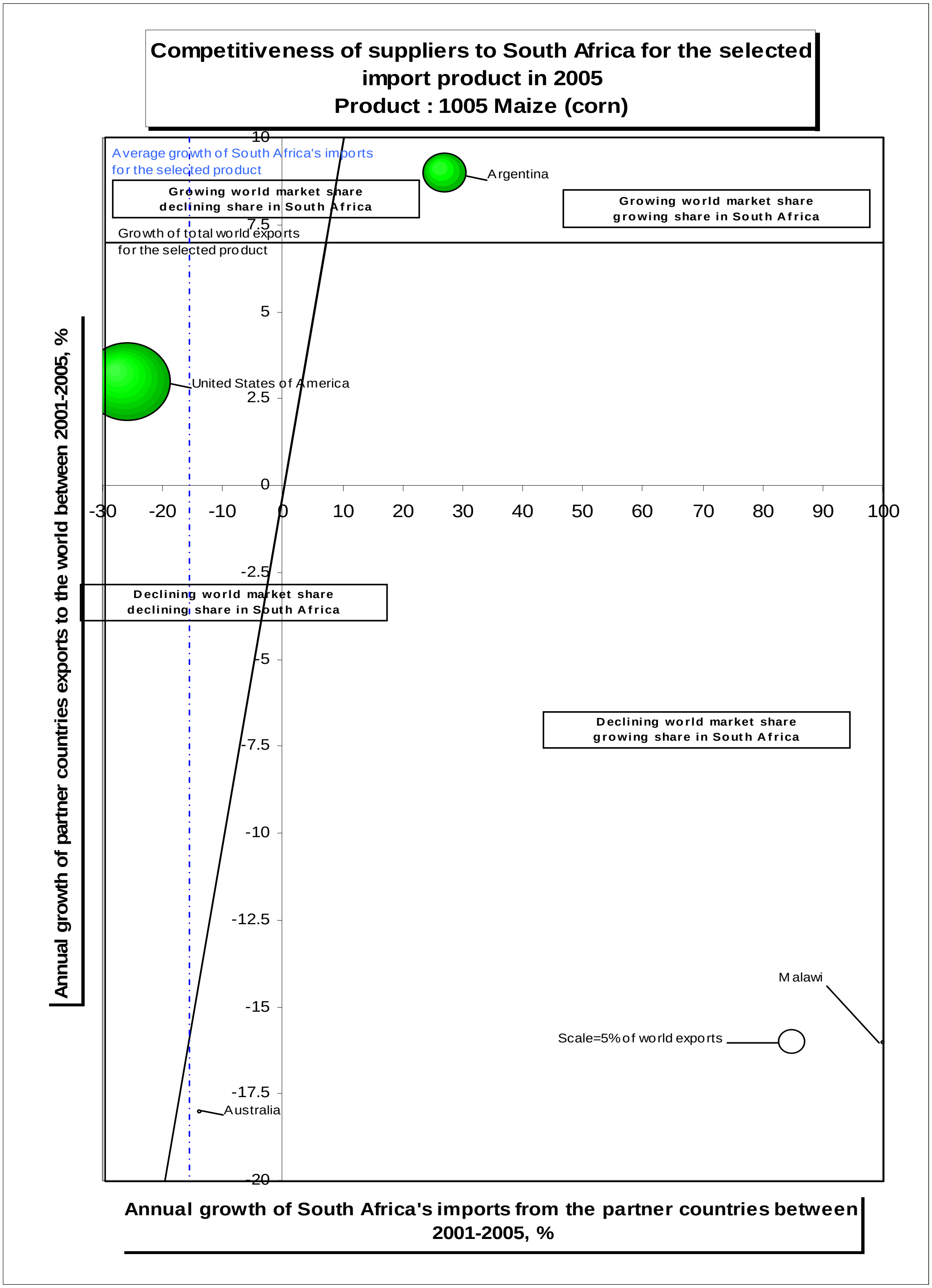


Figure 3.10: Competitiveness of suppliers to SA for maize imports in 2005

Source: ITC calculations based on COMTRADE statistics, (2007)

Total GM maize imported by SA during 2004 for the purpose of being used as a commodity was 623 460 tons. During 2005, no imports for this purpose were recorded. The amount of GM maize imported for planting purposes in 2004 was much higher than in 2005. The imports for this purpose in 2004 and 2005 were 302 tons and 24 tons, respectively. GM maize imports for seed production, planting trials and contained use in 2004 amounted to 0.35 tons, 503 tons and 0.11 tons, respectively. During 2005, imports for seed production were only 5 tons (Jooste *et al.* 2007).

For the period of January to December 2006, a total of 121 permits were granted for the importation of maize shipments (commodity clearance) that do or may contain GM. All of these commodity imports originated from Argentina and amounted to a total volume of 1.261 million tons. GM maize seed imported for planting purposes, mostly from the USA, amounted to 18 tons, and 66 permits were issued. GM maize seed imported for contained use amounted to 4.02 tons (Jooste *et al.* 2007).

### 3.9 SA maize exports

Table 3.2 shows the countries of destination of SA maize exports. Most of SA's maize exports are destined for the SACU countries and Zimbabwe, which form part of the bigger group of SADC countries. The highest exports since 2003 resulted in the 2005/2006 marketing year, being 2 137 420 tons, while 2006/2007 maize exports only amounted to 538 795 tons.

SA's main export customers do not permit the importation of GM maize, and maize exports to these countries have to be non GM certified. The cost of segregating and identity-preserving (SIP) non GM maize is increasing as farmers continue to adopt GM maize.

**Table 3.2: SA maize exports since 2003**

| | 2003/2004 | 2004/2005 | 2005/2006 | 2006/2007 |
|---|---|---|---|---|
| **Country** | **Metric Tonnes** | | | |
| **Zimbabwe** | 413,657 | 210,335 | 1,045,470 | 111,663 |
| **Botswana** | 141,515 | 120,888 | 196,452 | 128,856 |
| **Lesotho** | 130,002 | 118,782 | 86,694 | 76,029 |
| **Mozambique** | 90,189 | 53,884 | 150,161 | 43,637 |
| **Namibia** | 121,769 | 56,573 | 71,217 | 66,679 |
| **Swaziland** | 55,294 | 46,402 | 61,295 | 67,191 |
| **Kenya** | 48,150 | 129,451 | 40,038 | 2,792 |
| **Japan** | 10,374 | - | 113,098 | - |
| **Zambia** | 6,829 | - | 89,559 | 35 |
| **Iran** | - | - | 93,284 | |
| **Malawi** | - | - | 68,563 | 159 |
| **Angola** | 14,834 | 34,181 | 14,366 | 3,742 |
| **Indonesia** | - | - | 49,500 | |
| **Tanzania** | 34,781 | - | - | - |
| **Cape Verde** | 28,840 | - | - | - |
| **Mexico** | - | - | - | 27,410 |
| **Sudan** | - | - | 28,272 | - |
| **Dar-es-Salaam** | - | - | 10,000 | 9,289 |
| **Madagascar** | 12,381 | 2,382 | 967 | 1,033 |
| **Ghana** | - | - | 7,638 | - |
| **Somalia** | - | - | 3,158 | - |
| **Cameroon** | - | - | 3,001 | - |
| **Senegal** | 2,600 | - | - | - |
| **Benin** | - | - | 2,278 | - |
| **Mali** | - | - | 2,258 | - |
| **Mauritius** | 1,333 | - | - | - |
| **Congo** | 225 | 216 | - | 280 |
| **Chad** | - | - | 151 | - |
| **Comores** | 15 | - | - | - |
| **Total** | **1,112,788** | **773,094** | **2,137,420** | **538,795** |

Source: SAGIS, 2007

Figure 3.11 shows the growth in maize exports from SA. In countries like Kenya, Ghana and the United Kingdom, the demand for maize from SA is growing at a faster rate than world trade in general; SA has been able to outperform world market growth and increase its share in world exports in these two markets. Exports to these countries can therefore be seen as gains in dynamic markets.

The demand for exports of SA maize in countries like Japan and Malawi can be classified as losses in dynamic markets. This means that these markets present particular challenges for trade promotion. While international demand has been growing at above average rates, SA exports have declined or have grown less dynamically in these countries.

In countries like Tanzania and Indonesia, the growth in demand for SA maize can be seen as gains in declining markets. This means that SA is increasing its market share in countries where import growth has been declining.

The demand for exports of SA maize in countries like the Democratic Republic of the Congo and Turkey tends to be bleak. World imports of maize in these markets have increased at a below average rate and SA's market share has decreased. This can be classified as losses in declining markets.

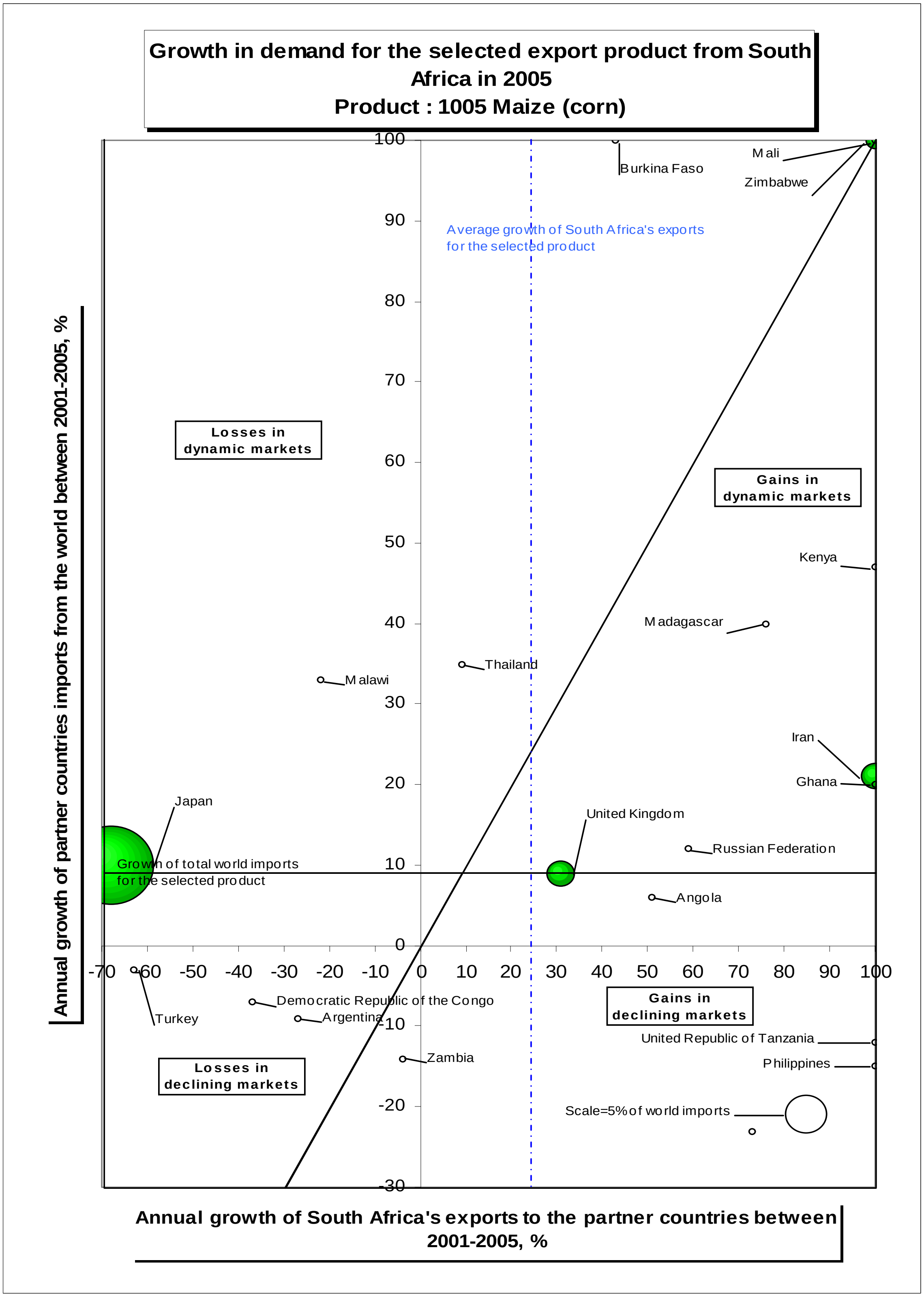


Figure 3.11: Growth in the demand for maize exports from SA in 2005

Source: ITC calculations based on COMTRADE statistics, (2007)

Only one permit for GM maize exports for the purpose of commodity export was issued in 2005 and none in 2004. This amounted to 90 000 tons, and the foreign receiver was Japan. In 2004, 11 permits were issued for the export of GMO maize for the purpose of research, which amounted to 0.51 tons. In 2005, no permits were issued for this purpose. In both 2004 and 2005, only one permit was issued for the export of GMO maize for the purpose of planting trials. In both cases, the foreign receiver was the Philippines. In 2004 and 2005, this was 0.0005 and 0.5 tons respectively. SA exports for the purpose of contained use during 2004 and 2005 amounted to 14 tons and 321 tons respectively, and for the purpose of planting, it amounted to 650 tons and 1 100 tons, respectively.

During 2006, no commodity-cleared GM maize exports occurred from SA. 27 permits were issued to allow GM maize seed to be exported for contained use in the countries of destination. This amounted to 518 kg, of which the majority was destined for the USA. Maize seed exported for the purposes of planting obtained 12 permits in 2006. This amounted to 1 232 tons destined for Asia.

## 3.11 Conclusion

This chapter provided perspectives regarding the importance of GM maize globally and domestically. Globally, 19% of the area planted with maize is GM. Domestically, GM maize constitutes 46% of SA's area cultivated with maize. The adoption rate of GM maize is on the increase worldwide.

Japan and Korea are the major importers of maize worldwide, while the US, France, Argentina and China represent the major exporters. SA's maize imports mostly come from Argentina, while SA's exports are destined for SADC countries and Japan.

# CHAPTER 4

## QUANTITATIVE APPROACH TO DETERMINE TRADE IMPACTS

### 4.1 Introduction

Achieving the objectives of this study lies partly in qualitative deductions, but primarily from modelling different policy measures and demand and supply responses. This chapter provides a background regarding applied models used in the international trade of agricultural products. A literature review of similar studies that apply the GTAP model is provided. The third part of this chapter describes the GTAP model, which is also the applied model for this study, and the changes made to the database in order to best reflect the SA situation regarding maize trade. A projection of the future adoption of GM maize follows the modelling background and framework. Last, the incorporation of assumptions applying to this study is discussed.

### 4.2 Modelling framework

Many different models and methodologies exist to quantify the impact of different policy changes. Van Tongeren and Van Meijl (1999) conducted a study to review applied models used in the international trade of agricultural products. Two main groups of models exist; the difference arises from the representation of national economies. In this sense, it is either a partial model or an economy-wide model.

Partial models usually treat the international market for a specific set of traded goods. The specific set of goods is considered as being closed in the sense that no linkages exist with the rest of the economy. Economy-wide models provide a complete representation of national economies, accompanied by specifications regarding trade relations between economies (Van Tongeren and Van Meijl 1999). Economy-wide models are generally called applied general equilibrium (AGE) models.

Examples of partial models include, amongst others, the AGLINK model of the Organisation for Economic Co-operation and Development (OECD) and the FAPRI model of Iowa State University. Examples of economy-wide models include, amongst others, the GTAP model of Purdue University and the RUNS model of the OECD. For the purposes of this study, partial models are ruled out because the objective of the study is to determine the trade and welfare implications of different policy measures from different countries on SA trade and welfare. Thus, this study requires an economy-wide, global model which is highly disaggregated.

According to Van Tongeren and Van Meijl (1999), when choosing a model, a few important specifications and modeling issues should be kept in mind. The model can be either dynamic or comparative static. Dynamic models allow the analysis of delayed transmissions and adjustment processes over time. Comparative static models study two different equilibriums (without providing information of the time path between the equilibriums) resulting from different assumptions regarding exogenous variables. The second specification to keep in mind involves how the model treats imported *versus* domestic goods. Imported and domestic goods can either be seen as perfect substitutes (homogeneous) or imperfect substitutes (heterogeneous, according to the Armington (1969) assumption). Third, sufficient representation of policy instruments (e.g. tariffs and quotas) is necessary in applied trade models. Last, and perhaps most important, the data requirements and parameter specification of the model should be considered. Data requirements for multi-regional models of international trade can be very demanding. The amount of data required is determined by the amount of sectors and commodities, and whether the goods are homogeneous or heterogeneous. Highly disaggregated models that apply the Armington (1969) assumption are therefore demanding in terms of data requirements.

According to Piermartini and Teh (2005), exercises in the quantification of the effects of policies on economic outcomes have been made possible by advances in theory and analytical techniques and, perhaps more importantly, by the drastically increased computational and data processing power of computers. This also led to the name of computable general equilibrium (CGE) models.

Piermartini and Teh (2005) state that a CGE model is an AGE model which uses the power of today's computers to compute numerically what the present economy will look like in the future as a result of a specified set of policy changes. A CGE model preserves the optimising assumptions and links between markets that are the distinguishing features of AGE models. The big attraction of analysts towards CGE models is that they arrive at numerically precise answers while ensuring that the results are theoretically consistent. Shoven and Whalley (1992) report that disaggregated CGE models provide results with respect to costs and benefits for various economic agents, which is usually not feasible with empirical macroeconomic models.

Within the context of this study, a CGE model named the Global Trade Analysis Project (GTAP) model is used to quantify the effects of policy measures, technology adoption, productivity increases and SIP costs. The GTAP model is generally accepted by trade researchers as the most suitable tool to analyse the impact of trade policy decisions on trade flows and national welfare on a global level due to its regional and sectoral coverage as well as its theoretical compliance. The GTAP model has been widely used over the last number of years mainly due to its suitability to analyse international trade within the general equilibrium framework and to provide answers on relative welfare changes (see, for example, Nielsen and Anderson (2000), Huang, Hu, Van Meijl and Van Tongeren (2002), Stone, Matysek and Dolling, (2002) and Anderson and Jackson (2004)).

## 4.3 Relevant studies using GTAP

As mentioned various studies have used the GTAP model to estimate the effects of GMOs on trade and welfare, namely, three papers by Anderson and Jackson (2004); Huang, *et al*. (2002), and Stone, *et al*. (2002), and two papers by Nielsen and Anderson (2000), and Nielsen, Anderson and Robinson (2000).

From the studies, numerous assumptions were employed by the researchers. The assumptions were found to be common to all the abovementioned studies. The assumptions included, amongst others, the following:

- In order to reflect yield advantages of GM crops over conventional crops, an output-augmenting productivity shock of 7.5% was applied to GM coarse grains.
- GM crops were split from conventional crops simply by applying adoption rates of the different countries at the time of the study.
- Most of the studies assumed trade flows to be correct after the split of GM and conventional crops and/or do not report any effort to correct the trade flows.
- In most cases, SIP costs were not included because they were implicitly introduced by conservative cost savings due to the new technology. Another way of introducing SIP costs was to introduce negative augmenting technology shocks.
- Elasticities of substitution between GM and non GM varieties of each product in regions where consumers are GM averse are set at low levels to capture the perceived low degree of substitutability.
- In most cases where consumer awareness was involved, a 25% reduction in demand for GMOs was introduced.

One can postulate, from the studies reviewed, that GM crops can increase the welfare of a country which in turn depends on its major trading partners' stances towards GMOs as well as those of consumers locally and globally. The welfare increases are due to yield advantages, which imply that while GMs need fewer inputs to produce the same amount of output, shifts in the allocation of resources may occur. This can also have a positive effect on the welfare of a nation if resources are shifted to more productive economic activities. The studies also showed that even if a country does not produce GM crops, it can increase the welfare of consumers if it allows the imports of GM products. On the other hand, a country's welfare may decrease alongside a ban of imports of GM products.

The global acceptance of GMOs will have a big impact on the further adoption and possible advantages linked to this new technology. (See Appendix C for a summary of relevant studies reviewed.)

## 4.4 The GTAP model

GTAP is a multi-regional, computable general equilibrium (CGE) model that was developed in 1996 by Prof. Hertel at the University of Purdue in collaboration with the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) in Australia. It is a comparative static model that allows for a base period scenario to which trade "shocks" could be applied to simulate the outcomes of specific trade policy measures. The model describes both the vertical and horizontal linkages between all product markets both within the model's individual countries and regions as well as between countries and regions via their bilateral trade flows (Hertel, 1997). The model's database is regularly updated, and the latest version of the model, Version 6, consists of 87 regions with 57 sectors[6] of economic activity based on 2001 data. The economics of consumers, producers and government are modelled according to neoclassical economic theory. This entails the following general assumptions:

- Perfect competition
- Full employment
- Constant returns to scale
- Imported and domestic goods are imperfect substitutes

[6] See Appendix D, Table D1 for a list of the GTAP regions and the participating countries of composite regions, and Table D2 for a list and description of the GTAP sectors.

Figure 4.1 provides a graphical exposition of the basic structure of the GTAP model and presents the basic value flows for one region in the model. Government intervention in the form of taxes and subsidies is omitted to keep the structure basic. At the top of Figure 4.1 is the regional household, which has a fixed endowment of primary factors of production (land, labour and capital). Without the income from government intervention (taxes), the only other source of income for the regional household lies in the selling of the factors of production to producers/firms, which yields factor payments in return. The regional household has an aggregate utility function which distributes regional income across the categories of private expenditure, government expenditure and savings. The formulation of a regional household in CGE modelling provides a clear indicator for overall regional welfare (Hertel, 1997 and Lotze, 1998)

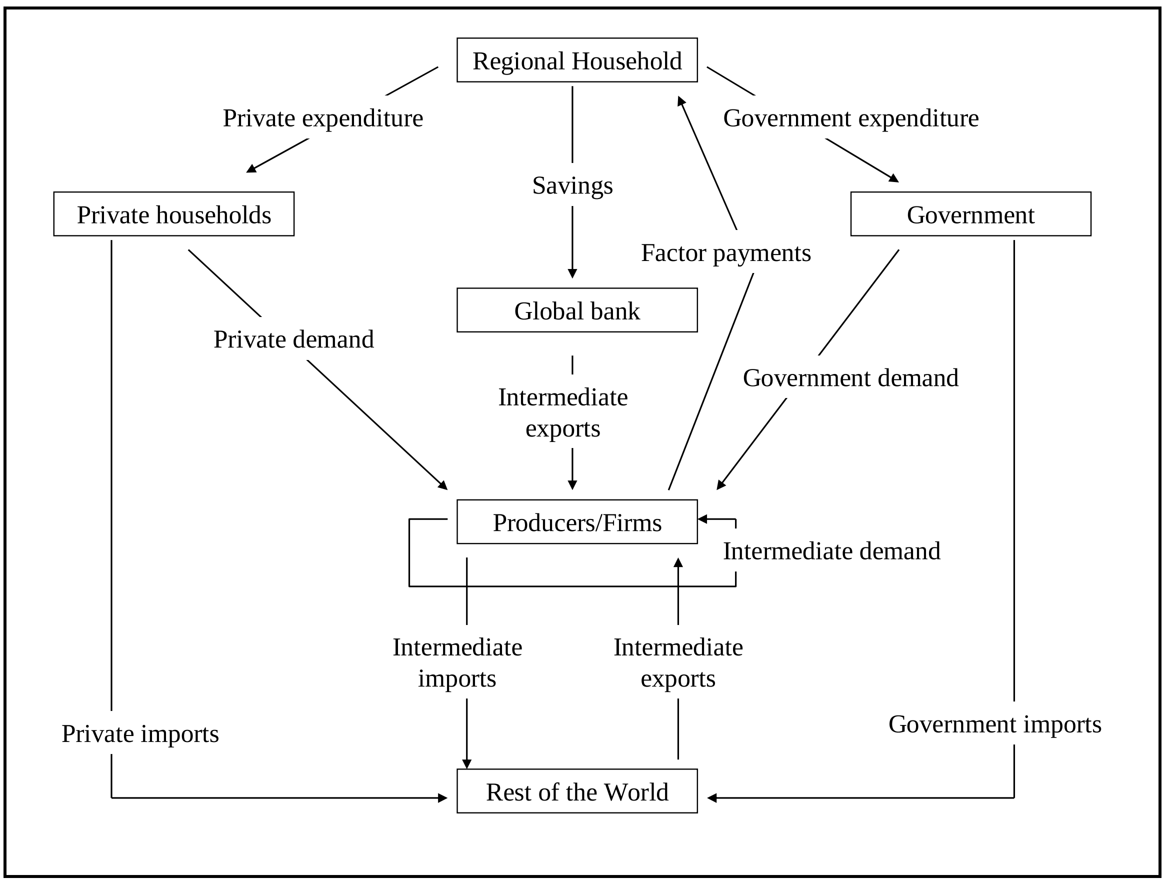


Figure 4.1: Graphical exposition of the GTAP model without government intervention
Source: Adapted from Brockmeier (1996)

Private households spend their income on domestic and imported goods. The government also needs domestic and imported goods in order to produce public goods and government services. Producers/firms use a combination of primary and intermediate inputs to meet the final demand of government and private households. The intermediate inputs that the firms/producers use can either be domestic or imported, and the producers also provide export commodities to the rest of the world. The rest of the world can be disaggregated into various regions structured in the same way as the region in Figure 4.1. Bilateral exports and imports are differentiated by destination and source region. Also, imports are divided between specific domestic user groups (private households, governments and firms/producers). This is important for the analysis of trade policy issues (Hertel, 1997 and Lotze, 1998).

Two global sectors can be observed in Figure 4.1. The first is the global bank and the second the global transportation sector. The global bank balances regional savings and investments and provides the macroeconomic closure of the model. In addition to final commodities, producers also supply artificial investment goods. The global bank collects investment goods and distributes them to regional households in order to satisfy the savings demand of households. The global transportation sector accounts for the differences between "free on board" (fob) export values and "cost, insurance and freight" (cif) import values in international trade on a global scale (Hertel, 1997 and Lotze, 1998).

On the production side, the model assumes that all markets operate under conditions of perfect competition, which allows resource allocation decisions to be analysed using the constant elasticity of substitution (CES)[7] and Leontief[8] production functions because of constant returns to scale (refer to Figure 4.2). Each commodity is produced by a distinct sector using intermediate inputs sourced domestically and from all over the world. The model uses the Armington assumption, which states that imported and domestic

[7] The CES production function combines two or more inputs into an aggregate quantity. The CES function is a function where the curvature of the function is variable at each point of the function, which means that the elasticity of substitution stays constant (De la Grandville, 1996)

[8] The Leontief production function is a special case of the CES function and implies that factors of production are used in fixed proportions and there is no substitutability between the factors (De la Grandville, 1996).

intermediate goods are assumed to be imperfect substitutes. Armington intermediate composites are then used in fixed proportions with a value-added composite CES nesting of primary factors (land, capital and labour) to produce final outputs (Stone *et al*. 2002).

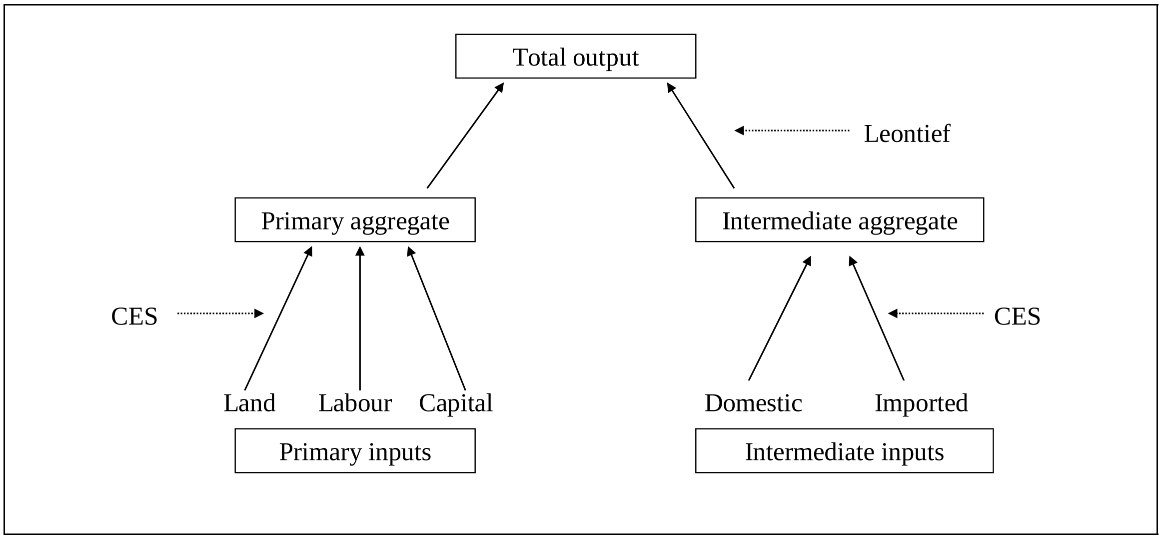


Figure 4.2: Production structure in the GTAP model
Source: Adapted from Hertel (1997)

Stone *et al.* (2002) mention that (within production, capital formation and trade) prices reflect perfect competition. Thus, sellers earn no pure profits, and costs determine revenues. The assumption of constant returns to scale in production is noteworthy because it implies that the percentage change in the price of any commodity will equal the weighted sum of the percentage changes in the prices of the inputs.

On the demand side, the model has three sectors: private households, government, and savings. At the macro level, a variable share of regional income consists of household and government consumption and net savings in each region. Households are assumed to consume a CES composite of domestic and imported commodities. Also, income and price elasticities of demand are specified for each region, potentially allowing for detailed representation of demand conditions (Hertel, 1997).

Within trade, Armington elasticities are defined as regionally standard across all agents, which means that import demand equations differ only according to their import shares

(Stone *et al.* 2002). Careful definition of imports and exports categorised by agent is important where import intensities of the same commodity differ greatly across uses, because it allows trade payments to be traced to specific sectors of the economy like private households, government or firms (Brockmeier, 1996).

The GTAP model not only estimates changes in trade flows due to trade policy decisions but also estimates the effect of such changes on the economic welfare of the community. Welfare in economic modelling refers in general terms to the (regional) income and the purchasing power of that level of income. There are many possible indexes that can be constructed to provide an understanding of welfare changes. Examples of such indexes are equivalent and compensating variations, equivalent and compensating surplus, and consumer and producer surplus. This matter was discussed already in 1939 by Hicks and later by Bonn (1984). More recently, modellers prefer to use Equivalent Variation (EV) to measure welfare. This is also the case for the GTAP model where economic welfare is derived from the allocation of regional income between private consumption, government consumption and savings.

To define EV is to ask "*how much money would have to be taken away from the consumer before a price change to leave him as well off as he would be after the price change*" (GTAP short course notes, 2006). In other words, EV can be defined as the tool which measures the maximum amount of income the consumer is willing to pay to avoid the price change.

The GTAP modelling framework also allows for the decomposition of welfare (see, for example, Hanslow (2000), Huff and Hertel (2001) and McDougall (2001)). The welfare decomposition in GTAP subdivides EV into the following components, which all contribute to the overall measure of welfare:

- Technical efficiency contributions
- Allocative efficiency contributions
- Terms of trade contributions

- Investment-savings contributions

**Technical efficiency contributions** result from changes in the use of available inputs in production. For example, output can be augmented due to new technology available for production or increased labour productivity. Most of the variables used to calculate the technical efficient contributions are exogenous in the model and can thus be "shocked" to augment or suppress technical change. Further decomposition of all the different contributions that add up to the total technical efficiency contribution can be found in Huff and Hertel (2001).

**Allocative efficiency contributions** arise from the reallocation of existing resources, for example, moving labour from the food sector to a more productive sector.

Welfare may change as a result of more/less favourable prices of exports or imports of a region due to trade policy reforms or changes in supply and demand conditions. This is called the **Terms of Trade (TOT) contributions** to welfare (GTAP short course notes, 2006).

**Investment-savings contributions** comprise two factors that influence the investment – savings balance in a country. These factors are (i) the percentage change in the price of capital goods and (ii) the percentage change in the price of savings. Both of these variables have a negative effect on the EV if they increase.

## 4.5 Changes to the GTAP model for the SA situation

The appropriateness of the model's results depends on the accuracy of its database. In order to best reflect the SA trade in maize, the database had to be adjusted as the database primarily focuses on the trade situations of the major countries. First, the regions and sectors in the model were aggregated to 22 and 17 respectively to make it more manageable.

Since the model classifies maize together with various other grains (barley, rye, oats, sorghum, millet and some other minor grains) in a sector called "Cereal grains not elsewhere classified" (sector 3 in appendix D), this sector had to be disaggregated into "maize" and "other cereal grains". This was done according to the relative share of maize production in the "Cereal grains not elsewhere classified" sector of each of the 22 aggregated regions in the model. Appendix E shows the regional production shares of maize as part of total cereals. These production shares were used to split the initial sector.

However, the adjusted model produced maize trade flows that were inconsistent with actual flows in the base period, and this necessitated further corrections to the database. In this regard, though, it must be realised that these corrections apply only to the SA situation (regarding import and export shares of maize only) and that the information in the database of other countries with whom SA may trade but who are also relatively minor in terms of world trade may well be incorrect and thus produce distorted images of their trade flows with SA.

## 4.6 Projecting the future adoption of GM maize

For the purposes of this study, it was decided to project the future adoption of GM maize. This was done to provide a more scientific basis for the assumption on adoption rates in an effort to quantify what the future impact of adoption might be. This does not make GTAP a dynamic model but simply enables the researcher to compare the possible future implications of GM maize with current impacts.

Aker *et al.* (2005) state that adoption commonly refers to an individual's decision whether to use a new technology and to what extent. The aggregate of a country's individual decisions gives the adoption rate of a country regarding a certain new technology. For the purposes of this study, it is vitally important to consider the GM maize adoption rates of SA and its trading partners. More important might be how the adoption rates of these countries will look in five years time.

Theoretical models that focus on adoption usually lead to an S-shaped adoption model over time (Aker *et al.,* 2005). This means that when a new technology is introduced, the adoption will initially be slow, followed by a period of fast growth, after which growth will flatten as the amount of new adopters decreases. The adoption rate cannot be higher than 100%, which means that everyone has adopted the technology.

For the purposes of this study, it is important to assess at which adoption rate SA might reach its ceiling of fast adoption. Expert opinion (surveys of numerous role-players) in SA suggests that the ceiling of adoption of GM maize in SA might be around 70 percent; this could change considerably when drought tolerant varieties are introduced, when the adoption rate could reach 100 percent.

With expert opinion in mind and the knowledge that new technology follows an S-shape of adoption over time, different models were fitted to the data. These included linear, quadratic and polynomial models. The only model that provided a turning point before 100 percent and corresponds to the actual trend was a fourth order polynomial with a 99.9 percent positive fit. Figure 4.3 shows the projection of future adoption (when applying a fourth order polynomial to the data) and provides for a turning point (slower adoption growth) just below 75 percent when SA's GM maize is considered. This will also be reflected in the assumptions of further scenarios.

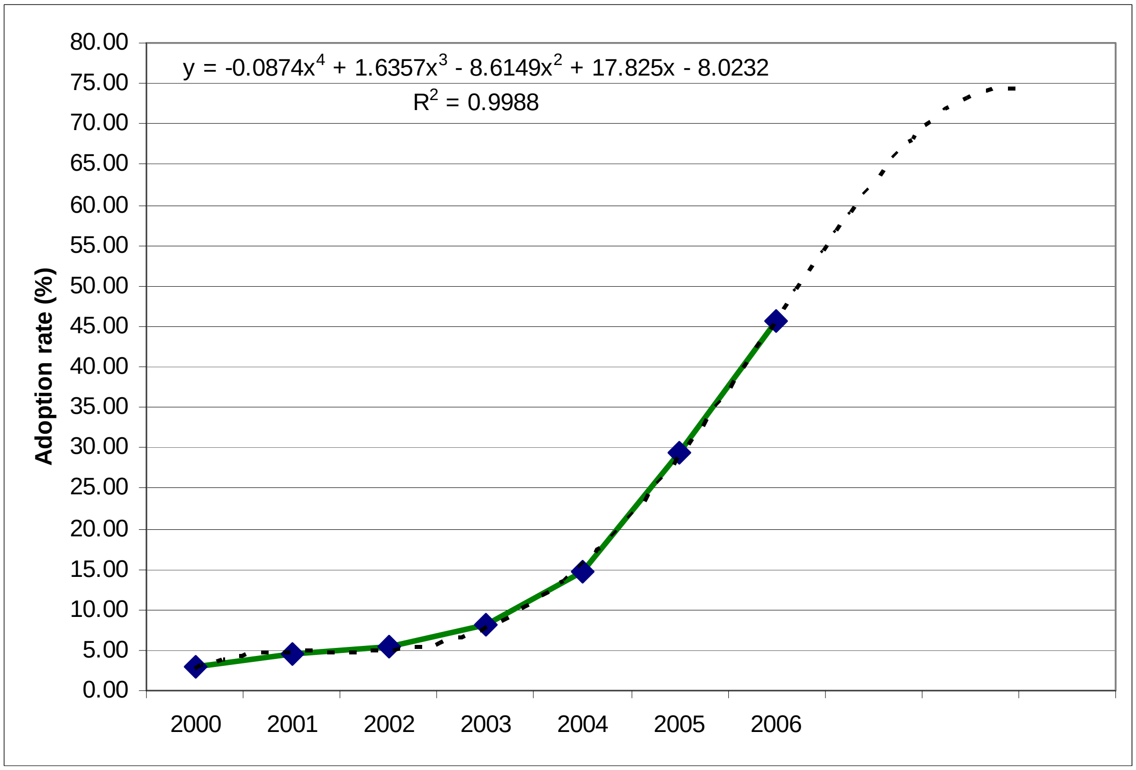


Figure 4.3: Projecting the future adoption of SA GM maize

Argentinean adoption of GM maize has followed a linear path since the introduction of GM maize to Argentina in 1999. Currently, the adoption of GM maize in Argentina is at 66%. The US adoption of GM maize started slowly, then declined in 2001 because farmers believed that the infestation of insects would be low that year (James, 2006). After 2001, the adoption of GM maize in the US recovered and is currently in the fast growing stage of adoption, having reached 61% in 2006.

When a fourth order polynomial is fitted to US data, it shows that the US has currently reached its ceiling. The reason that the model shows such a low ceiling is the aforementioned decline in adoption in 2001, which was a significant downward trend in the time series. Thus, it can be expected that the US will still maintain growth in adoption and reach a higher ceiling of adoption.

## 4.7 Important assumptions of this study

Adoption rates of GM maize are specified for each scenario and country or region involved. The adoption rates are based on the status quo and abovementioned projections and expert opinion.

As mentioned in chapter 1.2, there is scientific evidence that GM maize bears a yield advantage over non GM varieties. For the purposes of this study, a 10 percent yield advantage is employed for the GM part of total maize production. For example, if the adoption rate in a country is 60 percent GM, that country receives a 6 percent yield advantage. In order to model the yield advantage, an output-augmenting technology shock applied to the GM maize part in each adopting country.

SIP costs apply to the non GM maize[9] part of SA maize. The non GM maize SIP costs are specified for each scenario and are based on the results of the survey of the role players. In order to model the SIP costs, a negative productivity shock applies to services delivered to the non GM maize part of total maize production. This negative productivity shock increases the cost of services delivered and thus reflects SIP costs.

## 4.8 Conclusion

This chapter provided a background on agricultural trade modelling and focused on the applied GTAP model. The GTAP database had to be amended to better represent the SA maize trade situation. The future adoption of GM maize in SA was projected and showed that the ceiling of adoption can be around 75%.

[9] SIP costs involve keeping the non GM maize separate from the GM maize. The cost is borne by the non GM part of maize due to the fact that it is most likely to be the part of the maize that will fetch a premium for being non GM. Also with future adoption it will become the smaller part of maize in SA.

# CHAPTER 5

## SCENARIO DEVELOPMENT AND RESULTS

### 5.1 Introduction

This chapter consists of two major parts, namely scenario development and the model results of the developed scenarios. The scenario development explains the underlying assumptions of each scenario. The results are discussed in terms of national welfare and prices, trade, output and consumption of SA maize. The secondary agricultural effects of GM maize are also provided.

### 5.2 Scenario development

#### 5.2.1 Scenario 1 – The baseline

This scenario was developed to estimate the extent to which the GM maize regulations and developments to date (2001-2006) have advantaged or disadvantaged the SA maize industry and the country as a whole. It simulates the current world GM maize situation with the USA and Argentina planting 61% and 66% respectively of their maize areas to GM varieties, while SA plants 46% of its maize area to GM varieties. It was assumed that GM maize cultivars generally have a 10% yield advantage over non GM cultivars in all of these countries. The baseline scenario provides for SIP costs of R40 per ton which apply to non GM maize in SA. This scenario therefore serves as the basis against which the impact of various new policy measures should be compared.

### 5.2.2 Scenario 2 - Continued adoption

This scenario was developed to show the future advantages or disadvantages of the adoption of GM maize. New varieties are accepted and SA reaches its ceiling of GM maize adoption at 70%[10]. Producers in the USA and Argentina continue to expand their areas under GM maize (both to 80% of the total area planted with maize), and producers in China and Brazil started to adopt GM maize varieties (to 40% and 25% respectively, of the total area planted with maize). Due to the higher adoption rate in SA, it becomes increasingly difficult to segregate and identity preserve non GM maize in SA. Thus scenario 2 provides for SIP costs of R 100 per ton which apply to non GM maize in SA.

### 5.2.3 Scenario 3 – SA consumers reject GM maize

In this scenario, all human consumers of maize in SA demand non GM maize, while the animal feed demand for maize stays GM. This means that the adoption of GM white maize in SA theoretically becomes zero, while yellow maize continues on the path of adoption. According to SAGIS (2006), the ratio between animal and human consumption of maize in SA is 48% and 52%, respectively. Thus, in this scenario, it is assumed that total GM maize adoption is 48% in SA. The USA, Argentina, China and Brazil stay on their higher respective adoption rates for GM maize, which is the same as in Scenario 2. SIP costs in this scenario amount to R40 per ton for non GM maize in SA due to the lower adoption rate compared to the previous scenario.

[10] The expert opinion of role players in SA suggested a 70% ceiling of adoption and the projections of this study showed a 75% ceiling. Thus not to overestimate the advantages linked to the planting of GM maize, thus study incorporates the lower ceiling of 70%.

### 5.2.4 Scenario 4 – SA bans importation of all GM maize

In this scenario, the question was what the advantages/disadvantages will be if SA decides to impose a ban on the importation of GM maize while still permitting the domestic production of the GM events at the same adoption level as in Scenario 2. The USA, Argentina, China and Brazil stay on their higher respective adoption rates for GM maize, which are the same as in Scenario 2. Scenario 4 provides for SIP costs of R 100 per ton which apply to non GM maize in SA.

### 5.2.5 Scenario 5 - SA bans maize imports from the USA

In this scenario, it was assumed that the importation of GM maize from Argentina and China continues to be allowed, but all imports from the USA are banned. The adoption rates of GM maize are the same as in Scenario 2. Scenario 5 provides for SIP costs of R 100 per ton which apply to non GM maize in SA.

### 5.2.6 Scenario 6 - SA stops the further approval of GM events for domestic planting

In this scenario, it was tested what the effect would be if SA decided not to approve any further GM events for general release but continued to give commodity clearance to new GM events. It was assumed that this would cause the domestic adoption of GM maize varieties to stagnate at the current 46% level, while the producers in the USA, Argentina, China and Brazil would continue to adopt at the same levels as in Scenario 2. SIP costs in this scenario amount to R40 per ton for non GM maize in SA.

### 5.2.7 Scenario 7 - General domestic acceptance of GM maize in SA

Domestic companies that are biased towards GM maize accept that consumers have fully accepted GM maize. Thus, the current 600 000 tons of domestic non GM demand fall away. Non GM maize is grown under contract only for export demand. Thus SA can further adopt GM maize in this scenario. The adoption rate of SA, in this scenario, increases to 90%, while the adoption rates of the other trading partners remain the same as in Scenario 2. SIP costs for the non GM part of maize production in SA are assumed to be R 100 per ton. All the non GM maize will at this stage be stored in silo bags.

## 5.3 Results

The results will be reported in terms of national welfare (see table 5.1 and 5.2), prices, trade, output and consumption of the SA maize industry (see table 5.2). Changes in production and trade in selected secondary agricultural sectors will also be provided (see table 5.2).

It is important to note that when the results refer to welfare changes, the whole SA economy (all the sectors of economic activity) is involved to provide information regarding national welfare in US $ millions. The other variables refer to the SA maize industry or the selected secondary agricultural sectors.

**Table 5.1: Welfare decomposition of the different scenarios**

| | **US$ Million** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Scenarios** | | | | | | |
| **Welfare (EV) effects** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| Allocative efficiency | 0.34 | 0.50 | 0.34 | -4.81 | -0.29 | 0.22 | 2.51 |
| Technical efficiency | 16.05 | 23.62 | 17.91 | -31.46 | 8.76 | 16.03 | 54.20 |
| Terms of trade | -3.82 | -5.75 | -4.37 | 1.61 | -3.07 | -3.99 | -10.62 |
| Investment-Saving | -1.14 | -1.56 | -1.38 | -0.44 | -1.27 | -1.32 | -1.98 |
| Total EV | 11.42 | 16.82 | 12.50 | -35.10 | 4.13 | 10.94 | 44.10 |
| **Difference in EV from Scenario 1** | **0.00** | **5.40** | **1.08** | **-46.53** | **-7.29** | **-0.49** | **32.68** |

The data for Scenario 1 is the change from 2001 (the model's base year) until 2006 (the present situation). The data for the other scenarios show possible changes from the present situation. Note that when the results are interpreted, the underlying assumption is that all other factors, except the specific scenario, remain constant.

### 5.3.1 Scenario 1 – The Baseline

SA has had notable benefits from GM maize developments to date. The country has had a net welfare benefit of US$ 11.42 million. SA's welfare increase arises entirely from technical efficiency (increased productivity) in the maize sector due to the adoption of GM maize. The increased productivity of the maize sector releases resources previously employed for maize production. These can now be employed to increase the output of other sectors of economic activity. The welfare increase could be considerably higher if not for the SIP costs of R40 per ton that apply to the non GM (54%) part of SA maize production. TOT also shows a slight decrease and can be explained by the fact that the import parity maize price decreased by a greater margin than the export parity maize price.

The domestic production of maize is 0.09% lower than it otherwise would have been. This can be linked to the result of maize imports that are 5.92% higher while exports are 1.41% lower and the consumption of domestically produced maize basically remained constant. (Please note in this regard that the model does not calculate the change in the total domestic consumption of maize; however, the change in imports and exports, together with the change in the consumption of domestic maize give an indication thereof). GM developments have had a decreasing effect on the domestic maize price as well as the export parity maize price of 2.79%.

Secondary agriculture effects are minor. Scenario 1 results in increases in production and exports of the sectors alongside a decrease in imports. This is all linked to higher productivity in the maize sector and the lower price of maize.

In this scenario, the main implication is that GM developments to date have caused an increase in imports of maize by SA. This is due to a decrease of 7.12% in the import parity price. The decrease in the import parity price is due to the higher adoption rates of the USA and Argentina compared to that of SA. Thus, those countries enjoy the yield advantage on a bigger share of their maize production than SA. This makes their maize production more competitive.

### 5.3.2 Scenario 2 – Continued adoption

If SA continues the projected path of adoption and reaches its ceiling of 70% adoption of GM maize alongside the increased adoption rates of the USA and Argentina and the advent of adoption in China, SA could enjoy a further welfare increase of US$ 5.4 million. The welfare increase, as in Scenario 1, can entirely be ascribed to increased technical efficiency, again slightly offset by the R100 per ton SIP cost which now applies to 30% of SA's maize production. In this scenario, the TOT is still decreasing the overall welfare increase because the import parity maize price decreases by a further 1.23% over the initial decrease of 7.12% in scenario 1 and the domestic maize price decreases by 1.33%. Thus, the total decrease in the import parity maize price is still larger than the total decrease in SA's maize price, which leads to the deterioration in the TOT.

Domestic production of maize will increase by 0.13% and consumption of domestically produced maize will increase by 0.11%. Maize imports into SA will decrease by 0.83%, while exports of SA maize will increase by 0.27%.

The secondary agriculture effects again show increased production and exports alongside decreased imports.

### 5.3.3 Scenario 3 – SA consumers reject GM maize

If the food market in SA demands non GM maize, the adoption rate of GM maize in SA is effectively 48%. In this scenario, SA could enjoy a small further increase in welfare (over the welfare increase in scenario 1) of US$ 1.08 million. It is notable that 52% of SA's maize undergoes SIP costs of R40 per ton.

Compared to scenario 1, two changes came about. SA's adoption increased from 46% to 48%, leading to higher welfare, again due to technical efficiency. The other difference is continued adoption by the USA, Argentina, China and Brazil. Scenario 3 shows how the competitiveness of SA's maize production decreases relative to the other adopters. This can be explained by a decrease in maize exports (1.39%) from SA alongside an increase in maize imports (0.36%). Also, the export parity maize price decreases by a smaller margin compared to the import parity maize price (0.32% compared to 1.22%). The decrease in competitiveness is also explained by the decrease in the TOT of US$ 4.37 million.

### 5.3.4 Scenario 4 – SA bans importation of all GM maize

If SA bans the importation of all GM maize while the adoption rates of Scenario 2 apply, the country could see a considerable loss of welfare amounting to US$ 46.53 million. The biggest decrease in welfare arises from a decrease in technical efficiency due to the import ban, which lowers the availability of maize as an intermediate input in other sectors of economic activity. This loss in welfare is augmented by the SIP costs of R100 per ton which apply to 30% of SA's maize production.

The domestic production of maize increases by 6.91%, while the consumption of domestically produced maize increases by 8.52%. Domestic and export parity maize prices increase by 1.56%. Maize exports from SA decrease by 4.36%, while imports decrease by 100%.

Within secondary agriculture, one can observe the opposite in scenarios 1 and 2. Both production and exports decrease, while imports increase. This can be linked to the fact that there is not enough maize in SA to supply the non GM maize demand. Thus, there is not enough maize for animal feeds. That is why production decreases and imports increase.

From this scenario, it is important to note how the import ban forced SA to produce more maize to fill the gap between demand and supply. The increase in the domestic price of maize is far less than expected. This is due to the assumption that domestic and imported maize are imperfect substitutes. Also, imports of maize into SA in the GTAP database are minor relative to domestic production of maize.

Scenario 4 turned out to be the worst-case scenario (for this study) in terms of SA when welfare and maize trade are considered.

### 5.3.5 Scenario 5 – SA bans maize imports from the USA

If SA bans the imports of maize from only the USA, a loss in welfare of US$ 7.29 million could occur. This is because the USA contributes a minor share towards total SA maize imports. The loss in welfare compared to Scenario 1 is solely due to increased SIP costs of R100 per ton which apply to 30% of SA's maize production

Domestic maize production decreases by 0.51%. Maize imports and exports decrease by 1.34% and 3.57% respectively. The domestic maize price increases by 1.04% and the import parity maize price decreases by 1.22%.

The secondary agricultural effects are small and follow the same trend as in scenario 3.

### 5.3.6 Scenario 6 - SA stops the further approval of GM events for domestic planting

If SA's adoption of GM maize stagnates at 46% while the USA, Argentina and China adopts at the same level as Scenario 2, SA could experience a slight welfare loss of US$ 0.49 million. The only significant change is a decrease in SA's maize exports and an increase in imports due to the decrease in the import parity maize price of 1.16%. This again can be linked to higher competitiveness of the other adopters, who enjoy a yield advantage on a higher share of their maize production compared to SA.

### 5.3.7 Scenario 7 - General domestic acceptance of GM maize in SA

If the domestic companies that demand non GM maize accept that consumers have fully accepted GM maize and the adoption rate of SA increases to a level of 90%, a significant increase in welfare of US$ 32.68 million can occur in SA. This is linked to increased technical efficiency and the fact that the SIP costs of R100 per ton only apply to 10% of SA's maize production.

Under the circumstances of this scenario, the competitiveness of the SA maize industry increases considerably due to the higher share of maize production that receives a yield advantage of 10%. This is highlighted by the increase in maize exports (by 8.73%) caused by a decrease in the export parity and domestic price (by 6.05%). Also, imports decreased by 6.42% even though the import parity price of maize decreased (by 1.23%).

The secondary agriculture affects are the same as in scenarios 1 and 2. The effects are just slightly augmented.

Scenario 7 turned out to be the best-case scenario (for this study) in terms of SA when welfare and maize trade are considered.

## 5.4 Conclusion

This chapter consisted of two parts namely: (i) The development of 7 different “what if” scenarios linked to different domestic or international policy measures, (ii) The results of the scenarios were discussed in terms of national welfare, maize industry effects and secondary agricultural effects.

The results showed that scenario 4, where the importation of all GM maize was banned by SA, turned out to be the worst case scenario for the purposes of this study, while scenario 7, where general acceptance of GM maize in SA prevails, turned out to be the best case scenario in this study.

**Table 5.2: The welfare and industry effects of the different scenarios**

| | Scenarios | | | | | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **SA** | **US $ Million** | | | | | | |
| Total Welfare | 11.42 | | | | | | |
| Change from Scenario 1 | 0 | 5.40 | 1.08 | -46.53 | -7.29 | -0.49 | 32.68 |
| **SA maize** | **% change from database** | **% change from Scenario 1** | | | | | |
| Domestic maize production | -0.09 | 0.13 | -0.17 | 6.91 | -0.51 | -0.21 | 1.60 |
| Consumption of domestic maize | 0.10 | 0.11 | 0.00 | 8.52 | -0.07 | -0.02 | 0.58 |
| SA maize exports | -1.41 | 0.27 | -1.39 | -4.36 | -3.57 | -1.56 | 8.73 |
| SA maize imports | 5.92 | -0.83 | 0.36 | -100.00 | -1.34 | 0.67 | -6.42 |
| Domestic maize price | -2.79 | -1.33 | -0.32 | 1.56 | 1.04 | -0.02 | -6.05 |
| Export parity maize price | -2.79 | -1.33 | -0.32 | 1.56 | 1.04 | -0.02 | -6.05 |
| Import parity maize price | -7.12 | -1.23 | -1.22 | -1.28 | -1.22 | -1.16 | -1.23 |
| **Secondary Agriculture** | | | | | | | |
| **Domestic Production** | **% change from database** | **% change from Scenario 1** | | | | | |
| Raw milk | 0.06 | 0.03 | 0.00 | -0.21 | -0.03 | 0.00 | 0.13 |
| Meat: cattle, sheep, goats, horses | 0.07 | 0.04 | 0.01 | -0.32 | -0.01 | 0.00 | 0.12 |
| Dairy Products | 0.07 | 0.03 | 0.00 | -0.20 | -0.03 | -0.01 | 0.14 |
| Other food products | 0.11 | 0.04 | -0.01 | -0.41 | -0.07 | -0.01 | 0.24 |
| **SA exports** | | | | | | | |
| Raw milk | 0.10 | 0.11 | -0.25 | -2.24 | -0.47 | -0.21 | 0.95 |
| Meat: cattle, sheep, goats, horses | 0.44 | 0.20 | 0.02 | -2.19 | -0.11 | -0.02 | 0.67 |
| Dairy Products | 0.25 | 0.12 | 0.01 | -0.67 | -0.10 | -0.01 | 0.50 |
| Other food products | 0.33 | 0.11 | -0.05 | -1.30 | -0.25 | -0.03 | 0.80 |
| **SA imports** | | | | | | | |
| Raw milk | -0.28 | -0.11 | 0.03 | 0.78 | 0.11 | 0.02 | -0.41 |
| Meat: cattle, sheep, goats, horses | -0.23 | -0.10 | 0.00 | 1.27 | 0.07 | 0.01 | -0.34 |
| Dairy Products | -0.09 | -0.08 | 0.00 | 0.43 | 0.06 | 0.01 | -0.31 |
| Other food products | -0.09 | -0.05 | 0.02 | 0.55 | 0.10 | 0.01 | -0.34 |

# CHAPTER 6

## CONCLUSION AND RECOMMENDATIONS

### 6.1 Introduction

During the last century, human life and the quality of living have seen an amazing impact from science and technology. The advent of GMOs has brought rapid change to world agricultural production and trade. The area planted with GMOs increased from just over 40 million hectares in 2000 to 102 million hectares in 2006. During 2006, the USA was still the country with the largest area planted with GM crops, namely 54.6 million hectares, followed by Argentina and Brazil. SA is currently ranked number eight, with a total GM crop hectarage of 1.4 million hectares (this constitutes a 180% increase over 2005). Global area of GM crops is dominated by soybeans, using 57% of the area planted with GMOs, followed by maize, cotton and canola, using 25%, 13% and 5% of the global GM crop area respectively. Of the 1.4 million hectares of GM crops grown in SA, GM maize covers 87% of the area planted with GMOs, followed by soybeans and cotton covering 12% and 1% of this area respectively. Of all the maize planted in SA, GM maize covers 46% of that area

The ability to transfer genes between unrelated species provides a mechanism for the creation of various benefits but also raises concerns about the safety and acceptance of the new genetically modified products. The developments of GM technology led to several international agreements and various domestic regulations by countries on GMOs. Examples of these regulations include, amongst others, the Cartagena Protocol on Biosafety, the Codex Alimentarius and the non-tariff barriers to trade linked to the Sanitary and Phytosanitary agreement under the auspices of the World Trade Organisation. Whilst these agreements and regulations are aimed at the biosafety aspects of GMOs, they may have a distinct impact on the international trade in GM products.

In SA, the GMO Act is the key biosafety law and regulates the use of GMOs as well as imports and exports of living GMOs. The SA GMO Executive Council has recently placed a temporary moratorium on the importation of GM events that have not yet been approved for general release or commodity clearance in SA. The moratorium will most likely stay in place until the impact of new events on trade in maize and the future benefits to domestic farmers and consumers are determined. However, given the WTO Dispute Settlement Panel's conclusions in the dispute between the USA, Canada and Argentina on the one hand and the EU on the other, the moratorium is most likely in contravention of the SPS Agreement of the WTO and will thus not be sustainable indefinitely.

The SA authorities have to date approved four GM maize events for general release. Various other events have been approved for commodity clearance. As these events may be planted in Argentina and the USA but not in SA, one could postulate that the approval thereof for importation (commodity clearance only) discriminates against SA maize producers.

SA's main supplier of maize imports is Argentina (also being the sole supplier during the last two production years). Since 2003, small quantities of maize have been imported from the USA, China and Malawi, but Argentina was the only supplier during the previous two production years. Most of SA's maize exports are destined for the SACU countries, Zimbabwe and Japan. GM regimes could differ quite substantially between different countries and hence affect SA's patterns of maize export significantly.

The focus of this study was the maize industry and the contextualisation of SA's maize trade within the international GM environment in particular. Cognisance is taken of the fact that SA's main trading partners in maize have differing GMO regimes, and many of them may well change their current stances and regulations as the international conventions and agreements on GMOs further evolve. Over and above this regulatory framework, consumer attitudes to GM foods are also changing. Given the importance of the maize industry in SA, it is vitally important to measure and quantify the potential impacts of GM maize on the SA maize trade. This will provide scientific input to SA policy makers on GM maize related regulations in the domestic market as well as on their stances in the international conventions.

## 6.2 Methodology and scenarios

Many different models and methodologies exist to quantify the impact of different policy changes. Within the context of this study, the Global Trade Analysis Project (GTAP) model was used to quantify the effects of policy measures, technology adoption, productivity increases and Segregation and Identity Preservation (SIP) costs applicable to maize on the SA maize industry. GTAP is a multi-regional, computable general equilibrium (CGE) model. It is a comparative static model that allows for a base period scenario to which trade "shocks" could be applied to simulate the outcomes of specific trade policy measures. The GTAP model is generally accepted by trade researchers as the most suitable tool to analyse the impact of trade policy decisions on trade flows and national welfare on a global level due to its regional and sectoral coverage as well as its theoretical compliance. The GTAP model not only estimates changes in trade flows due to trade policy decisions but also estimates the effect of such changes on the economic welfare of the community.

The GTAP model was modified to include 22 regions and 17 sectors from the original 87 regions and 57 sectors to make it more manageable. Since the model classifies maize together with various other grains (barley, rye, oats, sorghum, millet and some other minor grains) in a sector called "Cereal grains not elsewhere classified", this sector had to be disaggregated into "maize" and "other cereal grains". The adjusted model, however, produced maize trade flows that were inconsistent with actual flows in the base period, which necessitated further corrections to the database.

The 7 “what if” scenarios that were developed are the following:

- Scenario 1 – The baseline
- Scenario 2 – Continued adoption
- Scenario 3 – SA consumers reject GM maize
- Scenario 4 – SA bans importation of all GM maize
- Scenario 5 – SA bans maize imports from the USA
- Scenario 6 – SA stops the further approval of GM events for domestic planting
- Scenario 7 – General domestic acceptance of GM maize in SA

## 6.3 Conclusions

From the analysis of the aforementioned scenarios, it became evident that the SA policy of allowing domestic production of approved GM maize events was to the benefit of the country in general. Policy measures that will restrict the country’s access to new GM maize events will gradually disadvantage both domestic producers and consumers of maize. Consumers will suffer a decrease in total welfare, while producers will be disadvantaged in terms of imported competition. For this reason, commodity clearance before general release should be the exception (e.g. in times of severe domestic shortages) rather than the rule. SIP costs applied to the non-GM maize part of SA impact negatively on welfare. Thus, welfare gains could increase significantly if the SIP costs do not apply; for example, if all SA maize were GM, no SIP costs would be necessary. However, this outcome will depend largely on the degree of general acceptance of GM maize.

## 6.4 Recommendations

- The SA maize industry should make concerted efforts to persuade the domestic consumers of the food safety of GM maize based foods. This could lead to the general acceptance of GM maize based products.

- The SA authorities and maize industry should assist the other SADC member countries to develop and adopt proper GM policies and regulations.

- The SA GM authorities should compel all maize imports to be retested for the presence of GMOs on arrival before permitting the cargoes to be discharged.

- With regard to future studies on this issue intended to further refine the results of this study, a specific effort should be made to improve the changes made to disaggregate the maize sector from other grain sectors nationally and internationally.

- In addition, it is recommended that actual trade flows between countries be scrutinised in detail for correctness. This would entail a proper evaluation of the base data of the GTAP model specific to countries playing a relatively smaller role in the international trade of agricultural products – surely a daunting task. Neglecting to do the aforementioned could result in incorrect policy recommendations.

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## APPENDIX

## A: World maize trade

### Table A1: World exporters of maize

| Exporters | Value exported in 2005, in US$ thousand | Quantity exported in 2005 | Quantity unit | Unit value (US$/unit) | Annual growth in value between 2001-2005, % | Annual growth in quantity between 2001-2005, % | Share in world exports, % |
|---|---|---|---|---|---|---|---|
| World estimation | 11250871 | 89935255 | Tons | 125 | 7 | 19 | 100 |
| United States of America | 5038540 | 45369240 | Tons | 111 | 3 | -1 | 44 |
| France | 1495246 | 7403427 | Tons | 202 | 9 | -2 | 13 |
| Argentina | 1367416 | 14642422 | Tons | 93 | 9 | 7 | 12 |
| China | 1096546 | 8610989 | Tons | 127 | -2 | -9 | 9 |
| Hungary | 286461 | 1813026 | Tons | 158 | 15 | -2 | 2 |
| Ukraine | 268890 | 2795641 | Tons | 96 | 68 | 64 | 2 |
| South Africa | 258589 | 2125515 | Tons | 122 | 24 | 22 | 2 |
| Germany | 184252 | 971366 | Tons | 190 | 19 | 10 | 1 |
| Brazil | 120862 | 649736 | Tons | 186 | -18 | -31 | 1 |
| Serbia and Montenegro | 109850 | 706964 | Tons | 155 | 65 | | 0 |
| Austria | 87412 | 334637 | Tons | 261 | 27 | 14 | 0 |
| India | 71650 | 419948 | Tons | 171 | 65 | 69 | 0 |
| Chile | 71362 | 58911 | Tons | 1211 | 3 | | 0 |
| Greece | 69459 | 426017 | Tons | 163 | 97 | 83 | 0 |
| Spain | 57793 | 113205 | Tons | 511 | 19 | -3 | 0 |
| Romania | 55311 | 430283 | Tons | 129 | 73 | 76 | 0 |
| Bulgaria | 54723 | 519104 | Tons | 105 | 73 | 73 | 0 |
| Netherlands | 50906 | 54761 | Tons | 930 | 11 | 9 | 0 |
| Canada | 48744 | 264676 | Tons | 184 | 18 | 131 | 0 |
| Paraguay | 44913 | 243075 | Tons | 185 | 1 | -22 | 0 |
| Poland | 38550 | 269869 | Tons | 143 | | 395 | 0 |
| Belgium | 35812 | 159401 | Tons | 225 | 24 | 20 | 0 |
| Italy | 31726 | 36677 | Tons | 865 | -9 | -34 | 0 |
| Thailand | 27554 | 70417 | Tons | 391 | 2 | -19 | 0 |
| Republic of Moldova | 23026 | 195084 | Tons | 118 | 24 | 47 | 0 |
| Slovakia | 22838 | 86316 | Tons | 265 | 44 | 80 | 0 |
| Turkey | 22327 | 127581 | Tons | 175 | 26 | 71 | 0 |
| United Arab Emirates | 19385 | 96759 | Tons | 200 | 37 | 22 | 0 |
| Zambia | 17101 | 47000 | Tons | 364 | 104 | | 0 |
| Mexico | 14269 | 53040 | Tons | 269 | 15 | -7 | 0 |
| Czech Republic | 14189 | 91954 | Tons | 154 | 53 | 39 | 0 |
| Croatia | 12525 | 65667 | Tons | 191 | 22 | 54 | 0 |
| Uganda | 12269 | 59814 | Tons | 205 | 4 | 12 | 0 |
| United Republic of Tanzania | 10548 | 98985 | Tons | 107 | 19 | 18 | 0 |
| Indonesia | 9048 | 54009 | Tons | 168 | 7 | -3 | 0 |
| United Kingdom | 8476 | 13008 | Tons | 652 | 36 | 17 | 0 |
| Myanmar | 8261 | 60167 | Tons | 137 | 26 | 54 | 0 |
| Guatemala | 7484 | 4919 | Tons | 1521 | 22 | -6 | 0 |
| Peru | 7407 | 7836 | Tons | 945 | 7 | 24 | 0 |

Source: ITC calculations based on COMTRADE statistics, (2007)

### Table A2: World importers of maize

| Importers | Value imported in 2005, in US$ thousand | Quantity imported in 2005 | Quantity unit | Unit value (US$/unit) | Annual growth in value between 2001-2005, % | Annual growth in quantity between 2001-2005, % | Share in world imports, % |
|---|---|---|---|---|---|---|---|
| World estimation | 13269004 | 88901494 | Tons | 149 | 9 | 2 | 100 |
| Japan | 2582239 | 16655910 | Tons | 155 | 10 | 1 | 19 |
| Korea | 1212640 | 8533254 | Tons | 142 | 10 | -1 | 9 |
| Taiwan | 717774 | 4980154 | Tons | 144 | 8 | -1 | 5 |
| Mexico | 714053 | 5743678 | Tons | 124 | 4 | -3 | 5 |
| Spain | 711358 | 4398617 | Tons | 162 | 15 | 7 | 5 |
| Egypt | 519185 | 5412907 | Tons | 96 | 0 | -1 | 3 |
| Germany | 416681 | 1817686 | Tons | 229 | 26 | 20 | 3 |
| Netherlands | 403255 | 2291438 | Tons | 176 | 12 | 25 | 3 |
| Iran | 377220 | 2241153 | Tons | 168 | 21 | 9 | 2 |
| Malaysia | 365523 | 2571065 | Tons | 142 | 13 | 10 | 2 |
| Colombia | 324410 | 2465423 | Tons | 132 | 13 | 8 | 2 |
| United Kingdom | 284174 | 1332998 | Tons | 213 | 9 | -4 | 2 |
| Italy | 244629 | 1285930 | Tons | 190 | 28 | 27 | 1 |
| Canada | 239651 | 2154224 | Tons | 111 | -10 | 8 | 1 |
| Morocco | 233278 | 1620311 | Tons | 144 | 21 | 14 | 1 |
| Algeria | 217244 | 2358646 | Tons | 92 | 12 | 8 | 1 |
| Portugal | 203177 | 1242022 | Tons | 164 | 8 | -1 | 1 |
| Saudi Arabia | 189182 | 1226478 | Tons | 154 | 5 | -1 | 1 |
| Peru | 171590 | 1314257 | Tons | 131 | 16 | 11 | 1 |
| Zimbabwe | 154898 | 1314725 | Tons | 118 | 225 | 271 | 1 |
| Syria | 154545 | 1633312 | Tons | 95 | 17 | 12 | 1 |
| Chile | 149332 | 1131074 | Tons | 132 | 2 | | 1 |
| France | 148594 | 258535 | Tons | 575 | 14 | 1 | 1 |
| Israel | 144641 | 779999 | Tons | 185 | 13 | | 1 |
| USA | 141873 | 282360 | Tons | 502 | -1 | 7 | 1 |
| Belgium | 122962 | 564378 | Tons | 218 | 9 | -1 | 0 |
| Greece | 113562 | 612037 | Tons | 186 | 8 | 2 | 0 |
| Dominican Republic | 98874 | 993024 | Tons | 100 | 0 | -4 | 0 |
| Tunisia | 91248 | 661527 | Tons | 138 | 2 | -6 | 0 |
| Guatemala | 88276 | 665616 | Tons | 133 | 10 | 5 | 0 |
| Jordan | 66185 | 430182 | Tons | 154 | 7 | -1 | 0 |
| Brazil | 64063 | 340876 | Tons | 188 | -1 | -29 | 0 |
| Cuba | 58654 | 557285 | Tons | 105 | 45 | 44 | 0 |
| Ecuador | 58065 | 425234 | Tons | 137 | 28 | 23 | 0 |
| El Salvador | 56369 | 498163 | Tons | 113 | 11 | 9 | 0 |
| Honduras | 53399 | 389406 | Tons | 137 | -11 | 290 | 0 |
| Costa Rica | 48654 | 372244 | Tons | 131 | 2 | -6 | 0 |
| Turkey | 47335 | 218059 | Tons | 217 | -3 | -17 | 0 |
| Austria | 42679 | 188214 | Tons | 227 | 16 | 22 | 0 |

Source: ITC calculations based on COMTRADE statistics, (2007)

**B: The SA GM maize events**

(a) For general/commercial release

- 1997: Bt[11] Insect resistance, MON 810, Monsanto
- 2002: Herbicide tolerance, NK603, Monsanto
- 2003: Bt 11 Insect resistance, Syngenta
- Feb. 2007: Bt Insect resistance + Herbicide tolerance, NK 603, Monsanto

(b) For food/feed commodity import clearance

- 1997: Bt Insect resistance, MON 810, Monsanto
- 2001: Insect resistance, Bt 176, Ciba-Geigy/Syngenta
- 2002: Herbicide tolerance, GA 21, Syngenta
- 2002: Herbicide tolerance, NK 603, Monsanto
- 2002: Herbicide tolerance + insect resistance, (Pioneer/DuPont?)
- 2002: Herbicide tolerance + insect resistance, TC 1507, Agrevo/Dow
- 2003: Herbicide tolerance + insect resistance, MON 0021-9 x MON 00810-6, Monsanto
- 2004: Herbicide tolerance + insect resistance, MON00603-6 X MON 00810-6, Monsanto

List of genetic modifications (events) approved for food/feed commodity grain imports from January 2004 to January 2007: MON 810, Bt 11, T25, Bt 176, NK 603, GA 21, TC 1506

[11] Bacillus thuringiensis (Bt) is a Soil bacterium used for biological pest control it produces a protein toxic to certain types of insects. By means of genetic engineering, the genes for the active agent (Bt toxin) can be transferred from Bt bacteria to plants. There they produce the toxic agent inside the plant cells. In this way, biotechnology has been used to confer insect resistance to a number of economically important crops.

(c) Permits granted for GM field trials

- 2003: Herbicide tolerance, Safemaize, CSIR
- 2003: Insect resistance, 3243, Syngenta
- 2005: Herbicide tolerance, GA 21, Syngenta
- 2005: Herbicide tolerance, DAS 1507, Dow
- 2006: Insect resistance + herbicide tolerance: MON 89034 and MON 89034 x NK 603, Monsanto
- 2006: Insect resistance + Herbicide tolerance, Bt 11 x GA 21, Syngenta

## C: Summary of relevant studies reviewed

### C1 Impacts of GM Crops on Australian Trade

According to Stone *et al.* (2002), their paper flows out of the fluid nature of both consumer and regulatory developments worldwide regarding GM crops and their use in food, which raises important questions and dilemmas for policy-makers and agricultural producers in Australia. Analysing these issues can provide useful insights for policy-makers as they weigh up the costs and benefits of alternative policy options and engage in international negotiations.

The paper analyses two types of crops: non-wheat grains (maize, sorghum and barley) and oilseeds (canola and soybeans), using assumptions about productivity gains, consumer attitudes and the cost of regulation. Their research aims to provide an initial quantitative assessment of possible short-term trade implications for Australia from the global trade of GM foods under certain domestic and international regulatory and consumer responses. The paper does not specifically address a number of other 'non-trade' issues relating to GM crops that are also important in terms of the economic and social welfare of Australians, e.g. issues concerning consumer choice and ethical and environmental implications of GM food production.

The model developed by Stone *et al.* (2002) made necessary modifications to the basic GTAP structure and changes to the 1997 database. The first database change was to aggregate the original 57 sectors and 66 regions to 11 sectors and 9 regions respectively. The change in regions was based on those regions that are important to Australian trade, and the change in sectors reflected the sectors affected most by GM technology, such as processed food. Therefore, as mentioned earlier, two crop sectors, grains and oilseeds, were chosen and split into GM and non GM components. The split was based on market share information for the nine regions. Shares of inputs, export shares and destinations, as well as the use of the two types of grains and oilseeds (GM and non GM) as intermediate inputs, were assumed identical in this initial stage.

Three different scenarios based on different sets of assumptions were tested by Stone *et al.* (2002). These are:

**Scenario 1: Productivity Gains**

An output-augmenting technical change shock was applied to the GM oilseed and grain sectors. This reflects productivity gains due to the adoption of GM crops. The shock was applied uniformly to all regions producing GM crops but varied according to the crop. 6% and 7.5% productivity shocks were given to oilseeds and grains respectively.

**Scenario 2: Adding Consumer Response**

Two separate mechanisms were used to simulate consumer resistance to GM crops in Australia, New Zealand, the European Union, Korea and Japan. First, the substitution parameters between GM and non GM grains and oilseeds were lowered. These parameters determine the degree of sensitivity in consumer demand to a relative price change between varieties. Response to prices differs across regions, i.e. regions were classified as being highly price sensitive (e.g. North America), somewhat price sensitive (e.g. Australia) and price insensitive (i.e. consumers will continue to consume non GM crops even if the relative price increases, e.g. EU).

The modelling of private demand in their paper leaves population growth and changes in income and living standards constant while allowing for changes in tastes and preferences.

A second mechanism was used with the introduction of a preference shift variable that was not related to price. The variables for both imported and domestic GM grains and oilseeds were shocked to show that no matter how expensive non GM crops may become relative to GM crops, some consumers may simply not want to consume them due to food safety or environmental reasons. The degree of consumer resistance was indicated by a 25% reduction in the demand for GM goods in the European Union, Australia, New Zealand, Korea and Japan

**Scenario 3: Adding Regulation**

The cost of regulation was accounted for by implementing a series of negative technology-augmenting shocks. Regulation is thus imposed as an additional cost to producers. In order to comply with SIP and labelling regulations, firms must incur additional non labour input costs (e.g. additional packaging material); labour costs (e.g. additional handlers to separate commodities); and capital costs (e.g. equipment to test the GM status of commodities). The most likely input sectors to be affected by regulations will be manufacturing, services, transport and storage.

**Table C1: Results of different scenarios: Australia**

| Scenarios | Results |
|---|---|
| Scenario 1 | **General:**<br>- There would be virtually no changes in any of the overall macroeconomic variables, including total imports and total exports for Australia.<br>- The major change would take place in the composition of trade, concentrated in the two GMO producing sectors (grains and oilseeds).<br>- Australia's major agricultural trade competitors, such as North America, would gain directly from the GMO productivity increases and make Australia's non GM goods relatively less competitive.<br>- North America's inputs of cheaper GM commodities into industries such as livestock and processed meat would further diminish Australia's competitiveness in its traditional export markets and also affect domestic consumption as cheaper imports entered the home market.<br>**Production:**<br>- The production of GM crops would increase across the board at the expense of conventional crops.<br>- North America and China experience an expansion in the output of industries using GMO inputs (such as livestock, meat and dairy and other food). |

| Scenarios | Results |
| --- | --- |
| | - Australia and Japan simply experience an increase in the production of GM goods, since their other industries currently have little or no GM inputs, and so do not benefit.<br>**Exports:**<br>- The largest producer of GM crops, North America, would gain the most from the assumed changes in productivity.<br>- Exports of food from the US are anticipated to increase, as would exports of livestock, processed animal products and other processed foods. As GMO commodities already represent a relatively large share of the inputs in these industries in North America, the region appears to gain a comparative advantage in production of several commodities from the productivity increases in the GMO sectors.<br><br>**Imports:**<br>- Imports of GMO goods increase for most countries.<br>- Imports of conventionally produced oilseeds and grains show declines in most regions but substantially so in North America. |
| Scenario 2 | **General:**<br>- A shift in consumer preferences is implemented for GM crops only, and since these goods represent small shares of the consumer's overall budget, large changes are not expected. This situation may, however, be substantially different in regions where maize represents a large share of the consumers overall budget, for example, in Africa.<br>**Production:**<br>- Output gains under Scenario 1 are reduced once consumer resistance is introduced.<br>- GM oilseed production declines in both the EU and Japan. Japanese GM oilseeds production falls by 3 per cent when there is a consumer preference shift.<br>- Output remains virtually unchanged in North America and China.<br>**Exports:**<br>- Exports increase less than in Scenario 1.<br>- Exports to markets where consumers are considered to be very sensitive decrease significantly, but opportunities open in markets where consumers are less sensitive.<br>**Imports:**<br>- Imports in sensitive regions drop, while imports by less sensitive regions remain nearly the same. |
| Scenario 3 | **General:**<br>- The largest regulatory costs would be incurred by those regions experiencing the |

| Scenarios | Results |
|---|---|
| | highest degree of consumer resistance.<br>- Increased regulatory costs for both non GM and GM crops will result in lower competitiveness. This is particularly evident for non GM crops where GM crops represent a small portion of total production in certain countries, such as Australia.<br>**Production:**<br>- Australia's production of GM grains and oilseeds is the lowest in Scenario 3 compared to the previous scenarios. This is because the original productivity gains assumed in Scenario 1 have been eroded not only by consumer preference shifts (Scenario 2) but also by higher input costs due to regulation.<br>- The results obtained for Australia are consistent across all regions.<br>- Increased costs would result in the affected regions losing export market share to those regions that do not incur similar additional costs.<br>**Exports:**<br>- GM grains exports still increase but at half the level observed in Scenario 1.<br>- Exports of agricultural produce other than crops, such as livestock, processed meat, dairy and other foods, do not change significantly.<br>- Exports would decline slightly in the EU and Australia as part of the regulatory costs imposed on GM and non GM crops passed through to industries by way of higher input prices.<br>**Imports:**<br>- Imports typically rise for regulated regions, as imported GM and non GM grains and oilseeds from those regions not affected by regulation would become relatively cheaper than domestic products.<br>- Imports of these commodities into unaffected regions, such as North America and China, would decline slightly as these regions switch to their cheaper domestically produced crops. |

Source: Jooste *et al.* (2003) and Stone *et al.* (2002)

**Conclusion** (Stone *et al.* 2002)

- Australia's overall trade position would only be significantly affected by the expansion of GM technology into non-wheat grains and oilseeds sectors if current market conditions change.

- The composition of trade will alter in favour of GM commodities at the expense of non GM commodities, both in Australia and globally.
- Value-added sectors like livestock and processed foods that use GM crops as inputs are affected by the adoption of GM grains and oilseeds under the scenarios considered. Exports of downstream industries fall slightly, while imports increase.
- If consumer resistance declines, the total trade impacts remain small whether Australia maintains its current adoption rates or increases them to the levels of North America.
- If Australia does not increase the adoption of GM crops, the markets for oilseeds and non-wheat grains are likely to stagnate.
- If Australia increases its adoption, small increases in output and exports are observed in the GM sector, with slight declines in downstream industries.

## C2 GM food technology abroad and its implications for Australia and New Zealand

The study by Anderson and Jackson (2004a) emphasises the need for food-exporting countries such as Australia and New Zealand (hereafter ANZ) to weigh the potential economic benefits of biotechnology development against any negative environmental risks associated with producing GM crops. Additional costs of segregation and identity preservation need to be weighed, and discounting and/or loss of market access abroad should be considered.

Anderson and Jackson (2004a) use a more recent version of the GTAP database than that of Stone *et al.* (2002) and examine a wider range of GM adopting countries and of policy responses. Coarse grains, oilseeds and prospective GM versions of wheat and rice are examined. The study examines within the same modelling framework the effects on both ANZ first without and then with the adoption of GM crop varieties, and it looks at effects on not only national economic welfare but also the real net income of farm households in both countries.

Anderson and Jackson (2004a) have aggregated the GTAP model to depict the global economy as having 17 regions and 14 sectors. Several assumptions have been made for the production side:

- 45% of US and Canadian coarse grain production is GM, while Latin American countries, Australia and New Zealand, if they adopt, are assumed to have 30% of their coarse grain production as GM. All other countries are assumed to have 15% GM as part of their coarse grain production.
- When it comes to oilseed production, the US, Argentina and Brazil adopt 75% GM; Canada other Latin American countries, Australia and New Zealand adopt 50% GM; the remaining regions adopt 25% GM oilseed production.
- US, Canada, China, India, and all other Asian countries are assumed to produce 45% of their rice crop using GM technologies, all other regions adopt 30% GM in their rice production.
- Wheat adoption occurs to the same extent as coarse grain adoption for all regions.
- The adopting sectors are each subdivided into GM and non GM product, and an output-augmenting productivity shock is implemented on the GM varieties. The total factor productivity is higher for GM than for non GM varieties by 6% for oilseeds and 7.5% for coarse grains; rice and wheat both have a 5% productivity increase.
- Segregation and identity preservation costs are not included because the policy response simulations assume that countries banning GM supplies exclude imports from GM-adopting countries of both GM varieties and GM-free substitutes.

Assumptions made on the consumption side by Anderson and Jackson (2004a) include the following:

- Elasticities of substitution between GM and non GM varieties of each product in regions where consumers are GM averse are set at low levels to capture the perceived low degree of substitutability.

- A 25% reduction in final demand for imported crops that may contain GMOs is assumed in some countries that, because of food safety and/or environmental concerns, refuse to consume GM crops regardless of their price.

The simulations of the model reported below are selected to show how different combinations of crop choice, country adoption and policy responses alter economic impacts of GM technologies. Three sets of crop adoption scenarios are considered:

**Scenario 1: Simulations 1a to 1e**

Here, the implications of the adoption of GM coarse grains and oilseeds by the US, Canada and Argentina without and with ANZ also adopting are examined, both without and with an EU moratorium. These are then compared with all the countries of the world adopting GM varieties for these crops to get an idea of economic benefits foregone by those reluctant to use GMOs.

**Scenario 2: Simulations 2a to 2e**

This scenario examines the impact of adding GM rice and wheat adoption in the US, Canada and Argentina to their adoption of coarse grains and oilseeds, together with China and India also adopting GM varieties of all four groups of crops. As with the first scenario, there are five simulations in this set: adoption with and without ANZ also adopting, and with and without an EU moratorium, plus one with all countries of the world adopting GM varieties of these crops.

**Scenario 3: Simulations 3a and 3b**

In the third set of simulations, Anderson and Jackson (2004a) examined the impact of GM adoption of coarse grains and oilseeds in just North America and Argentina in the presence of a GM import moratorium by not only the EU but also China and two key Northeast Asian countries (Japan and South Korea), first without and then with ANZ adopting GM varieties of those crops. Within this scenario, Anderson and Jackson (2004a) made more assumptions, which include the following:

- There are no externalities on the production side and no food safety concerns on the consumption side of the market.
- To estimate the effects on farm household income, it is assumed that ANZ farm households earn 75% of net income from farm activities (half from labour, one-eighth from land and the rest from physical capital) and the other 25% from non-farm activities (one third from wages and two thirds as returns to physical capital).
- ANZ farm households have the same spending pattern as the community average.

**Table C2: Results of different scenarios: Australia and New Zealand**

| **Results** |
|---|
| **Volume and price effects:**<br>• If Australia chooses not to adopt GM varieties and all countries treat GM and GM-free varieties as like products, its production and net exports of not only coarse grains and oilseeds but also meat products fall.<br>• The same is true for New Zealand but with smaller orders of magnitude.<br>• If ANZ join the GM adopters, Australian coarse grain production would expand instead of contracting and, if there was no EU moratorium, oilseed production would fall much less.<br>• Lower domestic prices for these products lead to an increase in domestic consumption, but those increases would not prevent coarse grain net export earnings from rising instead of falling.<br>• Oilseeds net exports would fall less in the absence of an EU moratorium but not in its presence should Australia adopt GM varieties not approved in the EU |
| **National trade balance and net welfare effects:**<br>• The effect on the aggregate trade balance is positive for ANZ in the absence of the EU moratorium and negative in its presence.<br>• The reduction in the trade balance from adopting GM coarse grain and oilseed varieties would be no more than US$2 million for Australia and less than US$0.5 million for New Zealand, with or without the EU moratorium.<br>• GM coarse grain and oilseed adoption by North America and Argentina benefits those countries despite deteriorating their terms of trade, although less so (especially for Canada) in the case where the EU moratorium continues. |

| Results |
| --- |
| • The EU and the rest of the world would benefit (US$2.3 billion per year) via improved terms of trade, except in the case of the EU moratorium. Australia gains US$14 million per year if it adopts in the presence of an EU moratorium and US$16 million if the moratorium were to be removed. New Zealand gains US$ 1-2 million per year if it adopts.<br>• When wheat and rice are added to the set of GM crops and China and India are included in the set of GM adopting countries, ANZ's production, prices and net exports of coarse grain and oilseeds are lowered even more than in scenario 1. There is also a negative effect on ANZ wheat and rice markets. The global economic welfare improves by US$4.3 billion per year if there are no trade policy responses.<br>• If ANZ do not adopt, Australia loses twice as much than in scenario 1 while New Zealand loses almost no more.<br>• If ANZ adopt, the Australian economic welfare would improve more than in scenario 1 in the absence of the EU moratorium, while New Zealand's would be no different.<br>• In the presence of the EU moratorium, Australia's welfare would improve but less than in scenario 1, while New Zealand's would improve more.<br>• In scenario 3, if Australia adopts, there will be a net loss of US$ 13 million per year (terms of trade [-$46 million], Benefits from technical change [$17 million] and improved allocative efficiency [$16 million]). If Australia does not adopt, it will result in a net positive welfare outcome of US$96 million. For New Zealand, GM adoption would not make a difference because its coarse grain and oilseed industries are too small. |
| **Real net farm household income effects:**<br>• In no cases in scenario 3 are the effects more than 1%.<br>• The terms of trade changes from GM adoption abroad are only small.<br>• If Northeast Asia copies the EU moratorium, Australian farm households would be 0.8% better off if they do not adopt GM coarse grain and oilseed varieties but 1% worse off if they do. |

Source: Anderson and Jackson (2004a)

**Conclusion** (Anderson and Jackson 2004a)

- In the short to medium term, ANZ's benefits from adoption depend on the extent to which GM products are accepted by ANZ's current major trading partners.
- Further research is required towards the impact of the cost and distributional consequences of national segregation and identity preservation (SIP) systems that will be needed to supply markets with strict GM labelling laws.

- It would be prudent for ANZ rural research and development (R&D) agencies to ensure that a portion of their portfolio includes the development of GM technologies appropriate to local conditions so that, when markets become more accepting, those technologies can be produced and disseminated relatively promptly.

## C3 Global market effects of alternative European responses to GMOs

Nielsen and Anderson (2000a) used an empirical model of the global economy (GTAP) to empirically quantify the effects on production, prices, trade patterns and national economic welfare of certain non-European countries adopting GM crops. The results were then compared to what they would have been if Western Europe banned imports of those products from countries adopting GM technology. A shift in consumer preferences in Europe is investigated as a consideration towards an alternative market-based approach. The simulations are based on the global economic structures and trade flows of 1995. The model was aggregated to 16 regions; these include the major role players in the global GMO debate as well as key interest groups. 17 sectors were aggregated with a focus on the primary agricultural sectors affected by the GMO debate and their related processing industries. This study is mainly concerned with maize and soybeans because they were benefiting most from GM technology at the time of the study.

The model used by Nielsen and Anderson (2000a) is restricted by a few general assumptions:

- GM-driven productivity growth is assumed to occur in only the cereal grains (excluding wheat and rice) and oilseeds GTAP sectors.
- The scenarios analysed here are based on the simplifying assumption that the effect of adopting GM crops can be shown as a uniform reduction in all inputs to obtain the same level of production

- The GM adopting sectors are assumed to experience a once-off increase in total factor productivity of 5%, thus lowering the supply price of the GM crop
- The 5% productivity shock represents an average shock over both commodities and regions.

Three scenarios were specified by the authors, and each scenario specified additional assumptions:

**Scenario 1:**

This scenario is a base case with no policy or consumer reactions to GMOs. The implications for the adoption of GM maize and soybeans are considered for North America, Mexico, the Southern Cone region of Latin America, India, China, East Asia's other lower-income countries, and South Africa. The countries of Western Europe and elsewhere are assumed to renounce the use of GM crops in their production systems. Among the developing countries, Sub-Saharan Africa (SSA) is assumed not to be able to take advantage of the new technology. Consumers are assumed not to be concerned about the introduction of GM crops in the agricultural food system; hence GM and conventional crops are not segregated in the production process or in the market place. There are also no restrictions on trade with GM products within this scenario.

**Scenario 2:**

In this scenario, Western Europe refrains from using GM crops in its own domestic production systems and rejects imports of GM oilseeds and cereal grains from GM adopting regions. It is assumed that the labelling requirements of the Biosafety Protocol enable Western European importers to identify all shipments of oilseeds and cereal grain exports from GM-adopting regions and label them as "may contain GMOs". Hence the distinction between GM and GM free products is simplified to one that relates directly to the country of origin. Labelling costs are ignored in this scenario.

**Scenario 3:**

The final scenario considers the case in which consumer preferences are expressed through market mechanisms and not through government regulation. It analyses the implications of Western European countries making a partial shift in preferences away from imported cereal grains and oilseeds towards domestically produced crops. This shift in preferences is implemented as an exogenous 25% reduction in final consumer and intermediate demand for all imported oilseeds and cereal grains, i.e. not only those which can be identified as coming from GM adopting regions. Some European consumers and firms are assumed to completely avoid products produced outside of Western Europe. Western European producers and suppliers are assumed to be able to declare, at no significant extra cost, that their products are GM free by labelling their products by country of origin.

**Table C3: Results of different scenarios: Europe**

| Scenarios | Results |
|---|---|
| Scenario 1 | - A 5% reduction in overall production costs leads to increases in cereal grains production of between 0.4% and 2.1% and increases in oilseed production of between 1.1% and 4.6% in the GM adopting regions.<br>- Crops for which export opportunities are more favourable will experience larger increases in production, e.g. oilseeds. The higher production will in turn lead to lower market prices that will benefit downstream industries.<br>- The increase in oilseed production will be particularly marked in the Southern Cone region of South America, where no less than one-fourth of this production is sold on foreign markets.<br>- In North America, cereal grains are also used as livestock feed; hence lower feed prices lead to an expansion of the livestock and meat processing sectors.<br>- Production increases, taking into account the world market share of South and North America in cereal grain and oilseed exports, would result in world market prices declining by 4.0% and 4.5% for cereal grains and oilseeds respectively.<br>- Increased competition leads to declines in the production of cereal grains and oilseeds in the non-adopting regions. |
| Scenario 2 | - North American oilseed exports will decline by almost 30%.<br>- Production in North America will decline by 10%, pulling resources such as land out |

| Scenarios | Results |
|---|---|
| | of this sector.<br>- The ban does not affect the production and exports of cereal grains to the same extent as oilseeds.<br>- Access to the Western European markets, when GMO adopting countries are excluded, expands for Sub-Saharan African countries.<br>- Increased export opportunities for Sub-Saharan African countries would stimulate production.<br>- Import substitution to more expensive inputs for downstream industries in Western Europe causes production in these downstream sectors to decline and competing imports to increase.<br>- Countries that mainly produce for their domestic markets will be less affected, e.g. India and China. |
| Scenario 3 | - Having consumers express their preferences through market mechanisms rather than through a government-implemented import ban has a much less damaging effect on production in the GMO adopting countries.<br>- In contrast to scenario 2, cereal grains and oilseeds will experience production increases, although not to the same extent as in scenario 1.<br>- The partial reduction in import demand leads to minor increases in production in Western Europe and has a marginal impact on prices.<br>- Sub-Saharan Africa loses export shares to the GMO adopting regions. |

Source: Jooste *et al.* 2003 and Nielsen and Anderson, 2000a

**Conclusion** (Nielsen and Anderson, 2000a)

- An import ban on GM crops would be very costly in terms of economic welfare for Western Europe.
- A ban will hinder European consumers and intermediate demanders in benefiting from lower import prices; domestic production of maize and soybean is forced to rise at the expense of other production.
- GM adopting regions will enjoy welfare gains due to the assumed productivity boost embodied in the GM crops, but those gains are reduced by the import ban.
- Letting consumers express preferences through the market reduces welfare gains from the new technology much less than if a ban on GMOs is imposed in Europe.

## C4 Biotechnology boosts to crop productivity in China: Trade and Welfare implications

The study by Huang *et al.* (2002) originated out of the need to find answers to issues raised by policy makers. Issues that were raised include:

- Whether China should continue to promote its agricultural biotechnology and commercialise its GM food crops (i.e. rice and soybean).
- How the rest of the world will react to China's GMO commercialisation, in particular EU and other Eastern Asia countries.
- The possible impacts of alternative biotechnology development strategies, both in China and the rest of the world, on China's agricultural economy and trade.

The impact assessment of Chinese biotechnology developments has been done with the GTAP modelling framework. The baseline modelling framework used by Huang *et al.* (2002) has several important aspects to consider. First, the productivity impacts of GMOs are based on micro-level data for cotton and on field trial data for rice in China, so detailed GMO cost savings, estimated specifically for China, are included. Second, the multi-sector framework captures backward and forward linkages between GM crops, also in the using and supplying sectors. Last, the baseline of the GTAP model incorporates new data for the Chinese economy.

The study by Huang *et al.* (2002) includes a baseline scenario and 4 scenarios related to GMO products. These scenarios are the following:

**Baseline scenario:**

The baseline projection does not contain any assumptions on biotechnology developments and serves as a basis for comparing the different scenarios.

**Scenario 1:**

The first scenario studies the impact of Bt cotton adoption during the period of 2002 to 2010. In this scenario, Chinese cotton is assumed to experience factor-biased productivity gains. This means that the yields realised for GM and non GM cotton are different. In 2002, Bt cotton is expected to have a 5.97% better yield than that of non Bt cotton. This bias increases to 7% in 2010. The costs involved with labour and pesticides are assumed to be lower for Bt cotton than for conventional varieties. A drop in pesticide costs of 53% in 2002 is assumed, which increases to 67% in 2010. Over the mentioned period, labour costs are assumed to be between 5% and 7% lower. Seed cost for Bt cotton is assumed to be 120% more expensive than seed for conventional varieties.

**Scenario 2:**

This scenario adds the commercialisation of GM rice over the period 2002-2010 to the adoption of cotton. As in scenario 1, GM rice will also experience factor-biased productivity gains. GM rice is expected to have a 6% better yield than that of normal rice in 2002, increasing to 7.03% in 2010. Pesticide and labour costs for GM rice are assumed to be lower than for conventional varieties. The pesticide cost for GM rice is assumed to be 52% lower in 2002, increasing to 65% lower in 2010. Labour costs are assumed to be between 7% and 10% lower over 2002-2010. Seed cost for GM rice is assumed to be 50% more expensive than seed of normal rice.

**Scenario 3:**

This scenario focuses on a possible import ban on GMOs from China. An import ban on GM rice by the main trading partners is simulated, given that China has commercialised both Bt cotton and GM rice.

**Scenario 4:**

The last scenario investigates the effects of the regulation on labelling imported soybeans which came into effect in March 2002. Thus, this scenario assesses the economic effects if China is to label its own GM food crops, given that it exercises the labelling requirements for imported soybeans. It is assumed that labelling requirements will increase the cost of production of rice by 3% and that the cost of imported soybeans from the US and South America will increase by 5%.

**Results**

The results of the 4 scenarios are summarised in Table x. It is important to note that the scenarios are additive in nature. This means that new elements are added one at a time, and the separate effects of each new element are disentangled where appropriate.

**Table C4: Results of different scenarios: China**

| Scenarios | Results |
|---|---|
| Scenario 1 | - The supply price will be 10.9% lower in 2010.<br>- Demand by the domestic textile industry increases significantly and reaps the benefits of lower input costs.<br>- Exports increase but are very small in relation to domestic demand.<br>- Imports of cotton drop with the result that the trade balance for cotton improves. |
| Scenario 2 | - The supply price of rice will be 12% lower in 2010.<br>- Output reacts sluggishly due to low income and price elasticities of demand.<br>- The increase in exports is significant, but exports as percentage total output remain low due to large domestic demand.<br>- Use of Bt cotton and the commercialisation of GM rice results in significant welfare gains. The latter contributes more to the increase in welfare than the former due to the relative size of the rice sector compared to the cotton sector.<br>- The aggregate demand for labour also increases.<br>- Land prices decline because factor demand is lower due to the yield-increasing effect of GM technology. Lower land prices favour other sectors such as grains and livestock. |
| Scenario 3 | - A ban on GM rice from China by the EU, Japan, Korea and South East Asia will |

| Scenarios | Results |
|---|---|
| | result in only marginal increases in exports of GM rice.<br>- The increase in the trade balance and welfare gains is significantly lower than in the previous scenario.<br>- Countries that ban GM rice imports also suffer welfare losses. |
| Scenario 4 | - The price of rice experiences a 10% drop compared to the baseline scenario.<br>- Labelling costs increase the import price of soybeans, resulting in a drop in imports, which negatively affects the US and the South American countries.<br>- The combined result is better prices for Chinese soybean producers, hence expansion in production, but the lower drop in the price of rice compared to the other scenarios is considered unfavourable for rice consumers. |
| Overall conclusions | - The economic gains from adoption are substantial.<br>- Estimated macro-economic welfare gains far outweigh public biotechnology research expenditure.<br>- Trade restrictions on GM products will not have a significant impact on biotechnology research if exports of a product only account for a small proportion of domestic production.<br>- China should continue to promote its GM biotechnology, including commercialising its GM food crops. |

Source: Jooste *et al.* 2003 and Huang *et al.* 2002

## D: GTAP regions and sectors

**Table D1: GTAP regions and participating countries of regions**

| Num ber | GTAP Regions | Participating countries of regions |
|---|---|---|
| 1 | Australia | Australia |
| 2 | New Zealand | New Zealand |
| 3 | Rest of Oceania | American Samoa |
| | | Cook Islands |
| | | Fiji |
| | | French Polynesia |
| | | Guam |
| | | Kiribati |
| | | Marshall Islands |
| | | Micronesia, Federated States of |
| | | Nauru |
| | | New Caledonia |
| | | Norfolk Island |
| | | Northern Mariana Islands |
| | | Niue |
| | | Palau |
| | | Papua New Guinea |
| | | Samoa |
| | | Solomon Islands |
| | | Tokelau |
| | | Tonga |
| | | Tuvalu |
| | | Vanuatu |
| | | Wallis and Futuna |
| 4 | China | China |
| 5 | Hong Kong | Hong Kong |
| 6 | Japan | Japan |
| 7 | Korea | Korea, Republic of |
| 8 | Taiwan | Taiwan |
| 9 | Rest of East Asia | Macau |
| | | Mongolia |
| | | Korea, Democratic People's Republic of |
| 10 | Indonesia | Indonesia |
| 11 | Malaysia | Malaysia |
| 12 | Philippines | Philippines |
| 13 | Singapore | Singapore |
| 14 | Thailand | Thailand |
| 15 | Vietnam | Vietnam |
| 16 | Rest of Southeast Asia | Brunei Darussalam |

| | | |
|---|---|---|
| | | Cambodia |
| | | Lao People's Democratic Republic |
| | | Myanmar |
| | | Timor Leste |
| 17 | Bangladesh | Bangladesh |
| 18 | India | India |
| 19 | Sri Lanka | Sri Lanka |
| 20 | Rest of South Asia | Afghanistan |
| | | Bhutan |
| | | Maldives |
| | | Nepal |
| | | Pakistan |
| 21 | Canada | Canada |
| 22 | United States of America | United States of America |
| 23 | Mexico | Mexico |
| 24 | Rest of North America | Bermuda |
| | | Greenland |
| | | Saint Pierre and Miquelon |
| 25 | Colombia | Colombia |
| 26 | Peru | Peru |
| 27 | Venezuela | Venezuela |
| 28 | Rest of Andean Pact | Bolivia |
| | | Ecuador |
| 29 | Argentina | Argentina |
| 30 | Brazil | Brazil |
| 31 | Chile | Chile |
| 32 | Uruguay | Uruguay |
| 33 | Rest of South America | Falkland Islands (Malvinas) |
| | | French Guiana |
| | | Guyana |
| | | Paraguay |
| | | Suriname |
| 34 | Central America | Belize |
| | | Costa Rica |
| | | El Salvador |
| | | Guatemala |
| | | Honduras |
| | | Nicaragua |
| | | Panama |
| 35 | Rest of Free Trade Area of the Americas | Antigua & Barbuda |
| | | Bahamas |
| | | Barbados |
| | | Dominica |
| | | Dominican Republic |
| | | Grenada |
| | | Haiti |
| | | Jamaica |
| | | Puerto Rico |

| | | |
|---|---|---|
| | | Saint Kitts and Nevis |
| | | Saint Lucia |
| | | Saint Vincent and the Grenadines |
| | | Trinidad and Tobago |
| | | Virgin Islands, U.S. |
| 36 | Rest of the Caribbean | Anguilla |
| | | Aruba |
| | | Cayman Islands |
| | | Cuba |
| | | Guadeloupe |
| | | Martinique |
| | | Montserrat |
| | | Netherlands Antilles |
| | | Turks and Caicos |
| | | Virgin Islands, British |
| 37 | Austria | Austria |
| 38 | Belgium | Belgium |
| 39 | Denmark | Denmark |
| 40 | Finland | Finland |
| 41 | France | France |
| 42 | Germany | Germany |
| 43 | United Kingdom | United Kingdom |
| 44 | Greece | Greece |
| 45 | Ireland | Ireland |
| 46 | Italy | Italy |
| 47 | Luxembourg | Luxembourg |
| 48 | Netherlands | Netherlands |
| 49 | Portugal | Portugal |
| 50 | Spain | Spain |
| 51 | Sweden | Sweden |
| 52 | Switzerland | Switzerland |
| 53 | Rest of EFTA | Iceland |
| | | Liechtenstein |
| | | Norway |
| 54 | Rest of Europe | Andorra |
| | | Bosnia and Herzegovina |
| | | Faroe Islands |
| | | Gibraltar |
| | | Macedonia, the former Yugoslav Republic of |
| | | Monaco |
| | | San Marino |
| | | Serbia and Montenegro |
| 55 | Albania | Albania |
| 56 | Bulgaria | Bulgaria |
| 57 | Croatia | Croatia |
| 58 | Cyprus | Cyprus |
| 59 | Czech Republic | Czech Republic |

| | | |
|---|---|---|
| 60 | Hungary | Hungary |
| 61 | Malta | Malta |
| 62 | Poland | Poland |
| 63 | Romania | Romania |
| 64 | Slovakia | Slovakia |
| 65 | Slovenia | Slovenia |
| 66 | Estonia | Estonia |
| 67 | Latvia | Latvia |
| 68 | Lithuania | Lithuania |
| 69 | Russian Federation | Russian Federation |
| 70 | Rest of Former Soviet Union | Armenia |
| | | Azerbaijan |
| | | Belarus |
| | | Georgia |
| | | Kazakhstan |
| | | Kyrgyzstan |
| | | Moldova, Republic of |
| | | Tajikistan |
| | | Turkmenistan |
| | | Ukraine |
| | | Uzbekistan |
| 71 | Turkey | Turkey |
| 72 | Rest of Middle East | Bahrain |
| | | Iran, Islamic Republic of |
| | | Iraq |
| | | Israel |
| | | Jordan |
| | | Kuwait |
| | | Lebanon |
| | | Palestinian Territory, Occupied |
| | | Oman |
| | | Qatar |
| | | Saudi Arabia |
| | | Syrian Arab Republic |
| | | United Arab Emirates |
| | | Yemen |
| 73 | Morocco | Morocco |
| 74 | Tunisia | Tunisia |
| 75 | Rest of North Africa | Algeria |
| | | Egypt |
| | | Libyan Arab Jamahiriya |
| 76 | Botswana | Botswana |
| 77 | South Africa | South Africa |
| 78 | Rest of South African Customs Union | Lesotho |
| | | Namibia |
| | | Swaziland |
| 79 | Malawi | Malawi |
| 80 | Mozambique | Mozambique |

| | | |
|---|---|---|
| 81 | Tanzania | Tanzania, United Republic of |
| 82 | Zambia | Zambia |
| 83 | Zimbabwe | Zimbabwe |
| 84 | Rest of Southern African Development Community | Angola |
| | | Congo, the Democratic Republic of the |
| | | Mauritius |
| | | Seychelles |
| 85 | Madagascar | Madagascar |
| 86 | Uganda | Uganda |
| 87 | Rest of Sub-Saharan Africa | Benin |
| | | Burkina Faso |
| | | Burundi |
| | | Cameroon |
| | | Cape Verde |
| | | Central African Republic |
| | | Chad |
| | | Comoros |
| | | Congo |
| | | Cote d'Ivoire |
| | | Djibouti |
| | | Equatorial Guinea |
| | | Eritrea |
| | | Ethiopia |
| | | Gabon |
| | | Gambia |
| | | Ghana |
| | | Guinea |
| | | Guinea-Bissau |
| | | Kenya |
| | | Liberia |
| | | Mali |
| | | Mauritania |
| | | Mayotte |
| | | Niger |
| | | Nigeria |
| | | Reunion |
| | | Rwanda |
| | | Saint Helena |
| | | Sao Tome and Principe |
| | | Senegal |
| | | Sierra Leone |
| | | Somalia |
| | | Sudan |
| | | Togo |

Source: www.gtap.agecon.purdue.edu

**Table D2: GTAP sectors and description**

| Number | Description |
|---|---|
| 1 | Rice, not husked |
| | Husked rice |
| 2 | Wheat and meslin |
| 3 | Maize (corn) |
| | Barley |
| | Rye, oats |
| | Other cereals |
| 4 | Vegetables |
| | Fruit and nuts |
| 5 | Oil seeds and oleaginous fruit |
| 6 | Plants used for sugar manufacturing |
| 7 | Raw vegetable materials used in textiles |
| 8 | Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds |
| | Beverage and spice crops |
| | Unmanufactured tobacco |
| | Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets |
| | Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes |
| | Sugar beet seed and seeds of forage plants |
| | Other raw vegetable materials |
| 9 | Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live |
| | Bovine semen |
| 10 | Swine, poultry and other animals, live |
| | Eggs, in shell, fresh, preserved or cooked |
| | Natural honey |
| | Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen |
| | Edible products of animal origin n.e.c. |
| | Hides, skins and furskins, raw |
| | Insect waxes and spermaceti, whether or not refined or coloured |
| 11 | Raw milk |
| 12 | Raw animal materials used in textile |
| 13 | Forestry, logging and related service activities |
| 14 | Hunting, trapping and game propagation including related service activities |
| | Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing |
| 15 | Mining and agglomeration of hard coal |

| | |
|---|---|
| | Mining and agglomeration of lignite |
| | Mining and agglomeration of peat |
| 16 | Extraction of crude petroleum and natural gas (part) |
| | Service activities incidental to oil and gas extraction excluding surveying (part) |
| 17 | Extraction of crude petroleum and natural gas (part) |
| | Service activities incidental to oil and gas extraction excluding surveying (part) |
| 18 | Mining of uranium and thorium ores |
| | Mining of metal ores |
| | Other mining and quarrying |
| 19 | Meat of bovine animals, fresh or chilled |
| | Meat of bovine animals, frozen |
| | Meat of sheep, fresh or chilled |
| | Meat of sheep, frozen |
| | Meat of goats, fresh, chilled or frozen |
| | Meat of horses, asses, mules or hinnies, fresh, chilled or frozen |
| | Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen |
| | Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease |
| 20 | Meat of swine, fresh or chilled |
| | Meat of swine, frozen |
| | Meat and edible offal, fresh, chilled or frozen, n.e.c. |
| | Preserves and preparations of meat, meat offal or blood |
| | Flours, meals and pellets of meat or meat offal, inedible; greaves |
| | Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry |
| 21 | Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed rape, colza and mustard oil, crude |
| | Palm, coconut, palm kernel, babassu and linseed oil, crude |
| | Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified |
| | Maize (corn) oil and its fractions, not chemically modified |
| | Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified |
| | Margarine and similar preparations |
| | Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared |
| | Cotton linters |

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| | Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes |
| 22 | Dairy products |
| 23 | Rice, semi- or wholly milled |
| 24 | Sugar |
| 25 | Prepared and preserved fish |
| | Prepared and preserved vegetables |
| | Fruit juices and vegetable juices |
| | Prepared and preserved fruit and nuts |
| | Wheat or meslin flour |
| | Cereal flours other than of wheat or meslin |
| | Groats, meal and pellets of wheat |
| | Cereal groats, meal and pellets n.e.c. |
| | Other cereal grain products (including corn flakes) |
| | Other vegetable flours and meals |
| | Mixes and doughs for the preparation of bakers' wares |
| | Starches and starch products; sugars and sugar syrups n.e.c. |
| | Preparations used in animal feeding |
| | Bakery products |
| | Cocoa, chocolate and sugar confectionery |
| | Macaroni, noodles, couscous and similar farinaceous products |
| | Food products n.e.c. |
| 26 | Beverages |
| | Tobacco products |
| 27 | Manufacture of textiles |
| | Manufacture of man-made fibres |
| 28 | Manufacture of wearing apparel; dressing and dyeing of fur |
| 29 | Tan and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear |
| 30 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials |
| 31 | Manufacture of paper and paper products |
| | Publishing, printing and reproduction of record media |
| 32 | Manufacture of coke oven products |
| | Manufacture of refined petroleum products |
| | Processing of nuclear fuel |
| 33 | Manufacture of basic chemicals |
| | Manufacture of other chemical products |
| | Manufacture of rubber and plastics products |
| 34 | Manufacture of other non-metallic mineral products |

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|---|---|
| 35 | Manufacture of basic iron and steel |
| | Casting of iron and steel |
| 36 | Manufacture of basic precious and non-ferrous metals |
| | Casting of non-ferrous metals |
| 37 | Manufacture of fabricated metal products, except machinery and equipment |
| 38 | Manufacture of motor vehicles, trailers and semi-trailers |
| 39 | Manufacture of other transport equipment |
| 40 | Manufacture of office, accounting and computing machinery |
| | Manufacture of radio, television and communication equipment and apparatus |
| 41 | Manufacture of machinery and equipment n.e.c. |
| | Manufacture of electrical machinery and apparatus n.e.c. |
| | Manufacture of medical, precision and optical instruments, watches and clocks |
| 42 | Manufacturing n.e.c. |
| | Recycling |
| 43 | Production, collection and distribution of electricity |
| 44 | Manufacture of gas; distribution of gaseous fuels through mains |
| | Steam and hot water supply |
| 45 | Collection, purification and distribution of water |
| 46 | Construction |
| 47 | Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel |
| | Wholesale trade and commission trade, except of motor vehicles and motorcycles |
| | Non-specialized retail trade in stores |
| | Retail sale of food, beverages and tobacco in specialized stores |
| | Other retail trade of new goods in specialized stores |
| | Retail sale of second-hand goods in stores |
| | Retail trade not in stores |
| | Repair of personal and household goods |
| | Hotels and restaurants |
| 48 | Land transport; transport via pipelines |
| | Supporting and auxiliary transport activities; activities of travel agencies |
| 49 | Water transport |
| 50 | Air transport |
| 51 | Post and telecommunications |
| 52 | Financial intermediation, except insurance and pension funding |
| | Activities auxiliary to financial intermediation |
| 53 | Insurance and pension funding, except compulsory social security |
| 54 | Real estate, renting and business activities |
| 55 | Recreational, cultural and sporting activities |
| | Other service activities |
| | Private households with employed persons |
| 56 | Public administration and defense; compulsory social security |

| | |
|---|---|
| | Education |
| | Health and social work |
| | Sewage and refuse disposal, sanitation and similar activities |
| | Activities of membership organizations n.e.c. |
| | Extra-territorial organizations and bodies |
| 57 | Dwellings |

Source: www.gtap.agecon.purdue.edu

## E: The regional production shares of maize as part of total cereals

**Table E1: The production shares of maize as part of total cereals**

| No | Region | Cereals | Maize |
|---|---|---|---|
| | | % | % |
| 1 | China | 7.3 | 92.7 |
| 2 | Japan | 99.9 | 0.1 |
| 3 | Rest of Asia | 32.3 | 67.7 |
| 4 | United States of America | 6.5 | 93.5 |
| 5 | Mexico | 27.1 | 72.9 |
| 6 | Argentina | 20.2 | 79.8 |
| 7 | Brazil | 6.7 | 93.3 |
| 8 | EU & EFTA | 62.9 | 37.1 |
| 9 | Middle East | 72.8 | 27.2 |
| 10 | Botswana | 77.3 | 22.7 |
| 11 | South Africa | 6.6 | 93.4 |
| 12 | Rest of SACU | 31.1 | 68.9 |
| 13 | Malawi | 3.3 | 96.7 |
| 14 | Mozambique | 21.4 | 78.6 |
| 15 | Tanzania, United Rep of | 24.3 | 75.7 |
| 16 | Zambia | 5.2 | 94.8 |
| 17 | Zimbabwe | 21.1 | 78.9 |
| 18 | Rest of SADC | 11.0 | 89.0 |
| 19 | Madagascar | 0.3 | 99.7 |
| 20 | Uganda | 45.3 | 54.7 |
| 21 | Rest of SSA | 67.4 | 32.6 |
| 22 | Rest of the World | 58.9 | 41.1 |

Source: FAO, 2006