PRECURSORY REPORT ON THE IMPACT OF GENETICALLY MODIFIED MAIZE ON THE SOUTH AFRICAN MAIZE TRADE

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1. Trends in the Global Production of GMOs

The dawn of agriculture happened 10 000 years ago (Barber, 2005). Since then people used mutation and hybridisation techniques to widely modify all of the plants we use now for food, feed and other purposes. In the 1970's and 80's the "Green Revolution", that was the result of sophisticated breeding programmes, led to more extensive agricultural production. The result of the "Green Revolution" was twofold a success, firstly it prevented starvation in a lot of places all over the world, and secondly productivity was increased on existing cropland (Evans, 1998). This prevented a lot of natural habitat (wilderness) to be lost or converted to cropland (Trewavas, 2001).

According to James (2005), GM (Genetically Modified) crops were grown by 8.5 million farmers in 21 countries and covered a global area of 90 million hectares in 2005 (figure 1.1). The increase from 2004 was 9 million hectares or 11%. The total global area planted to grain crops is 272 million hectares (AFAA, 2003). Thus the commercially grown GM crops (maize, soybean, cotton and canola) constitute for 33% of this area. James (2005) mentions that 2005 marks the tenth anniversary of the commercialisation of GM crops and that the global GM crop area has increased more than fifty-fold since 1996. The 21 countries that grow GM crops include 11 developing countries and 10 industrial countries.

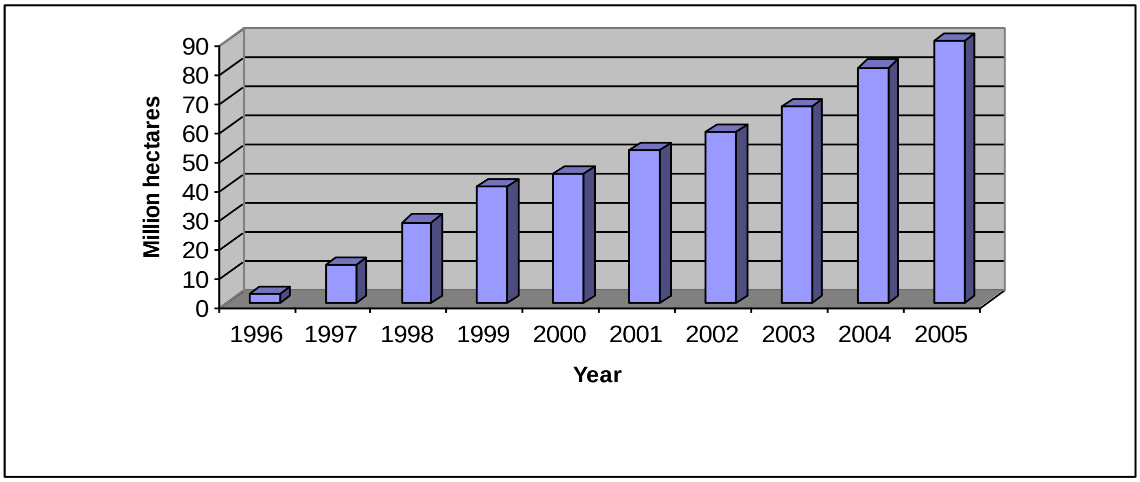

Figure 1.1: The global area under GM crops for the period 1996 to 2005
Source: James, 2005

James (2005) reports that Brazil had the largest year-on-year growth (2004 to 2005) with a doubling of its area from 5 million to 9.4 million hectares. This was followed by the US, Argentina, and India who increased their areas by 2.2, 0.9 and 0.8 million hectares respectively. India had the largest proportional increase by enlarging its GM crop area threefold.

During 2005 the US was still the country with the biggest cultivation of GM crops with 49.8 million hectares followed by Argentina and Brazil with 17.1 million hectares and 9.4 million hectares respectively. South Africa's adoption amounted to 0.5 million hectares in 2005 (figure 1.2)

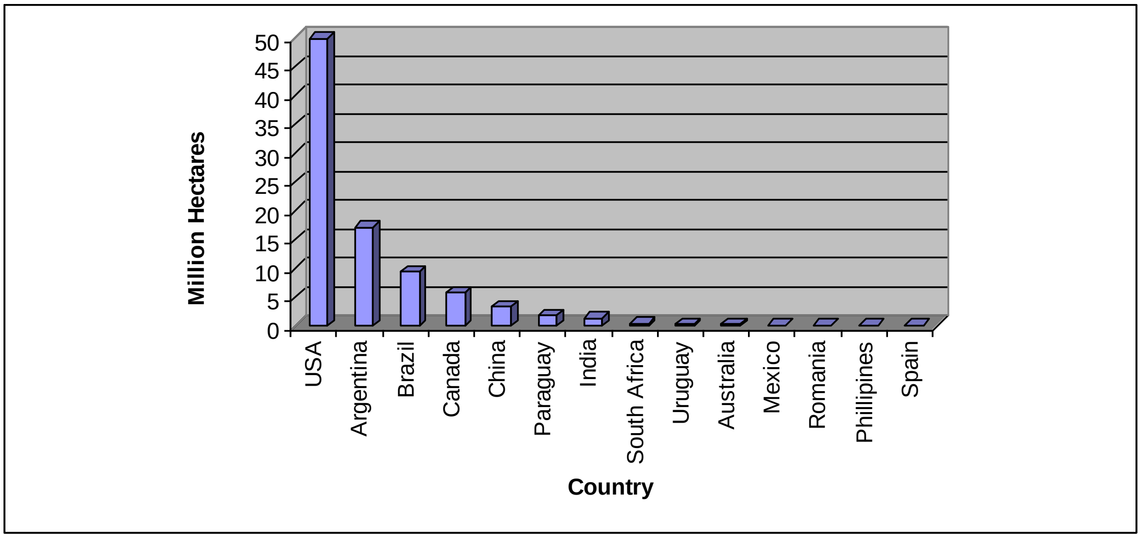

Figure 1.2: Cultivation of GM crops in countries planting 50 000 hectares or more during 2005
Source: James, 2005

GM soybean in 2005 was still the biggest GM crop with 60% of the global GM area, followed by maize with 24%, cotton with 11% and canola that occupies 5% of the area (figure 1.3). Herbicide tolerance, which can be found in soybean, maize, canola and cotton, continued to be the most dominant trait in 2005 occupying 71% (63.7 million hectares). This was followed by Bt insect resistance with 18% and 11% to stacked genes (James, 2005).

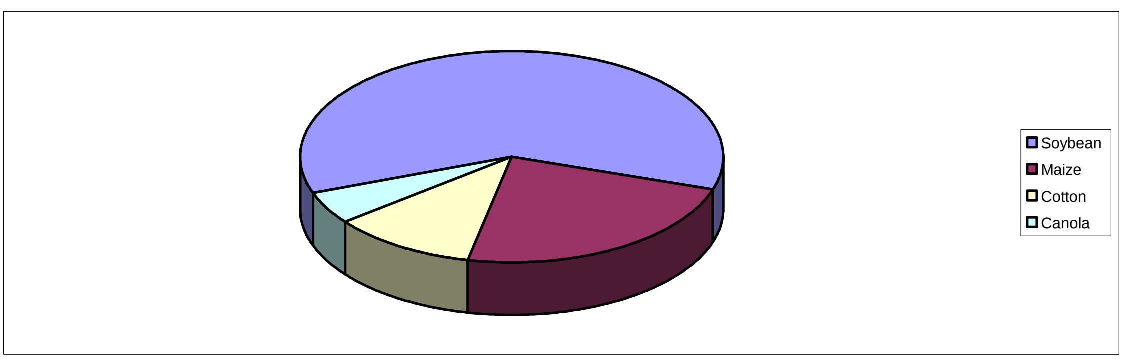

Figure 1.3: The division of the global GM area between the commercially grown GM crops
Source: James, 2005

According to James (2005), 90% of the beneficiary farmers who increased their income, by planting GM crops, were resource poor farmers from developing countries. The countries where a major impact was observed were: China, India, South Africa and the Philippines. The Millennium Development Goal of reducing poverty by 50% by 2015 will help with development in the second decade of commercialisation. James (2005) mentions that there is cause for optimism that the growth in GM crops will continue, and that the Countries of the South (MERCOSUR) will be the major deployers of GM crops in the next ten years.

2. South African maize production

Table 2.1 shows that white maize is still the major maize type in South Africa but with the lowest yield. In South Africa, white maize is used for human consumption and yellow maize is normally for animal consumption and constitutes part of animal feeds.

Table 2.1: South African maize production for 2004/2005

2004/2005	Tons	Hectares	Yield (t/ha)
White Maize	6540700	1700000	3.85
Yellow Maize	4909300	1110000	4.42
Total Maize	**11450000**	**2810000**	**4.07**

Source: Crop Estimates Committee, 2006

3. Trends in South African GMO maize production

Figure 3.1 (and table 3.1) shows that the adoption of GM maize is taking place at a phenomenal rate. Between 2002 and 2004 the area planted to GM white maize increased by 145%, while non-GM White maize decreased with 17%. In the same period the hectares of GM Yellow maize increased with 50%, while non-GM Yellow maize increased with 13% (figure 3.2 and table 3.1).

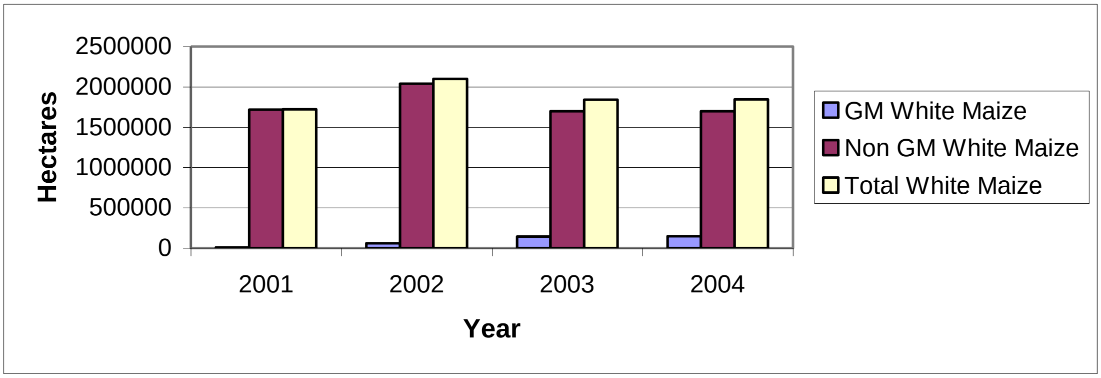

Figure 3.1: The South African adoption of GM White Maize for the period 2001 to 2004

Source: Van der Walt, 2005

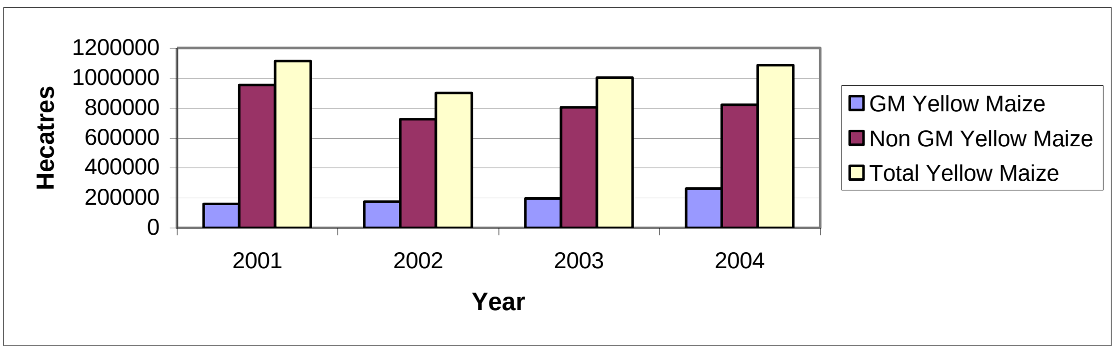

Figure 3.2: The South African adoption of GM Yellow Maize for the period 2001 to 2004

Source: Van der Walt, 2005

Table 3.1: The adoption of GM maize in South Africa

			2001	2002	2003	2004	% change (2002-2004)
White Maize	**GM**	ha	6167	60000	144000	147000	145
	Non Gm	ha	1715833	2040000	1698000	1698000	-17
Total White		ha	1722000	2100000	1842000	1845000	-12
Yellow Maize	**GM**	ha	159554	175780	197000	263000	50
	Non Gm	ha	952446	724220	804300	821500	13
Total Yellow		ha	1112000	900000	1001300	1084500	21
Total Maize		ha	2834000	3000000	2843300	2929500	-2

Source: Van der Walt, 2005

4. World and South African maize trade

4.1 World maize trade trends

The major importers of maize in the world are Japan, Republic of Korea, Taiwan, Mexico, Spain, Netherlands and Egypt with respective shares in world imports of 20%, 10%, 5%, 5%, 3%, 3% and 3%. The world annual growth in quantity imported for the period 2000-2004 was 1%. The growth in the value of world maize imports between 2003 and 2004 was 15% (Annexure table 1). The countries with the biggest annual growth in quantity imported for 2000-2004 were SACU, Syria, Equador and Italy with 38%, 38%, 34% and 33% growth respectively (Annexure table 1).

The major exporters of maize in the world are US, France, Argentina, Brazil, China and Hungary with respective shares in world exports of 52%, 12%, 10%, 5%, 2% and 2%. The world annual growth in quantity exported for the period 2000-2004 was 61%. The growth in the value of world maize exports between 2003 and 2004 were 6% (Annexure table 2). The countries with the biggest annual growth in quantity exported for 2000-2004 were Canada, Brazil, India and Myanmar with 784%, 259%, 152% and 116% growth respectively (Annexure table 2).

4.2 South African maize trade trends

The main importers of South African maize are Zimbabwe, Kenya, Angola, Mozambique, Tanzania and Zambia with respective shares of 46%, 29%, 8%, 6%, 4% and 2% of South Africa’s exports. South Africa’s exports in quantity per annum from 2000-2004 declined with 4% (Annexure table 3). The world imports as mentioned above increased with 1% per annum for the same period. The countries with the biggest annual growth in import quantity of South African maize for the period 2000-2004 were Zimbabwe, Morocco and Zambia with respective growth of 283%, 79% and 74%. South Africa exported a total of 450290 tons of maize in 2004 (Annexure table 3)

The main countries from which South Africa imports maize are Argentina, US, Democratic Republic of the Congo and Brazil with respective shares of 79%, 17%, 2%, and 1% of South Africa's imports. South Africa's imports in quantity per annum from 2000-2004 increased with 38% (Annexure table 4). The world exports as mentioned above increased with 61% per annum for the same period. The countries with the biggest annual growth in export quantity of maize destined for South Africa for the period 2000-2004 were Malawi, Zambia and Argentina with respective growth of 448%, 141% and 448%. South Africa imported a total of 596429 tons of maize in 2004 (Annexure table 4).

Figure 4.2.1 below shows that only Tanzania's and Angola's demand for maize from South Africa are growing at a faster rate than world trade in general and that South Africa 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 South African maize in countries like Congo, Mozambique, Peru and Sweden 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, South African exports have declined or have grown less dynamically in these countries.

In countries like the UK, Spain, Morocco and Zimbabwe the growth in the demand for South African maize can be seen as gains in declining markets. This means that South Africa is increasing its market share in countries where imports are declining or growing below average.

The demand for exports of South African maize in countries like Saudi Arabia and Portugal tend to be bleak. World imports of maize in these markets have increased at a below average rate and South Africa's market share has decreased. This can be classified as losses in declining markets.

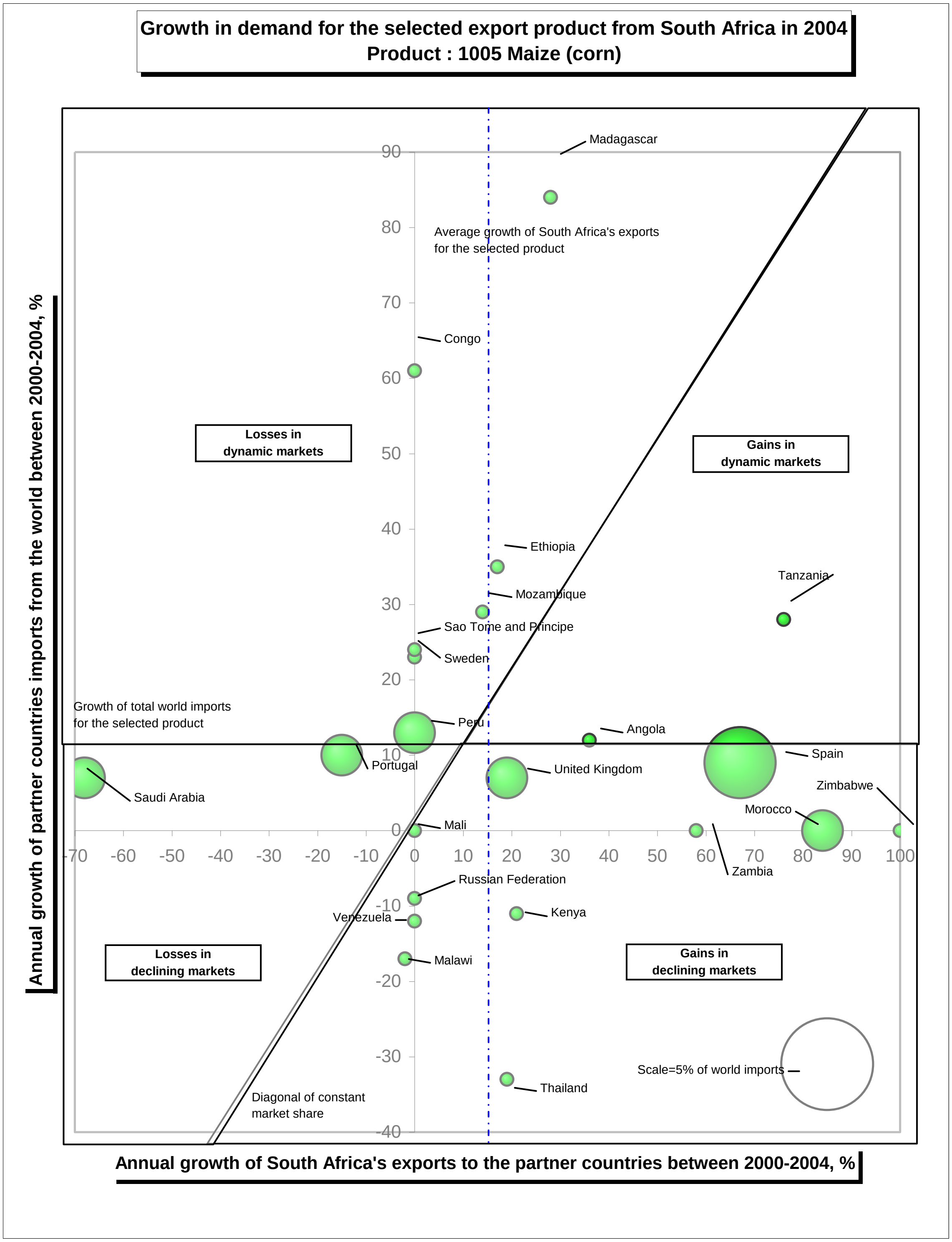

Figure 4.2.1: Growth in the demand for maize exports from South Africa in 2004

Source: Trademaps, 2006

Figure 4.2.2 below shows that in 2004 there were no dynamic suppliers specialised in South African maize imports. France and Argentina can be seen as non-dynamic suppliers specialised in South African maize imports. Countries like the US, Congo and Chile can be seen as non-dynamic suppliers that are under-represented in South African maize imports. The dynamic suppliers that are under-represented in South African maize imports are Brazil, Malawi, Turkey, Mozambique and the Netherlands.

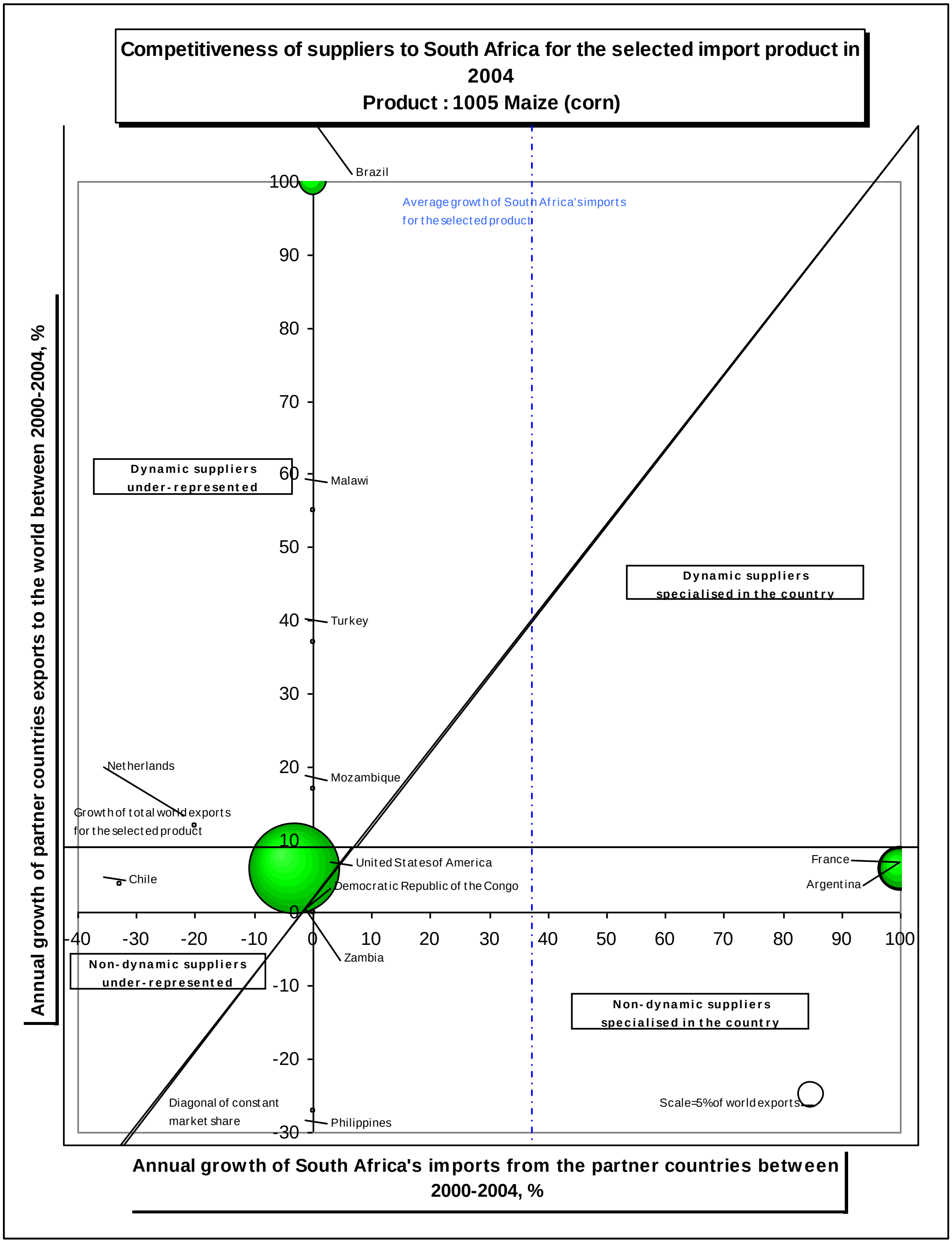

Figure 4.2.2: Competitiveness of suppliers to South Africa for maize imports in 2004

Source: Trademaps, 2006

4.3 South African GMO maize trade

Figure 4.3.1 shows that GMO maize imports only occurred in 5 months during 2004. Total GMO maize imported during 2004 for the purpose of being used as a commodity was 623460 tons. Of this, 200000 tons originated from the US containing less than 1% GMO and the rest from Argentina. February recorded the highest imports of GMO maize, namely 285273 tons (note this includes the 200000 tons from the US). During 2005 no imports for this purpose were recorded.

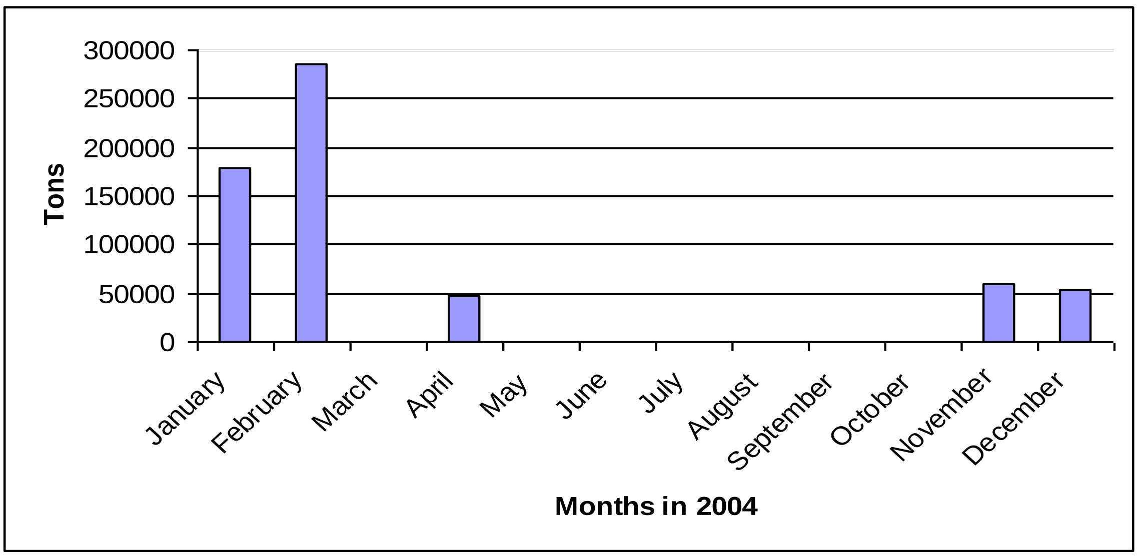

Figure 4.3.1: South African monthly GMO maize imports in 2004 for maize used as a commodity

Figure 4.3.2 shows the amounts of GMO maize imported for planting purposes. The imports in 2004 were much higher than the imports in 2005 which were 302 tons and 24 tons respectively. One can also see that the imports of GMO maize for planting purposes are much less than the imports for commodity use in the same period.

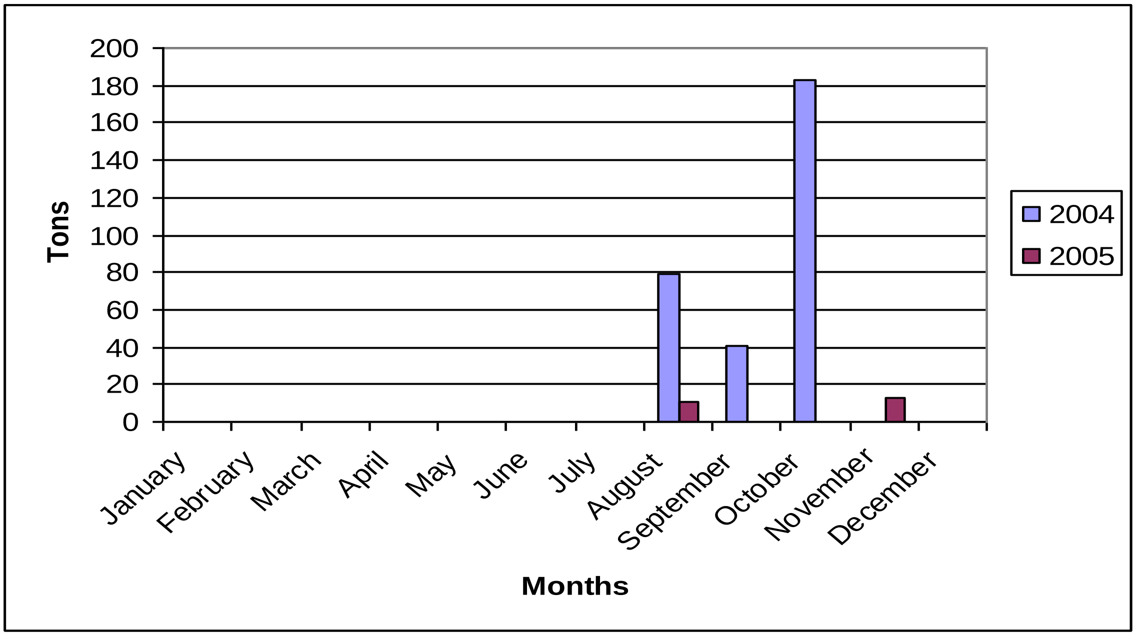

Figure 4.3.2: South African monthly imports of GMO maize for the purpose of planting for the period 2004 and 2005

The other purposes for which GMO maize were imported during 2004 were: Seed production (0.35 ton), planting trials (503 tons) and contained use (0.11 ton). During 2005 the imports for seed production were 5 tons. The total imports of GMO maize for all purposes in 2004 and 2005 were, 624226 tons and 29 tons respectively. The number of permits issued for the importation of GM maize in 2004 totalled 74, and in 2005 it amounted to 33. The countries from which South Africa imported GMO maize during this period were: US, Argentina, France and Philippines.

On the export side, only one permit for GMO maize was issued in 2005 for the purpose of a commodity export and none in 2004. This amounted to 90000 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 ton. 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 with 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 ton respectively.

South African 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 1100 tons respectively (Table 4.3.1).

Table 4.3.1: South African GMO maize exports for the purposes of contained use and planting in the period 2004 and 2005

Purpose	Contained use exports		Planting exports	
	2004 (kg)	**2005 (kg)**	**2004 (kg)**	**2005 (kg)**
January	0.00	0.00	100.00	169000.00
February	0.00	87.28	500007.20	1800.00
March	25.00	0.00	0.00	0.00
April	0.10	0.80	0.00	15030.00
May	65.00	442.97	0.00	0.00
June	13576.30	0.00	0.00	68.78
July	319.10	165.00	0.00	143483.50
August	3.30	0.00	150000.00	100.00
September	0.50	320058.00	1.00	86020.68
October	0.06	0.90	137.43	285117.70
November	6.80	20.00	144.00	400060.00
December	0.76	0.00	0.00	0.00
Total (kg)	**13996.93**	**320774.95**	**650389.63**	**1100680.66**
Total (t)	**14.00**	**320.77**	**650.39**	**1100.68**

The total amount of export permits issued for all purposes during 2004 and 2005 amounted to 56 and 61 respectively and totalled 665 tons and 91422 tons respectively. The countries to which South Africa exported GMO maize in this period were: US, Argentina, France, The Philippines, Japan, Austria, Zimbabwe and Chile.

5. Regulatory Regimes

5.1 International

Nielsen and Anderson (2000) mention that different responses to the introduction of GMOs in agrifood production around the world reflect different national regulatory approaches. Various European countries adopted a highly precautionary approach given the scientific uncertainties associated with GMOs. For example, a *de facto* moratorium on the authorization of new releases of

GMOs since June 1999 was imposed by the European Union. This is despite the fact that Europe hosts some 1570 dedicated biotech companies with R&D investment of €5 billion and that a 15-year investigation into GM crops involving some 81 projects and costing some US$ 64 million has not found any new risks to human health or the environment (Van der Walt, 2001). This study also concluded that with proper regulation food produced from GM crops may even be more safe than conventional. Interesting to note is that Spain continues to grow GM maize.

On the other hand, US authorities do not distinguish between crops developed through conventional breeding techniques and those that have been genetically modified and found safe for use. The US believes that once a GM event has been approved, after a set of rigorous health and environmental testing criteria, it becomes a standard product. Hence, once this process has been completed no discrimination takes place against this product.

Countries that are generally positive about GMOs, such as the US, accuse the European Union of using this issue as an excuse to replace tariff barriers and price-support policies with non-tariff barriers to trade (Sykes, 1999). The most notable case is perhaps the one that was brought to the WTO's Dispute Settlement Mechanism by the US and Canada against the European Union on the approval and marketing of GM products. On 13 May 2003, the US and Canada asserted that (a) A moratorium applied by the EU since October 1998 on the approval of GM products had restricted imports of US and Canadian agricultural products into the EU, and (b) a number of EU member states maintained a ban on the importation of GM products despite the fact that the EU had approved the importation of those products. The Dispute Panel had eventually on Tuesday 7 February 2006 found that the EU and the relevant member states had indeed broken the WTO's rules in this regard. The panel's findings set a precedent for many other nations that have regulations on the labelling and tracing of food and feed products containing GM ingredients. The panel's report of 1047 pages is currently still confidential to the parties to the case, and these parties will now study the findings to finalise their positions.

Countries in Africa have also voiced their concern about the use of GM crops. Zimbabwe and Zambia receiving food aid containing GM grains have initially refused such donations. Zimbabwe banned the import of GM maize after scientists said they were not sure it was safe, but has approved the importation since subject to specific protocols. Zambia has still not approved the import of GM food aid, but regularly imports potentially GM commodities from South Africa and the US. Statements by the World Health Organization, Food and Agriculture Organization, the OECD, the Codex Expert Consultation Group, scientists worldwide, and scientific academies including the French Academy of Science, suggests that there has been no safe review of GM commodities by African countries, other than South Africa.

5.2 International agreements

5.2.1 The Cartagena Protocol on Biosafety to the Convention on Biological Diversity

The Cartagena Protocol is an outflow of Articles 8 (g), 17 and paragraphs 3 and 4 of article 19 of the Convention on Biological Diversity (CBD) which came into place on 29 January 2000. 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.

The protocol gives specific procedures by which commodities, i.e. 'LMOs intended for direct use as food or feed, or for processing, may be imported or exported. This will have an impact on countries importing animal feeds from countries producing GM feed crops, also the importing of commodities from countries producing GM grains.

The Protocol entered into force in September 2003, which was 90 days after the receipt of the 50^{th} instrument of ratification. By January 2006, 130 instruments of ratification or accession have been deposited with the United Nations Secretary General. South Africa gave accession in November 2003.

The US is unable to ratify the Protocol because it is not a party to the CBD. The US has also rejected EU demands that the new protocol take precedence over WTO rules on agricultural trade which require any restrictions to be based on a scientific risk assessment. In contrast, the EU favours the so-called "precautionary approach" that would permit imports of GM foods to be restricted over concerns about their environmental or health impacts, even if the science remained uncertain (Jooste *et al*, 2003)

The Protocol contains several articles that have the potential to impact negatively on international trade in agricultural products as a result of variable interpretations and manipulations. Van der Walt (2001) mentions that the Precautionary Principle and the Substantial Equivalence concept have not been clarified sufficiently and mean different things to different people. It gives leeway to regulators to make decisions in the absence of complete scientific data and may lead 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) that may be interpreted and manipulated in such a way so as to constitute impediments or barriers to international trade.

5.2.2 Codex Alimentarius

Codex Alimentarius is an international organisation responsible for the development of international guidelines for food standards under the joint umbrella of the World Health Organisation (WHO) and Food and Agriculture Organisation (FAO) of the United Nations. It has been tasked with developing international standards for the testing and labelling of GM foods and food products derived thereof (Van der Walt, 2001). 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'.

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

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, there are no examples 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.

Until Codex guidelines are finalised, most countries have no labelling requirements. Those with labelling requirements base these on detectable levels of GM material, e.g. 5 per cent GM content in Japan. The EU and possibly other OECD countries are moving to an audit trail to support the GM free claim, even for food and feed ingredients where detection of novel DNA and its protein is not possible (Jooste *et al*, 2003).

5.2.3 The General Agreement on Tariffs and Trade 1994 (GATT)

GATT relates to the international trade of goods or products. Articles within the agreement prohibit WTO members from imposing quantitative limitations on trade in products or to treat like products differently. It does however allow members to implement the necessary measures to protect human, animal and plant life and health. The agreement also allows members to implement measures "relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption" (Kennett, 2003). Whilst members may adopt such measures as to be barriers towards GMOs, the GATT also requires that such measures may not represent disguised protectionism. Questions may now be raised because of these stipulations, i.e. what exactly are like products in terms of genetic constructs, how safe is safe in terms of biosafety and what exactly public morals are.

5.2.4 The Agreement on Agriculture

The Agreement on Agriculture (AoA) is part of the document finding the World Trade Organisation (WTO) and provides rules for international trade and agricultural production. The AoA is aimed at agricultural reform in such ways as to protect the environment. It gives countries some freedom in devising agricultural support programmes and the governments may impose unilateral restrictions on imports of specific agricultural products, but the agreement outlines the broader commitment to liberalisation. The future of the AoA will be debated between those role-players who view agricultural trade as a means of food security and rural development and those who consider it an end in itself (Murphy, 2002). Whether measures to protect the environment may be used in relation to GMOs is still to be tested.

5.2.5 The Agreement on the Application of Sanitary and Phytosanitary Measures (ASPS)

The ASPS is a separate agreement covering food safety, animal and plant health standards. It ensures that consumers of members of the WTO are supplied with food that is safe for consumption, and at the same time it ensures that domestic producers are not given trade protection through the health and safety regulations. The agreement gives governments the right to implement their own measures regarding human, animal or plant life or health. These measures may even be higher than the international level as long as it is based on sound principles and scientifically justifiable evidence. Discrimination between members with similar conditions prevailing is prohibited. Members may implement precautionary measures on certain imported products if they believe that there is not sufficient scientific evidence ensuring the biosafety of the product. Differences on the sufficiency of scientific research on the imported products may lead to abuse of the agreement for purposes of protectionism in favour domestic products. This can have a major impact on the international trade in GMOs.

5.2.6 The Agreement on Subsidies and Countervailing Measures (ASCM)

The agreement disciplines the use of subsidies, and it regulates the actions that countries can take to counter the effects of subsidies. It says that a country can use the WTO's dispute settlement procedure to withdraw a subsidy or to help remove the adverse effects of a subsidy. The country can also charge extra duties on subsidised commodity imports that are found to negatively affect local producers. The agreement allows governments to subsidise firms' costs for adopting new environmental regulations. This can be used to help farmers implement new regulations in relation to the regulation of GMOs.

5.3 Domestic Regulations

The regulation of GMO resulting in Biosafety in South Africa is constituted by the following acts:

5.3.1 The Genetically Modified Organisms Act, No15 of 1997 (GMO Act)

The GMO Act is the key Biosafety law in South Africa. In 1999 all previous guidelines regarding the legislation of GMOs were replaced by the GMO Act. The Act regulates the use of GMOs and also regulates the imports and exports of living GMOs. When GMOs are being imported or exported, approval must be obtained by receiving a permit. There are three considerations 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 the 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 are taken into account when decisions are made regarding the commercialisation of GMOs.

The fact that South Africa only has one deciding body when it comes to GMOs, the GMO executive council, improves the efficiency of the Act. The US, for instance, has three bodies which complicates their decision making processes.

Draft legislation, to ensure safe and responsible developments related to the field of GMOs, was tabled in Parliament in October 2005. The Genetically Modified Organisms Amendment Bill seeks to change existing laws to ensure South Africa complies with provisions of the Cartagena Protocol on Biosafety, to which South Africa is a signatory. The bill is aimed at ensuring the development, production, use and application of genetically modified organisms, is carried out in a safe and responsible manner. The bill will extend the scope of current legislation to include the export of GMOs and will create a "Biosafety Clearing-House", under the auspices of the National Department of Agriculture. The primary function of the body will be to oversee the exchange of scientific, technical, environmental and legal information on living modified organisms, essentially any living organism that has a novel combination of genetic material obtained through the use of biotechnology

In November 2005 the Executive council decided to put on hold all imports of GM maize into South Africa. According to them it is not a moratorium, but merely a temporary hold on the consideration of applications for now events until a study on the impact of GM maize on South African trade is concluded. The study is conducted under leadership of Mrs. Elize Koekemoer of the DTI and will be done in close consultation with all role players in the industry. The study is currently expected to be completed by May 2006 (News24 2005)

5.3.2 The Environment Conservation Act, No 73 of 1989 (ECA)

The ECA and Certain Regulations require mandatory environmental impact assessments (EIA) for GMOs, but are in practise impractical to implement. The EIA regulations require that EIAs should be conducted prior to the genetic modification of an organism, and not prior to the release of the GMO into the environment (Mayet, 2000)

5.3.3 The Foodstuffs, Cosmetics and Disinfectants Act, No 54 of 1971 (FCD Act)

According to Mayet (2000), the FCD Act sets out control measures to ensure food safety. It is also the Act under which regulations for labelling or identity preservation (IP) of GMOs and the products in which they are found should be challenged. The food safety of GM food commodities such as grains, fresh fruit and vegetables that fall within the definition of GMO in terms of the GMO Act, will be regulated through the risk assessment procedure under the GMO Act. The FCD Act to date does not require any GM food to be labelled. The labelling of GM foodstuffs is one of the most important ways of safeguarding the right of consumers to choose what they want to consume. It also helps by providing the means for tracing GMOs through the food chain.

5.3.4 The National Environment Management Act, No107 of 1998 (NEMA)

NEMA has general application but contains a few critically important provisions that enhance other environmental laws. These include biosafety legislation in particular by regulating decision making and placing assured obligations on “polluters”. NEMA also augments such legislation by providing a number of incentives for civil society to enforce environmental laws (Mayet, 2000).

6. Literature review of relevant studies

6.1 The GTAP Model

From the literature reviewed it is apparent that the Global Trade Analysis Project (GTAP) model is most often used to estimate the potential impacts of GMO trade regulations. GTAP is a multi-regional computable general equilibrium (CGE) model that was developed by Prof. Hertel at the University of Purdue in collaboration with the International model for Policy Analysis of Agricultural Commodities and Trade. The GTAP is a comparative static model that allows for a base period scenario to be determined. “Shocks”, of appropriate magnitudes consistent with economic theory, practical realities and possible negotiation positions, can then be applied to the base period. 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 (Jooste *et al.,* 2003).

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 Leontief and constant elasticity functions because of constant returns to scale. Each commodity is produced by a distinct sector using intermediate inputs that is sourced domestically and from all over the world. The model uses the Armington assumption, which states that: Imported and domestic intermediate goods are assumed to be imperfect substitutes, which is represented by the constant elasticity of substitution (CES) function. Firms can now decide on the source of their imports, which will determine the composite price of their imports. The mix of imported and domestic goods will then be based on this price. 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).

Stone *et al.,* (2002) mentions 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, namely: private households, government and savings. At the macro level a variable share of regional income is compiled 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 a detailed representation of demand conditions (Hertel, 1997).

Trade is modelled as a series of import and export flows defined by commodity and region of origin or destination. Armington elasticities are defined as regionally standard across all agents, this 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).

6.2 Studies done with the GTAP model

6.2.1 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 that raises important questions and dilemmas for policy-makers and agricultural producers in Australia. By analysing these issues, it 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 namely, 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 was due to those 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 for 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:

<u>Scenario 1: Productivity Gains</u>

An output-augmenting technical change shock was applied to the GM oilseeds and grains sectors. This reflects the 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. A 6% and 7.5% productivity shock 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 differ 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 Segregation and Identity Preservation

(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

Results of different scenarios: Australia

Scenarios	Results
Scenario 1	**General:** – There would be virtually no changes in any of the overall macroeconomic variables, including total imports and total exports for Australia. – The major change would take place in the composition of trade, concentrated in the two GMO producing sectors (grains and oilseeds). – 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. – 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. **Production:** – The production of GM crops would increase across the board at the expense of conventional crops. – North America and China experience an expansion in the output of industries using GMO inputs (such as livestock, meat and dairy and other food). – 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. **Exports:** – The largest producer of GM crops, North America, would gain the most from the assumed changes in productivity. – 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

Scenarios	Results
	advantage in production of several commodities from the productivity increases in the GMO sectors. **Imports:** – Imports of GMO goods increase for most countries. – Imports of conventionally produced oilseeds and grains show declines in most regions, but substantially so in North America.
Scenario 2	**General:** – 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. **Production:** – Output gains under Scenario 1 are reduced once consumer resistance is introduced. – 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. – Output remains virtually unchanged in North America and China. **Exports:** – Exports increase less than in Scenario 1. – Exports to markets where consumers are considered to be very sensitive decrease significantly, but opportunities open in markets where consumers are less sensitive. **Imports:** – Imports in sensitive regions drop, whilst imports by less sensitive regions remain nearly the same.
Scenario 3	**General:** – The largest regulatory costs would be incurred by those regions experiencing the highest degree of consumer resistance. – 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. **Production:**

Scenarios	Results
	− Australia's production of GM grains and oilseeds is the lowest in Scenario 3 compared to the previous scenarios. This is due to the fact that the original productivity gains assumed in Scenario 1 have not only been eroded by consumer preference shifts (Scenario 2), but also by higher input costs due to regulation. − The results obtained for Australia are consistent across all regions. − Increased costs would result in the affected regions losing export market share to those regions that do not incur similar additional costs. **Exports:** − GM grains exports still increase, but at half the level observed in Scenario 1. − Exports of agricultural produce other than crops, such as livestock, processed meat, dairy and other foods do not change significantly. − 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. **Imports:** − 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 compared to domestic products. − 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 the 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.

6.2.2 GM food technology abroad and its implications for Australia and New Zealand

The study by Anderson and Jackson (2004a) emphasises the necessity that food-exporting countries such as Australia and New Zealand (hereafter ANZ) need to weigh the potential economic benefits from biotechnology development against any negative environmental risks associated with producing GM crops. Additional costs of segregation and identity preservation needs 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 them adopting 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, namely:

- 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 to be 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 in the policy response simulations it is assumed that countries banning GM supplies exclude imports from GM-adopting countries of both the GM varieties and GM-free substitutes.

Assumptions made on the consumption side by Anderson and Jackson (2004a) includes 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 adoption of GM coarse grains and oilseeds by the US, Canada and Argentina without and with ANZ also adopting are examined, and 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 of 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 too. 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.

Results of different scenarios: Australia and New Zealand

Results
Volume and price effects: • 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. • The same is true for New Zealand but with smaller orders of magnitude. • 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. • Lower domestic prices for these products leads to an increase in domestic consumption, but those increases would not prevent coarse grain net export earnings from rising instead of falling. • Oilseeds net exports would fall less in the absence of an EU moratorium but not in its

Results
presence, should Australia adopt GM varieties not approved in the EU
National trade balance and net welfare effects: • The effect on the aggregate trade balance is positive for ANZ in the absence of the EU moratorium and negative in its presence. • 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. • 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 were the EU moratorium continues. • 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. • 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, it lowers ANZ's production, prices and net exports of coarse grain and oilseeds even more than in scenario 1. It also has a negative effect on ANZ wheat and rice markets. The global economic welfare improves, if there are no trade policy responses with US$4.3 billion per year. • If ANZ don't adopt, Australia loses twice as much than in scenario 1 while New Zealand loses almost no more. • If ANZ adopts, the Australian economic welfare would improve more than in scenario 1 in the absence of the EU moratorium, while New Zealand's would be no different. • In the presence of the EU moratorium, Australia's welfare would improve, but less than in scenario 1, while New Zealand's would improve more. • In scenario 3 if Australia adopts there will be a net loss of US$ 13 million per year (Terms of trade [-$46 million], Benefits from technical change [$17 million] and improved allocative efficiency [$16 million]). If Australia doesn't 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: • In no cases in scenario 3 are the effects more than 1%. • The terms of trade changes from GM adoption abroad are only small. • If Northeast Asia copies the EU moratorium, Australian farm households would be

Results
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 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.

6.2.3 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 it would have been if Western Europe banned the 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 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 one-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:

Scenario1:

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 of 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 consumers preferences are expressed through market mechanisms and not through government regulation. It analyses the implications if the Western European countries made 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 that are 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.

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. – Crops for which export opportunities are more favorable 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. – 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. – In North America cereal grains are also used as livestock feed, and hence the lower feed prices lead to an expansion of the livestock and meat processing sectors. – Production increases, and 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%, respectively for cereal grains and oilseeds. – 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%. – Production in North America will decline by 10%, pulling resources such as land out of this sector. – The ban does not affect the production and exports of cereal grains to the same extent as for oilseeds.

Scenarios	Results
	– Access to the Western European markets, when GMO adopting countries are excluded, expands for Sub-Saharan African countries. – Increased export opportunities for Sub-Saharan African countries would stimulate production. – Import substitution to more expensive inputs for downstream industries in Western Europe leads to declines in production in these downstream sectors and competing imports to increase. – 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. – In contrast to scenario 2, cereal grains and oilseeds will experience production increases, although not to the same extent as in scenario 1. – The partial reduction in import demand leads to minor increases in production in Western Europe and has a marginal impact on prices. – Sub-Saharan Africa loses export shares to the GMO adopting regions.

Source: Jooste *et al*., 2002 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 gaining from lower import prices; and domestic production of maize and soybean are 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.
- By 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.

6.2.4 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 answer 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. Firstly the productivity impacts of GMOs are based on micro-level data for cotton and on field trial data for rice in China, thus detailed specific GMO cost savings , estimated specifically for China, are included. Secondly the multi-sector framework captures backward and forward linkages between GM crops, also in the using and supplying sectors. Lastly 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:

<u>Baseline scenario:</u>

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 the 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 of the 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 the 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 of 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 increases by 5%.

Results

The results of the 4 scenarios are summarized 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.

Results of different scenarios: China

Scenarios	Results
Scenario 1	– The supply price will be 10.9% lower in 2010. – Demand by the domestic textile industry increases significantly and reaps the benefits from lower input costs. – Exports increase, but are very small in relation to domestic demand. – 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. – Output reacts sluggish due to low income and price elasticities of demand. – The increase in exports is significant, but exports as percentage total output remain low due to large domestic demand. – Use of Bt cotton and the commercialisation of GM rice will 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. – The aggregate demand for labour also increases.

Scenarios	Results
	– Land prices decline because factor demand is lower due to the yield increasing effect of the GM technology. Lower land prices favour other sectors such a grains and livestock.
Scenario 3	– A ban on GM rice from China by the EU, Japan, Korea and South East Asia will result in only marginal increases in exports of GM rice. – The increase in the trade balance and welfare gains is significantly lower compared to the previous scenario. – 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. – Labelling costs increase the import price of soybeans resulting in a drop in imports, which negatively affects the US and the South American countries. – The combined result is better prices for Chinese soybean producers and 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. – The estimated macro economic welfare gains far outweigh the public biotechnology research expenditure. – 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. – China should continue to promote its GM biotechnology, including commercializing its GM food crops.

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

6.2.5 More GTAP studies

There are more studies than these that also used the GTAP model to investigate the impact of different GMO scenarios. From these studies it is evident that there are no other assumptions that can be gathered that is not already included in the studies mentioned above. For completeness the studies will be listed:

Anderson, K. and Jackson, L.A. (2004b). *Global Responses to GM Food Technology: Implications for Australia.* Canberra: Rural Industries Research and Development Corporation, RIRDC Publication No 04/…, RIRDC Project No UA-57A.

Nielsen C. & Anderson K. (2000b). *GMOs, Trade Policy, and Welfare in Rich and Poor Countries*. Policy discussion paper no. 0021. Centre of International Economics Studies, Adelaide University, Australia.

Nielsen C., Anderson K. & Robinson, S. (2000). *Estimating the Economic Effects of GMOs: the Importance of Policy Choices and Preferences*. Policy discussion paper no. 0035. Centre of International Economics Studies, Adelaide University, Australia.

6.3 Common assumptions from the GTAP studies

From the literature reviewed one can draw numerous common assumptions which will be very important in the methodology and scenario development for the model in this study. The assumptions used in the reported studies can be summarised as follows:

GMO coarse grains received a total factor output augmenting productivity shock of 7.5%, (from the older studies assigned only a 5% productivity increase).

The adoption of GMO coarse grains in the US and Canada was 45%; in Latin America and ANZ it was 30 %; all other countries adopted 15%.

In most cases the SIP costs were not included because it was implicitly introduced by conservative cost savings due to the new technology. Another way of introducing SIP costs was to introduce negative augmenting technology shocks.

The elasticities of substitution between GM and non-GM products or commodities were set at low levels in the constant elasticity of substitution (CES) nesting. Producers first have to choose between imported and domestic maize and then choose whether to use GM or non-GM maize in the production process.

In most cases were consumer awareness were involved, a 25% reduction in demand for GMOs were introduced. There was no loss of welfare measures for consumers who does not want to consume GMs but had to because the market forced them, i.e. not to segregate.

No negative risks net of positive environmental benefits associated with producing GM crops were assumed.

Population growth, changes in income and living standards were held constant. All factors of production except natural resources were assumed to be perfectly mobile.

When it comes to market structure, perfect competition, full employment of all factors and flexible exchange rates were assumed.

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Annexure

Table A1: World Importers of maize

Source: Trademaps, 2006

Importers	Value imported in 2004, in US$ thousand	Quantity imported in 2004	Quantity unit	Unit value (US$/unit)	Annual growth in value between 2000-2004, %	Annual growth in quantity between 2000-2004, %	Annual growth in value between 2003-2004, %	Share in world imports, %
World estimation	14197734	0	No quantity		10	1	15	100
Japan	2936519	16479437	Tons	178	12	1	22	20
Korea, Rep. of Korea	1431563	8371011	Tons	171	10	0	37	10
Taiwan, Province of (China)	817771	4860242	Tons	168	9	-1	20	5
Mexico	745120	5802837	Tons	128	8	-1	2	5
Spain	489119	3006084	Tons	163	9	-5	-8	3
Netherlands	464706	2241893	Tons	207	16	4	26	3
Egypt	431090	3817925	Tons	113	-1	-6	-16	3
Germany	362767	1325821	Tons	274	19	9	43	2
Italy	338647	1506046	Tons	225	31	33	43	2
Colombia	332085	2272078	Tons	146	12	5	26	2
Malaysia	330943	3790714	Tons	87	8	12	20	2
Algeria	298432	1790349	Tons	167	12	3	41	2
United Kingdom	280389	1276815	Tons	220	7	-1	7	1
Canada	253240	2099737	Tons	121	10	8	-34	1
Portugal	211114	1122728	Tons	188	10	1	8	1
Morocco	201922	1223013	Tons	165			29	1
Israel	199223	1255014	Tons	159	19		57	1
France	194677	322142	Tons	604	24	0	38	1
Turkey	190477	1049744	Tons	181	22	8	-31	1
Saudi Arabia	179205	0	No quantity		7	2	23	1
Indonesia	177675	1088928	Tons	163	5	0	5	1
Iran (Islamic Republic of)	168650	58466365	Tons	3	47	15	-26	1
Peru	159768	1097015	Tons	146	13	6	30	1
Chile	144727	984688	Tons	147	0		13	1
United States of America	140298	325243	Tons	431	-3	7	-17	0
Belgium	133975	558946	Tons	240	14	6	-4	0
Greece	121760	513459	Tons	237	13	1	29	0
Tunisia	120572	723304	Tons	167	8	-4	53	0
Syrian Arab Republic	118582	854891	Tons	139	44	38	13	0
Zimbabwe	106483	319974	Tons	333				0
Dominican Republic	93894	778813	Tons	121	1	-5	-7	0
Costa Rica	91440	540178	Tons	169	14	3	32	0
Poland	90583	265147	Tons	342	7	-14	120	0
Venezuela	89352	488822	Tons	183	-12	-21	6	0
Guatemala	84062	559109	Tons	150	19	11	21	0
Russian Federation	75096	448828	Tons	167	-9	-8	148	0
South Africa	73701	596429	Tons	124	37	38	12	0
Jordan	72259	427327	Tons	169	12	2	-1	0
Ecuador	67833	464052	Tons	146	41	34	45	0

Table A2: World Exporters of maize

Source: Trademaps, 2006

Exporters	Value exported in 2004, in US$ thousand	Quantity exported in 2004	Quantity unit	Unit value (US$/unit)	Annual growth in value between 2000-2004, %	Annual growth in quantity between 2000-2004, %	Annual growth in value between 2003-2004, %	Share in world exports, %
World estimation	11719540	0	No quantity		8	61	6	100
United States of America	6137514	48741184	Tons	126	6	-1	23	52
France	1425128	6009231	Tons	237	6	-5	7	12
Argentina	1193805	10692004	Tons	112	6	1	-3	10
Brazil	597336	5030999	Tons	119	123	259	59	5
China	324259	2318161	Tons	140	-12	-18	-82	2
Hungary	269903	1319537	Tons	205	17	4	30	2
Germany	224661	947474	Tons	237	26	13	35	1
India	210785	0	No quantity		145	152	3375	1
Thailand	199783	1175323	Tons	170	89	101	633	1
Ukraine	175572	1091585	Tons	161	74	44	183	1
South Africa	112949	450290	Tons	251	15	-4	-18	0
Austria	85385	237746	Tons	359	34	18	26	0
Chile	70694	62758	Tons	1126	4		-17	0
Canada	60464	348059904	Tons	0	16	784	36	0
Belgium	54266	232098	Tons	234	47	54	27	0
Netherlands	52471	69726	Tons	753	12	8	11	0
Spain	46635	168824	Tons	276	31	15	29	0
Romania	43336	310839	Tons	139	41	31	185	0
Italy	42845	177550	Tons	241	-8	-20	146	0
Zambia	39236	0	No quantity					0
Paraguay	33390	370246	Tons	90	13	16	-47	0
Bulgaria	27128	251747	Tons	108	40	34	0	0
Serbia and Montenegro	22675	105063	Tons	216	3	1	-55	0
Free Zones	21875	6109	Tons	3581	42	32	5	0
Slovakia	19421	50767	Tons	383	22	19	-26	0
Moldova, Rep.of	15967	85184	Tons	187	13	29	-4	0
Turkey	15805	10525	Tons	1502	37	24	21	0
Myanmar	14302	0	No quantity		30	116	24	0
Tunisia	12273	70313	Tons	175	19	14	15	0
Greece	12065	51981	Tons	232	56	48	51	0
Viet Nam	11950	70256	Tons	170	-11	54	981	0
Portugal	10498	44169	Tons	238	24	26	205	0
Uganda	10435	63029	Tons	166	37	67	141	0
Czech Republic	9140	44924	Tons	203	57	39	-28	0
Indonesia	9074	32679	Tons	278	6	-7	64	0
United Kingdom	8964	19693	Tons	455	19	7	81	0
Tanzania, United Rep. of	8149	53747	Tons	152	75	62	-56	0
Guatemala	7670	4500	Tons	1704	11	-14	122	0
Mexico	7413	15416	Tons	481	19	14	30	0

Table A3: South African Maize Exports

Source: Trademaps, 2006

Importers	Exported value 2004 in US$ thousand	Share in South Africa's exports, %	Exported quantity 2004 (Tons)	Export trend in value between 2000-2004, %, p.a.	Export trend in quantity between 2000-2004, %, p.a.	Export growth in value between 2003-2004, %, p.a.
World	112949	100	450290	15	-4	-18
Zimbabwe	52217	46	184549	285	283	-35
Kenya	33098	29	145914	21	6	329
Angola	9307	8	39126	36	15	84
Mozambique	7245	6	44381	14	3	-38
Tanzania, United Rep. of	4180	4	18807	76	52	-2
Zambia	1703	2	5223	58	74	-88
Thailand	801	1	1892	19	32	48
Spain	694	1	341	67		11467
Sweden	559	0	2881			
Venezuela	394	0	209			
Morocco	391	0	1410	84	79	41
Malawi	266	0	224	-2	-39	-57
Mali	263	0	1032			
Russian Federation	249	0	193			
United Kingdom	195	0	521	19	10	-4
Congo	146	0	55			70
Peru	130	0	194			
Madagascar	112	0	825	28	15	-93
Ethiopia	99	0	41	17		-19
Portugal	99	0	500	-15		
Saudi Arabia	84	0	58	-68		
Sao Tome and Principe	76	0	300			
Democratic Republic of the Congo	74	0	102	-33	-55	-91
Egypt	61	0	40	-43		
Netherland Antilles	57	0	200			

Table A4: South African maize imports

Source: Trademaps, 2006

Exporters	Imported value 2004 in US$ thousand	Share in South Africa's imports, %	Imported quantity 2004 (Tons)	Import trend in value between 2000-2004, %, p.a.	Import trend in quantity between 2000-2004, %, p.a.	Import growth in value between 2003-2004, %, p.a.
World	73701	100	596429	37	38	12
Argentina	58515	79	508669	110	86	143
United States of America	12166	17	62633	-3	6	97
Democratic Republic of the Congo	1606	2	17500			14500
Brazil	524	1	3273		-66	-80
Chile	223	0	40	-33		
Zambia	187	0	150		141	-55
Malawi	176	0	1205		448	15
Mozambique	140	0	2899			678
France	79	0	5	139	50	-78
Philippines	35	0	10			
Netherlands	21	0	5	-20	25	133
Turkey	21	0	5			-90