Modelling Possible Impacts of GM Crops on Australian Trade

Staff
Research Paper

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The views expressed in this paper are those of the staff involved and do not necessarily reflect those of the Productivity Commission. Appropriate citation is indicated overleaf.

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Preface

A key strand of the Productivity Commission's contribution to informing policy development, has been the provision of empirical assessments of the economic impacts of different industry assistance and regulatory arrangements. Over time, the Commission's remit has broadened from a focus on economic regulation, to encompass assessments of social and environmental regulation. All can have significant implications for trade, growth and living standards.

The present modelling study has been motivated by calls within Parliament and the wider community for a better understanding of the implications of genetic modification of agricultural produce for Australia's trade and income levels.

Its contribution is to build on existing cross-country modelling by including an explicit treatment of regulation costs. The modelling is confined to non-wheat grains and oilseeds and, among other assumptions, constructs some specific scenarios about productivity, consumer responses and regulation, to illustrate potential trade impacts.

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Abbreviations

ABSP	Agricultural Biotechnology Support Project
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ANZFA	Australia and New Zealand Food Safety Authority (now Food Standards Australia New Zealand)
BSE	Bovine Spongiform Encephalopathy
Bt	Bacillus thuringiensis
CES	Constant Elasticity of Substitution
CND	Canadian dollars
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EC	European Commission
EU	European Union
ERS	Economic Research Service
GDP	Gross Domestic Product
GM	genetically modified
GTAP	Global Trade Analysis Project
HoRSCIST	House of Representatives Standing Committee on Industry Science and Technology
HoRSCPIRS	House of Representatives Standing Committee on Primary Industries and Regional Services
ISO	International Standardisation Organisation
NZ	New Zealand
OECD	Organisation for Economic Co-operation and Development
OGTR	Office of the Gene Technology Regulator
RIRDC	Rural Industries Research and Development Corporation
SIPs	segregation and identity preservation systems

SPS	sanitary and phytosanitary standards
TBT	technical barriers to trade
US	United States
USDA	United States Department of Agriculture
US EPA	United States Environment Protection Agency
WTO	World Trade Organization

Glossary

allocative effects	A measure of changes in resource allocation that occur as a result of policy changes. If a policy shift causes economic activity to move closer to an undistorted equilibrium, this represents a gain in allocative efficiency. If a policy causes economic activity to move away from an undistorted equilibrium, this represents a loss.
Armington assumption	Imported and domestic competing goods are imperfect substitutes in demand, representing product differentiation by country of origin.
contamination threshold	The percentage of GM material allowable as accidental contamination in non-GM products before labelling is required.
downstream industries	Industries that may use GM crops as inputs in their production processes, such as the processed foods, livestock and meat/dairy industries.
externalities	Spillover effects that occur when one person's actions affect another person's wellbeing and the relevant costs and benefits are not reflected in market prices.
genetically modified crops	Crops that have had their genetic structure altered through biotechnology to contain genes with specific traits, such as pest resistance or herbicide tolerance.
identity preservation	Documentation verifying whether a food or ingredient is, or is not, from a GM source.
kilotonnes	10^6 kilograms.
precautionary principle	Regulators may take pre-emptive actions to avoid possible negative outcomes, despite scientific uncertainty.
revealed preference	Demand theory based solely on how consumers have responded to changes in prices and income.
segregation	Deliberate separation of GM crops and products from non-GM crops and products to prevent cross-contamination.

substantial equivalence	Food derived using genetic engineering is assumed to be substantially equivalent to conventional food if its composition, nutritional value, metabolism, intended use and content of undesirable substances is the same.
terms of trade effects	These measure changes in the relative price of exports and imports for a region. Where export prices rise more quickly than import prices, or export prices fall less quickly than import prices, there is a terms of trade gain for that region.
traceability	The ability to trace the production of a crop or food product back to the farm gate, such as through segregation and identity preservation.

OVERVIEW

Key points

- The work presented in this report explores a more comprehensive modelling framework for analysing the economic implications of genetically modified (GM) agricultural products by including an explicit treatment of regulation costs.
- The modelling was undertaken with three sets of assumptions regarding the productivity of selected GM crops, and possible consumer and regulatory responses of Australia and its major trading partners, looking at trade in non-wheat grains and oilseeds.
- Under all scenarios, GM technology in non-wheat grains and oilseeds is estimated to have little effect on Australia's overall trade position. This result stems from both the small share these chosen sectors have in Australia's overall trade, and the small share of GM technology prevailing in these sectors in Australia.
- Under the scenario involving GM-induced productivity gains, markets for GM crops expand, for both Australia and its trading partners, while non-GM markets contract.
- When GM-specific regulation costs and consumer resistance are added to the modelling framework, the GM crop markets do not gain as much and non-GM markets do not decline as far. Output and exports in Australia's downstream commodity markets, such as meat, dairy and processed foods, decline as a result of these estimations, while imports increase. Downstream markets fare best in regions that produce significant amounts of GM crops and that experience no GM-specific regulatory costs.
- According to the modelling, if Australia continued to produce low levels of GM crops whereas most of its trading partners expanded their adoption of GM crops, Australia could lose some opportunities to expand (or even maintain) its market shares over time (whether regulatory costs are imposed or not), both in its primary crop markets and downstream commodity markets.

Overview

Aim of the study

This study examines the possible impacts of genetically modified (GM) technology on Australia's output, exports and imports of non-wheat grains and oilseeds using various assumptions about productivity gains, consumer attitudes and regulation costs in Australia and overseas. Since changes in Australia's trading patterns do not occur in isolation, the paper also provides an indication of some of the effects on Australia's main trading partners.

What are GM crops?

GM crops are produced using scientific techniques that enable the alteration or transfer of genetic material across living cells and organisms, with an aim to engineer particular traits or characteristics. Some of the potential benefits of GM crops include improved productivity (by way of higher yields and lower input costs), more sustainable production, lower adverse externalities (eg from pesticide use), and expansion in the range of products available for consumption. Concerns have also been raised, however, over the potential for adverse effects of producing and consuming GM crops, including risks to human health, harm to the environment, further concentration of supply and, for some, unacceptable ethical implications.

Rate of uptake

GM crops have been adopted rapidly since commercialisation began in 1996, increasing over 30 fold between 1996 and 2001. In 2001, GM crops were grown by approximately 5.5 million farmers in 13 countries and covered around 4 per cent of the world's agricultural land. Between 2000 and 2001, the area planted with GM crops increased by 19 per cent, despite consumer concerns in some markets. However, this adoption has not been uniform across countries or crop species. The most significant adopters have been the United States, Argentina, Canada and China. The dominant GM crops have been soybeans, corn (maize), cotton and canola.

Productivity gains

The estimates of productivity gains attributable to GM crops used in the modelling are based on a number of studies that have reviewed the net on-farm effects of GM crops across several countries. While the evidence has been mixed, it appears, on balance, that net productivity gains in the order of 5 to 10 per cent have been achieved for a range of GM crops.

Regulatory and consumer responses

Regulatory and consumer responses to GM crops will be key determinants of the uptake of GM products. Consumer responses vary according to differences in income levels, cultural backgrounds, food safety concerns, the amount of information available to consumers, and consumer understanding of the technology. To date, consumer attitudes to GM foods have varied greatly between countries. Survey data indicates that US consumers have the most ‘relaxed’ view about the use of gene technology in food production. By contrast, European consumers appear more cautious toward GM food, and this view has been strengthening over time (ERS 2001b). Australian consumer attitudes to GM food appear to fall somewhere in between.

The regulation of GM crops typically depends on consumer attitudes in the country concerned, the perceived risks associated with GM food, the level of government involvement required to manage those risks, the relative strength of lobby groups, and the degree of compliance with international rules and standards deemed appropriate. It can also be influenced by more strategic trade issues, such as the desire to ‘protect’ fledgling (in this instance, biotechnology) industries. Thus, the regulation of GM crops and foods varies significantly between countries.

There are costs associated with meeting regulatory requirements for the production of GM crops. Many of these are included in the seed and technology costs faced by farmers. Other costs may include the use of Segregation and Identity Preservation (SIP) systems to verify the origin of crops and to help in labelling the GM status of agricultural products. The size of these additional costs will depend on the crop concerned, the volume of production going through SIP systems and, importantly, the threshold level of ‘contamination’ accepted. The size of these costs is important because it has been argued that under certain conditions, such costs can more than outweigh the potential agronomic benefits offered by GM crops (Foster 2001).

Modelling assumptions

This paper uses the global general equilibrium modelling framework GTAP (Global Trade Analysis Project). GTAP is an international trade model (Hertel 1997) consisting of 57 commodities and 66 regions, and was developed to provide researchers with a consistent framework for analysing global economic issues.

Of the major GM crops, corn (maize) is included in the 'grains' category and soybeans, cotton seed and canola are included in the 'oilseeds' category. Wheat is not included in the grains category, as there is currently no commercial production of GM wheat anywhere in the world.

Three scenarios are developed:

Scenario 1 — assumes a 7.5 per cent productivity improvement in the GM non-wheat grains sector and a 6 per cent productivity improvement in the GM oilseeds sector, with no other changes.

Scenario 2 — builds on scenario 1 by introducing consumer resistance to, and regulation of, GM crops in some regions. A 25 per cent reduction in demand for GM crops is imposed in those regions viewed as experiencing greater consumer resistance (including Australia). Two different assumptions are made about the size of regulation costs based on the allowable 'contamination' threshold in a region, for example, Australia, at a 1 per cent allowable accidental contamination level, incurs higher regulation costs than Korea, at a 3 per cent level of contamination. No increases in regulatory costs are imposed for the remaining regions (notably the United States and Canada).

Scenario 3 — allows for the evolution of policy using a series of simulations whereby productivity gains associated with GM crops eventually decline to 2 per cent, and regulation is gradually removed over time, in line with more relaxed consumer sentiment. This scenario is conducted under two assumptions about Australia's adoption of GM crops — first, that Australia maintains its current GM market share and, secondly, that Australia increases its GM market shares to the levels of North America.

These scenarios represent only three of many feasible scenarios regarding GM adoption and productivity, consumer and regulatory responses. As such, results should be interpreted strictly within the context of the assumptions made, particularly since regional situations are liable to change.

Results

In all scenarios considered, absolute changes to overall import and export flows for Australia are very small. However, the share of GM production does increase. The minimal impact on Australia of the assumed productivity improvements in GM sectors, and the minor effects of consumer and regulatory responses, can be attributed to the small shares of oilseeds and non-wheat grains in Australian trade. For example, oilseeds account for about 4 per cent of total crop production in Australia and only 10 per cent of that production is assumed to be genetically modified. Therefore, 90 per cent of the oilseeds sector does not experience the productivity gains from the GM technology. Oilseeds represented only about 7 per cent of total crop exports for Australia in 2000-01.

Under all scenarios, the largest impacts on trade and income occur in those regions that currently have significant GM sectors, such as North America. These regions gain market share with their cheaper GM crops, which also benefit the production of downstream commodities such as meat and dairy (that is, cheap GM grains used as cattle feed decrease input costs for meat production, as compared with using non-GM feed).

When consumer resistance and regulation costs are accounted for, output and trade in non-GM commodities decline less, and producers do not take up GM varieties to the same degree. This is because consumer resistance to GM ensures a larger market for non-GM varieties and also because regulation costs, such as those stemming from segregation, cancel out some of the cost advantages bestowed upon GM varieties through higher productivity. Under this scenario, those regions with the largest unregulated GM sectors gain most, displacing some of the exports of small, regulated GM markets such as Australia.

Under the policy evolution scenario, Australian markets for non-wheat grains and oilseeds would stagnate if Australia chose not to increase its adoption of GM crop technology. However, even when increased adoption rates are assumed, overall gains to Australia’s trade position are small. If Australia’s adoption does not increase, while its trading partners expand their use of GM crop technology, Australia may lose some opportunities to raise (or even maintain) its market shares over the long run, both in its primary crop markets, and also in its downstream markets, such as meat, dairy and processed foods. However, this assumes that no GM-free price premiums develop in the marketplace.

1 Introduction

In 2001, genetically modified (GM) crops covered almost 53 million hectares and were grown by approximately 5.5 million farmers in 13 countries (James 2002). The area covered by GM crops is more than 30 times greater than it was in 1996, the year after the first GM crops were commercialised. GM crops are now grown on an area equivalent to approximately twice the size of the United Kingdom, and have been estimated to represent around 4 per cent of the world's agricultural land area (Anderson and Nielsen 2001a; James 2001b). Much of this expansion has been attributed to the potential on-farm benefits offered by GM crops, such as the reduced use of conventional pesticides, more convenient and flexible crop management, and higher productivity and net returns (James 2001a). GM crops are now used in many common food items around the world, such as bread, potato chips and cooking oils, as well as in animal feed.

The rapid adoption of GM crops has raised considerable debate in Australia and overseas. Much of this debate has been driven by concerns over the potential for adverse effects (although a number of benefits have also been argued). Concerns have been raised over food safety, implications for the environment, consumers' right to choice, and several economic aspects of GM adoption (including the potential for further concentration in agricultural and food markets). In many countries, these concerns have contributed to consumer suspicion of GM crops, and have encouraged governments to introduce new regulatory regimes. Potential on-farm effects, and emerging regulatory and consumer responses, could all have implications for trade in these crops.

Not surprisingly, questions are starting to be asked in Australia about how the global trading of GM crops is likely to affect Australia's trade flows, especially as the farming sector generates approximately 18 per cent of Australia's total exports (ABARE 2001). Uncertainty over both consumer and regulatory responses worldwide, and the size of farm benefits, however, makes answering such questions particularly challenging.

The possible trade implications for Australia of global trade in GM crops and related impacts on economic welfare are analysed in this paper. The evidence on farm-level effects of GM crops is reviewed, along with the consumer and regulatory environments that have been emerging in recent years, and which are likely to shape the circumstances under which GM crops are produced. The trade and economic welfare implications for Australia are quantified under several regulatory and consumer response scenarios. Results are also given for some of Australia's main trading partners, including China, Japan, Korea, New Zealand, North America and the European Union. Two major GM crop types are considered — oilseeds (which includes cottonseed, soybeans and canola) and grains (which includes corn/maize, sorghum and barley, but *excludes* wheat). The modelling was undertaken using the global general equilibrium model GTAP (Global Trade Analysis Project) and its database for 1997.

1.1 What are GM crops?

Genetically modified crops are developed using techniques of 'modern' gene technology (also referred to in this report as 'biotechnology'). These techniques alter or transfer genetic material across living cells and organisms (such as plants, animals and bacteria) to engineer particular traits or characteristics (ANZFA 2000; OGTR 2002a). The term 'modern' is often used to distinguish such techniques from traditional plant and animal breeding techniques which have been used to achieve genetic changes for hundreds of years.

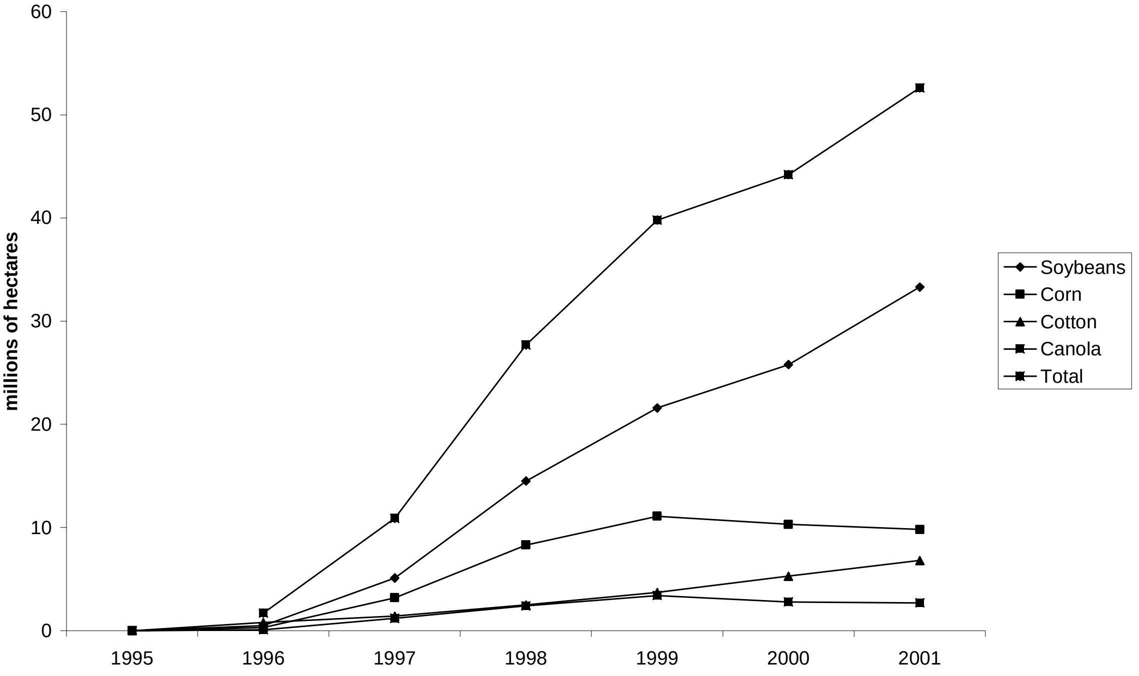
The application of modern gene technology may offer producers several distinct advantages over traditional techniques. First, its use can result in easier, more precise and faster transfer of genetic material between living organisms. For some applications this can reduce the time required to successfully develop a new trait (ANZFA 1999). Second, modern gene technology use means that genetic material can be transferred between distantly related organisms or species that would not have been achievable using traditional breeding techniques (ANZFA 1999; OGTR 2002b). An example is the insertion of genes from fish into plants to provide resistance to cold temperatures. Gene technology can therefore be used for various purposes (such as improving crop performance or developing new products with enhanced nutrients), and involve different types of modifications (such as within and across species). Some of the potential applications of gene technology in relation to crops are discussed in appendix A.

For its advocates, modern gene technology holds the promise of markedly improved productivity performance, more sustainable agricultural production, and expansion in the range of agricultural products. For its opponents, it remains an unproven technology which brings with it significant economic and environmental risks, further concentration of agricultural markets and, for some at least, questionable health and ethical implications.

1.2 Current adoption of GM crops

The worldwide adoption of key GM crops has been rapid in recent years (figure 1.1). In 2001, the area planted with GM crops increased 19 per cent compared to 2000 (despite consumer concerns in some markets). Much of this growth has been driven by the significant uptake of GM soybeans (figure 1.1).

Figure 1.1 **Worldwide growth in farm area by key GM crops, 1995–2001**



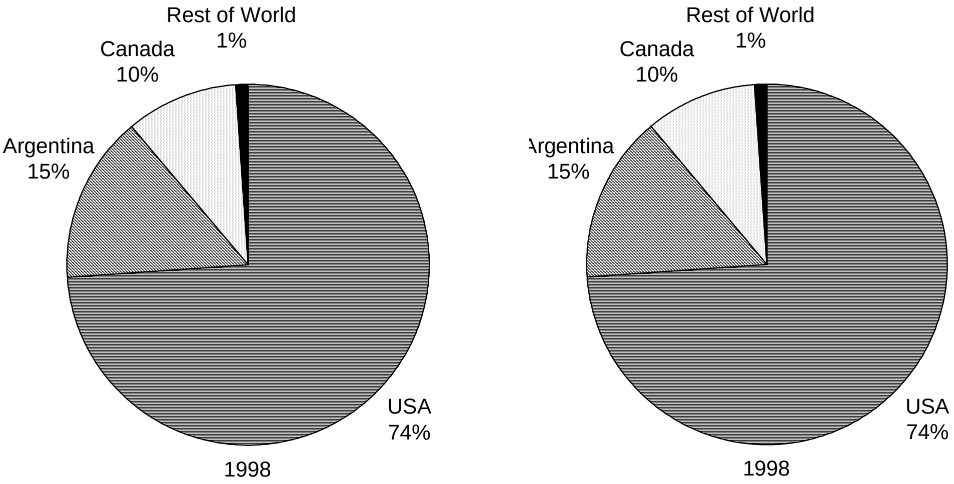
Data sources: James (1998, 2001a, 2002) .

Key features of GM crop adoption

There are several distinctive features of the recent adoption of GM crops.

First, the uptake of GM crops has not occurred uniformly across countries. Four countries together accounted for 99 per cent of the total crop area in 2001, when 68 per cent of all GM crops were grown in the US, 22 per cent in Argentina, 6 per cent in Canada and 3 per cent in China. These shares did not change dramatically from previous years (figure 1.2).

Figure 1.2 **World shares of GM crops by area, 1998 and 2001**



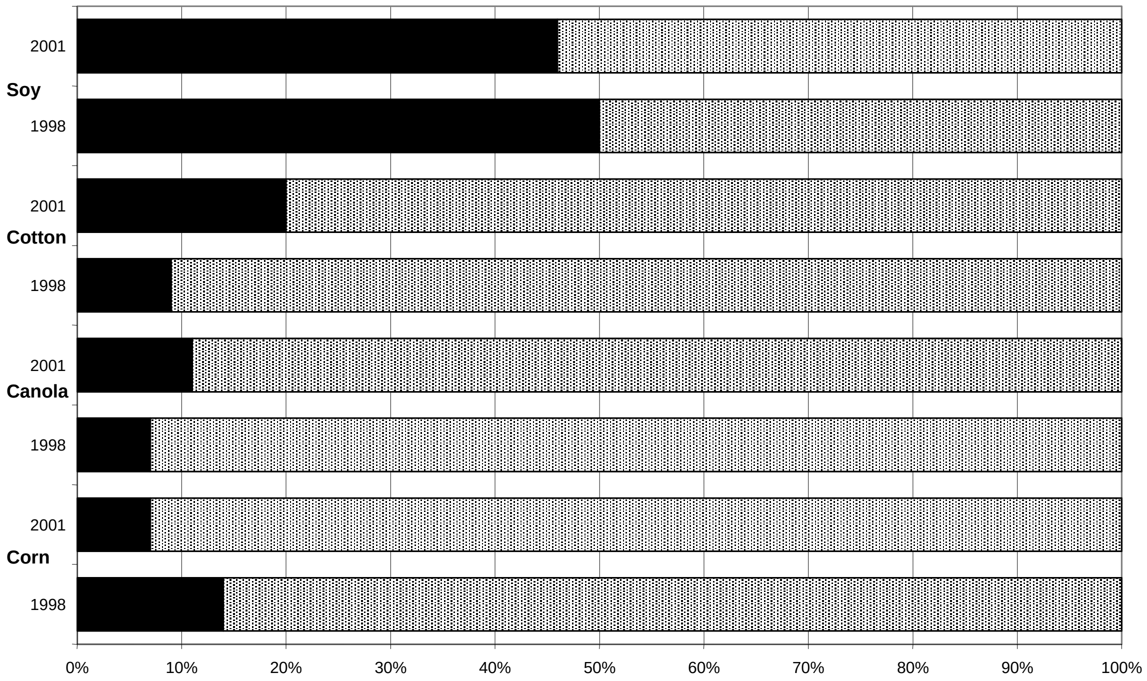
Data sources: James (1998, 2002).

Second, adoption of GM varieties has almost exclusively involved only four main crops — soybeans, corn, cotton, and canola, which represented approximately 63, 19, 13 and 5 per cent of the global area of GM crops respectively in 2001 (James 2002). Herbicide tolerant soybeans are by far the most common GM crop, grown in seven countries and representing 63 per cent of the global GM crop area. While other GM crops, such as tobacco and potatoes, are commercially grown, their contribution to total GM crop area is small (EC 2000; James 2001b).

The fact that there are only four main GM crops does not mean their impact on world agricultural and food markets is small. These four crops are extensively used as inputs in food products, and are important in food processing and animal feeds. For example, soybeans and canola provide around 45 per cent of the world's edible oils, and 75 per cent of the vegetable protein meals commonly fed to livestock.

A third feature of the adoption of GM crops is that, for the four main crops, a significant proportion of their total worldwide production (GM and non-GM) now comprises GM varieties. Around 19 per cent of the total global area grown with these crops were planted with GM varieties in 2001 (up from 16 per cent in 2000). In the case of soybeans, 46 per cent of the total global production area was planted with GM varieties in 2001. In the case of cotton, 20 per cent of the total production area was GM. GM varieties made up 11 per cent of canola production and 7 per cent of corn production (James 2001a). GM and non-GM shares of total crop area for these four crops in 2001 and 1998 are illustrated in Figure 1.3, with changes in cotton and corn shares standing out. In the case of cotton, strong growth has occurred in the United States and China, with the GM share of the total cotton crop in the United States increasing from 55 to 72 per cent between 1999 and 2000. The global declines in GM shares of corn crops also reflects changes in the United States. Reasons given include low infestations of European Corn Borer pests in the United States in 1999 and 2000 lowering perceived needs for Bt[1] corn, along with farmer uncertainty over markets for GM corn (James 2001a, 2001b).

Figure 1.3 **Percentage of world crop area grown with GM varieties (by crop), 2001 and 1998**



Black areas refer to GM shares.

Data sources: James (1998, 2001a).

The situation in Australia

Farming accounts for around 2.6 per cent of Australia's gross domestic product and approximately 18 per cent of Australia's total exports (ABARE 2001). Of the four major GM crops, Australia is a major grower of cotton and canola. In 2000-01, Australia produced approximately 741 kilotonnes of cotton (accounting for approximately 1.5 per cent of world area harvested with cotton), and 1661

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[1] Bt is the soil bacterium Bacillus thuriengiensis, used to insert resistance to insect pests in genetically modified crops.

kilotonnes of canola (approximately 4 per cent of world production). Together, canola and cotton represented almost 20 per cent of the gross value of Australia's total principal crop production in 2000 (ABS 2001). Australia grows smaller amounts of corn and soybeans producing approximately 355 and 105 kilotonnes respectively in 2000-01 (representing only 0.56 per cent and 0.33 per cent of Australia's total principal crop production by gross value). Other crops Australia grows on a large scale include wheat, barley and sugarcane (which made up 44 per cent, 7.9 per cent and 8 per cent of the gross value of Australia's principal crops in 2000 respectively) (ABS 2001). For each of these three crops, trials of GM varieties have been undertaken in Australia.

To date, however, only four licences for the commercial release of GM plants have been granted in Australia. These licences are for two varieties of cotton and two varieties of carnations.[2] In 2001, 33 per cent of Australia's cotton crop was GM (the maximum allowed under requirements specified by the National Registration Authority).[3] However, Monsanto, a multinational biotechnology company has recently lodged an application for the commercial release of GM canola in Australia (OGTR 2002f). Further, over 100 field trials have been approved to test GM varieties of wheat, barley, sugarcane, field peas, potatoes, lupins, pineapples and apples .

In addition to the four licences allowing the commercial release of GM plants in Australia (OGTR 2002d), a total of 23 applications for the sale of GM foods have been received with 17 approved. Another four applications are pending Ministerial approval. Products approved include glyphosate tolerant soybeans, insect resistant cotton, insect resistant corn, glyphosate tolerant canola, and high oleic acid soybeans (Food Standards Australia New Zealand 2002) (. Appendix B contains a list of currently approved field trials and food in Australia.

1.3 Aim of this paper

The fluid nature of both consumer and regulatory developments worldwide regarding GM crops, and their use in food, raises important questions and dilemmas for policy-makers and agricultural producers in Australia.

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[2] The two varieties of GM cotton include *Bt* (insect resistant) and Roundup Ready (herbicide resistant) cotton. The two varieties of carnation include a violet carnation and a carnation with improved vase life (OGTR 2002c).

[3] These regulations were introduced by the National Registration Authority to restrict the potential development of pesticide resistance in insect populations.

- How sensitive, for example, is Australia's agricultural trade to changing regulatory and consumer responses overseas?
- What overall impact can be expected from GM crops when economy-wide effects and adjustments are taken into account?

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. It can also assist in informing the community more broadly.

This paper provides an analysis of the economic and trade implications of the introduction of GM technology in the grains (which, in this report, does not include wheat) and oilseeds sectors. The first part of the paper provides a detailed review of the evidence of the on-farm benefits achieved from the main GM crops commercialised to date. It also assesses the consumer and regulatory environments in which GM crops are being introduced, including any associated costs. The second part of the paper models the trade implications for Australia, and its main trading partners, of the introduction of GM oilseeds and grains under different domestic and international regulatory and consumer response scenarios. This quantitative assessment, using the general equilibrium model GTAP, draws on information provided in earlier chapters. It expands on past work by explicitly including regulatory costs and modelling the combined impacts of both GM grains and oilseeds on Australia's trade position and economic welfare.

The paper does not specifically address a number of other 'non-trade' issues relating to GM crops, such as consumer choice, the ethical and environmental implications of GM food production, and intellectual property rights.[4] The analysis in this paper should therefore be seen as a useful *component* of what needs to be a broad analysis of all the costs and benefits to Australia of GM crops.

1.4 Structure of the paper

The next chapter identifies the factors affecting the supply of GM crops, including a review of the evidence on the on-farm benefits of GM crops compared to conventional varieties. Chapter 3 reviews consumer attitudes to GM crops and national and international regulatory responses. This chapter links developments in consumer attitudes with regulatory responses in various countries, and reviews the nature and magnitude of regulatory costs that may impact on trade. The main implications of chapters 2 and 3 for the modeling work are summarised at the end of

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[4] Several issues relating to consumer choice were discussed in Dolling and Peterson 2000. Other useful sources discussing these issues include Biotechnology Australia (2001); CSIRO (1999); EC (2000); HoRSCIST (1992).

each chapter. The modelling approach and assumptions are outlined in chapter 4, alongside a description of the scenarios of productivity improvements, and consumer and regulatory responses used. The results of the modelling are then described in Chapter 5. Chapter 6 concludes the paper and provides insights for future research.

2 Production of GM crops

The current supply of GM crops worldwide has been shaped by a number of factors. One of these is the extent to which GM crops compare with conventional varieties in providing benefits to farmers. The evidence to date of on-farm benefits from GM crops has been mixed; varying across crops, regions and time, depending on different weather conditions, disease occurrence and pest and weed infestations. Overall, the results, however, are positive.

In this chapter, the evidence on the factors likely to affect the supply of GM and non-GM crops is examined. In particular, the chapter reviews the performance of the main GM crops currently grown — cotton, soybeans, canola and corn. The conclusions are used to develop estimates of productivity effects for the oilseed and grains sectors resulting from the introduction of GM technology to be used in the modelling work (with oilseeds including cottonseed, soybeans and canola, and grains including corn).

2.1 Factors affecting supply of GM and non-GM crops

In the absence of national or international bans or moratoriums (see chapter 3), the main factors that will affect the worldwide supply of GM crops in the near to medium term include:

- the extent to which on-farm benefits and costs from growing GM crops compare to conventional crops — including changes in yields, the costs of inputs (such as pesticide, herbicide, fertiliser, seed and fuel costs), and labour and management practices and flexibility;
- the degree of consumer acceptance of GM foods, both domestically and internationally — consumer acceptance may affect access to markets and the prices received by GM crop producers; and
- the costs of meeting regulatory requirements for GM and non-GM crop management, segregation and labelling.

This chapter reviews the first factor, while the other two are discussed in chapter 3.

2.2 On-farm benefits and costs from GM crops

GM crops can offer benefits to farmers through changes in farm yields and costs of production. Benefits can also arise from improved flexibility and ‘convenience of operations’, such as more choice of when to apply herbicides. Other ‘non-monetary’ benefits include better health conditions for workers and improved water quality in downstream rivers (see table 2.1).

Table 2.1 **Types of potential benefits from GM crops**

Potential benefits	*GM characteristic*	*Examples*
More efficient herbicide use and/or safer herbicide use, including: • fewer herbicide applications • less total herbicide use • more flexible timing of application • use of more environmentally benign herbicides and less tillage	Herbicide tolerance	Glyphosate tolerant soybeans, canola and corn
Reductions in pesticide use and/or more efficient pest control and yield protection	Disease/insect tolerance	*Bt* cotton, corn, potatoes Virus resistant papaya, tobacco and melon
Yield improvements	Plant productivity improvements	High yielding rice and cotton
Improved resistance to environmental conditions (eg resistance to droughts, easier production in marginal areas)	Improved tolerance to biological stresses	Research on drought tolerant corn
New or improved foods	Quality improvements	Ripening delayed tomatoes, improved soybean oil quality, ‘golden rice’ containing additional nutrients

Source: Adapted from Nelson (1999).

At the same time, however, GM crops may also increase costs, most obviously in terms of seed price premiums and technology fees — estimated at up to 30 per cent for GM corn and soybeans (EC 2000). Requirements to purchase seed every year as part of contractual arrangements may also push annual seed purchase costs up.[1] Farmers may also have to accept some yield losses in order to gain benefits in terms

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[1] Concerns have been raised on this point about the use of market power by biotechnology companies, and the use of contracts under which access to GM crops is provided. However, seed price premiums may fall if GM crops are more widely grown and if competition grows in the GM seed sector. For a discussion of these issues see EC (2000) or Buckwell et al. (1999).

of herbicide use (as appears common for herbicide-tolerant soybeans). In addition, there may also be some operating costs if farmers have to provide for buffer zones or refuges of non-GM crops as part of contractual arrangements with seed companies or to meet regulatory requirements.

Evidence on the on-farm effects of GM crops can be gathered from observing farm decisions on whether to adopt GM crops (ie anecdotal evidence from observed behaviour), and from direct farm or field level studies (ie empirical evidence).

In terms of anecdotal evidence from observed behaviours, the rapid global adoption of GM crops over the last 5–6 years suggests that farmers have experienced benefits (EC 2000; Furtan and Holzman 2001; Marra, Pardey and Alston 2002). Although a slow down in the rate of expansion has been occurring recently, GM crop plantings are still expected to rise over their levels in 2001-2002, suggesting that farmers are receiving, and continuing to expect, some benefits (James 2001a; see also Reuters 2002). A problem with this anecdotal evidence is that it does not provide information on the magnitude or the nature of the benefits being derived by farmers. Nor does it provide information on the extent to which adoption may have been driven by expectations rather than experience.

Assessing the performance of GM crops, however, is not straightforward as there are many ways in which their use can affect farm benefits. For example, decisions to adopt GM crops can affect yields, production costs (such as pest management and seed costs including technology fees), and management flexibility and convenience (such as on crop rotation or the timing and number of herbicide applications) (see, for example, Fernandez-Cornejo and McBride 2002; Marra, Pardey and Alston 2002). However, many studies to date have not captured all the factors influencing adoption, especially those which extend beyond immediate yields, cost savings or short-term profitability measures (EC 2000). It can often take farmers several seasons to learn how to make the most of a new technology so that farm level benefits may take some time to manifest themselves.

In addition, seasonal production conditions, such as weather, pest infestations and global market conditions, make isolating GM impacts difficult. While data on yields are widely available, information on factors which influence yields, such as temperature or weed control method, is often missing (EC 2000). It can also be difficult to extrapolate findings across countries or regions as conditions (land, water, insect population, etc) differ. Finally, methodological and time period variations between studies make it difficult to come up with a consistent picture of the net impacts of GM technology.

Further complicating the process of obtaining estimates of productivity gains associated with the adoption of GM technology is the fact that different studies look at different outcome measures.

Table 2.2 **Summary of farm benefits/costs from GM crops**

Crop type and study (country)	*Farm effects compared to non-GM varieties*	*Source*
Corn/maize		
Corn, insect-resistant (United States)	Yield gains between 3 and 12 bushels per acre.	Carpenter and Gianessi (2001)
	Yield gains up to 8%.	Furtan and Holzman (2001)
	Yield gains of 4–8%.	Marra, Carlson and Hubbell (1998)
	Net returns lower by 3.4%.	Fernandez-Cornejo and McBride (2002)
Corn, herbicide resistant (United States)	Yields varied between -10% and +25%.	Foster (2001)
Soybeans		
Soybeans, herbicide-tolerant (United States)	Yields lower on average between 2% and 6 %. Herbicide use increased.	Benbrook (2001)
	Yields lower by 6.7%.	Benbrook (1999)
	Yields ranged from -2% to -11%.	Hofer et al (1998)
	Herbicide applications reduced 12%. Net weed control costs down.	Carpenter and Gianessi (2001)
	Yields lower by 4% and 3%.	Carpenter (2001)
	Average net returns not affected.	Fernandez-Cornejo and McBride (2002)
	Yields 5–10% lower.	Elmore et al. (2001)
	Yields 3% higher.	ERS (2001b)

Table 2.2 **(continued)**

Crop type and study (country)	*Farm effects compared to non-GM varieties*	*Source*
Cotton seeds		
Bt Cotton, insect-resistant (United States)	Pesticide use down but mixed yield results	Marra, Carlson and Hubbell (1998)
	Net revenue gains in 1998 and 1999.	Carpenter and Gianessi (2001)
	Yield gains of 9% for *Bt* cotton insecticide use 17% lower.	
	Net returns higher by 2.2%.	Fernandez-Cornejo and McBride (2002)
	Average increase in net income of US$20 an acre.	Gianessi et al (2002)
Bt Cotton, insect-resistant, (Australia 1999/2000 growing season)	Average number of sprays (all pest) reduced by 40 per cent.	Cotton Research and Development Cooperation (2000)
	54% recorded some economic benefit, but individual comparisons variable with extremes at either end.	
Bt Cotton, insect-resistant (India 1998-99)	Yield gains of 40% and 37%.	James (2000)
Bt Cotton, insect-resistant, (China)	Production costs 28% lower, but yields no different.	Huang et al (2001)
Cotton, herbicide-tolerant (United States)	Yield changes of between -7% and 2%. Herbicide costs reduced for all varieties.	Carpenter and Gianessi (2001)
Canola/rape seed		
Canola, herbicide-tolerant (Canada)	Yield -7.5% on average and system cost $US4.75 per acre lower. Estimated net gain of US $ 28 per hectare.	Fulton and Keyowski (1999)
	Yield changes of between -15% and + 15%.	EC (2000)
	Yield gains of 10% and herbicide costs lower. Overall profit advantage of CND$10.58 per acre.	Canola Council of Canada (2001)

As shown in table 2.2, some studies report changes in yields, others in pesticide or herbicide use, and yet others net return or profitability. While estimates of profitability can be useful (as they capture many of the yield and cost variables that affect farm decisions in a net figure), care is needed in making comparisons, both because of the various ways in which profits can be calculated, and because prices received for crops can affect results.[2] However, a general review of the evidence to date is useful in informing estimations of productivity gains to be used in the modelling process. Elaboration of some of the limitations associated with this evidence and a summary of findings are provided below.

2.3 Summary of evidence to date

Table 2.2 presents some of the key findings from a number of studies that have reviewed the on-farm performance and effects of GM crops.

In the case of insect-resistant Bt corn, yield gains have been widely reported. For example, Furtan and Holzman (2001) reported that trials in the United States found Bt corn yield gains of up to 8 per cent over conventional varieties. However, they highlight that studies on Bt corn have shown that yield gains are highly sensitive to pest infestations, along with weather conditions.

Yield improvements alone may not necessarily increase the profitability or net benefits of GM crops. The EC (2000), for example, noted that although significant yield gains had been observed for Bt corn, its cost-effectiveness depended on growing conditions (particularly the degree of corn borer infestations). Overall, profit results were summed up as being variable.

One reason yield improvements may not increase net farm benefits is that GM seeds are often more expensive than conventional seeds. The EC (2000) reported seed cost premiums of between 3 Euro and 35 Euro per hectare. However, Marra, Carlson and Hubbell (1998) found improved yields of between 4 and 8 per cent outweighed the higher Bt corn seed costs and technology fees.

Several studies on **herbicide-tolerant corn** have indicated that neither yields nor profits have increased (ERS 2001b). Fernandez-Cornejo and McBride (2000), for example, report that although lower herbicide use was significantly associated with

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[2] It is likely, however, that in the first years since the commercialisation of GM crops, their impact on commodity prices has not been significant, and this has been the assumption in most studies comparing profitability (EC 2000). Moreover, although profitability is an imperfect measure it remains a key variable in explaining the extent and rate of technology adoption (Fernandez-Cornejo and McBride 2002).

the adoption of herbicide-tolerant corn, with a small effect on yields, there was no statistically significant effect on profits in 1996. This was seen as largely to do with higher seed costs.

In the case of **herbicide-tolerant soybeans,** where a number of studies on performance have been undertaken, yields have often been found to be lower or no better than for non-GM varieties. Benbrook (2001), for example, reports GM soybean yields being lower on average by 2.3 per cent in Illinois, 6.1 per cent in Minnesota and 2.9 per cent in Nebraska (in comparisons of the top five yielding Roundup Ready GM and non-GM varieties).

Hofer et al. (1998) also reported similar results, showing yields on average to be approximately 2, 9 and 11 per cent lower across three sites in Kansas compared to non-GM varieties However, an ERS (2001b) study found an increase in yields of about 3 per cent. This is consistent with some earlier studies of field trials where both higher yields and net returns were found (see Roberts et al. 1999; Arnold et al. 1998).

These findings highlight the variability in yield performance reported, depending on data sources used. Benbrook (2001) argues that differences of opinion on yields for soybeans can sometimes be explained by differences in soil productivity and management skill. He argues that large scale operations which have tended to adopt GM varieties had higher yields prior to adoption, and that studies failing to account for this can give misleading findings. Lower yields for GM soybeans (EC 2000) might be explained by selection bias. GM traits are often not introduced into top yielding varieties of soybean.

Gains from adopting GM soybeans are more apparent when related to herbicide use. Carpenter and Gianessi (2001), for example, point to United States Department of Agriculture (USDA) pesticide use estimates showing a 12 per cent decrease in the number of herbicide applications in 1999 compared to 1995 (the year before Roundup Ready varieties were introduced). The authors estimate reductions in net weed control costs of US$216 million comparing 1999 with 1995 (based on herbicide applications in 13 States representing 80 per cent of total herbicide expenditure in the United States).

However, not all studies have pointed to herbicide use reductions. Benbrook (2001) reported increased herbicide use for GM compared to non-GM soybean varieties (although changes in use do not necessarily equate to changes in cost). Differences in conclusions can often be explained by the differences in the measure used to estimate the farm effects of herbicide use. Benbrook (2001), for example, argues that USDA data suggesting reduced herbicide use are based on poor measurements referring to herbicide acre treatments and not total pounds applied. In reporting on the pounds of active ingredient used, the ERS (2001b) notes that herbicide use was 3 per cent higher nationwide for herbicide-tolerant soybeans.

In summing up the performance of GM soybeans, the EC (2000) noted that while cost savings due to the reduced use and cost of herbicides could offset higher seed prices, yields were often lower. The report concluded that there were no significant differences appearing in overall returns per hectare or per labour unit. Fernandez-Corenjo and McBride (2000) similarly estimated that the herbicide savings from herbicide-tolerant soybeans of between US$9–11 per acre roughly offset additional soybean seed costs of between US$11–13 per acre (although the cost savings given did not include fuel cost savings due to reduced chemical applications). Duffy (2001) also reported that there were essentially no differences in returns to farmers from herbicide-tolerant soybeans compared to non-tolerant varieties.

The ERS (2001a) summed up the performance of herbicide-tolerant soybeans slightly more positively. They report the increased adoption of herbicide-tolerant soybeans as being associated with small increases in yields and significant overall decreases in herbicide use. However, the ERS (2001a) was also unable to conclude that GM soybean crops yielded higher profits, noting considerable variation in net returns by region.

The evidence on the performance of insect-resistant **Bt cotton** generally indicates net economic benefits for farmers planting such crops. For example, Marra, Carlson and Hubbell (1998) found statistically significant yield increases in a survey of farmers in Alabama and Georgia, but not for South Carolina and North Carolina. However, the authors found statistically significant reductions in pesticide use for all regions, with profits higher. Carpenter and Gianessi (2001) reported similar net benefits with yield gains outweighing the increased per acre insect control costs (including technology fees).

A number of other studies have also found a net economic advantage from using Bt cotton in the United States. Stark (1997), for example, found reduced spray applications for insect control, improved yields and a sizeable economic advantage despite a US$32 per acre technology fee. In a three year study in Arkansas, yields and profits for Bt cotton growers compared to non-Bt growers were higher in 1996 and 1998, but lower in 1997 (Bryant, Robertson and Lorenz 1999). The ERS (2001a) reported that the adoption of Bt cotton led to a significant increase in yields and decreased insecticide use.

In Australia, Bt cotton reduced the average number of sprays (for all pests) by around 40 per cent in 1999-2000, reducing the per hectare cost to manage insect pests by US$72 on average, although yield outcomes have been variable (Cotton Research and Development Cooperation 2000). In particular, Bt cotton has been reported as not as effective against the Australian pest *Helicoverpa spp.* as it is against the American species (House of Representatives Standing Committee on Primary Industries and Regional Services 2000).

Significant gains from Bt cotton have been reported in China. A survey of 282 farmers in two provinces in the North China Plain found farmers of Bt cotton sprayed pesticide fewer times, and used less than one fifth of the total pesticide used by non-Bt farmers. As a result, growing Bt cotton costs 28 per cent less per kilogram than non-Bt varieties, while yields were statistically indistinguishable (Huang et al. 2001). Significant yield gains were also reported in two field trials in India.

The evidence for **herbicide-tolerant cotton** varies considerably more than for Bt cotton. The ERS (2001a) found that the adoption of herbicide-tolerant cotton in 1997 led to significantly increased yields, increased but variable profits, and no significant change in herbicide use. This conclusion, however, differs from an analysis of herbicide-tolerant cotton by Culpepper and York (1998). They concluded that yields and net returns (after including the technology fee) were similar to those of the most effective traditional systems, although fewer herbicide applications were required and less total herbicide used.

A mixed picture is also evident in the case of **herbicide-tolerant canola**. On the one hand, a study commissioned by the Canola Council of Canada (2001) suggests generally positive outcomes. The study, which surveyed 650 growers in western Canada and included 13 case studies over 1997–2000, reported that over 80 per cent of GM growers found weed control was more effective, and pointed to yield increases in the order of 10 per cent over conventional varieties. The study also reported less tillage, lower herbicide costs (down 40 per cent), fuel savings and an overall profit advantage of CND$10.62 per acre for GM canola.

Mayer and Furtan (1999) also suggest net benefits from using herbicide-tolerant canola. They estimated economic benefits in western Canada in the range of CND$5-8 per acre (after accounting for cost increases including technology fees and cost reductions such as reduced herbicide use).

A less positive picture is provided by Fulton and Keyowski (1999). They find that although Roundup Ready canola offers lower input costs (accounting for seed, technology fees and herbicide costs) of around US$5 per acre compared to conventional varieties, it was also associated with lower yields of around 7.5 per cent. Fulton and Keyowski (1999) emphasise, however, that yield differences for GM canola vary from farm to farm due to farm size, product specialisation, geographical location and farm management skill — factors which affect the performance of all crops. The EC (2000) also noted that yield data in Alberta, Canada, varied between 15 per cent higher and 15 per cent lower for GM compared with conventional crops, depending on region and variety. They concluded that there were no clear cut results for comparing the profitability of GM and non-GM canola.

A study of **several GM crops** by Fernandez-Cornejo and McBride (2002) also presented field and whole–farm analysis, which suggested little by way of financial gains by farmers. While they reported that herbicide-tolerant cotton, Bt cotton and herbicide tolerant corn showed positive economic results, herbicide-tolerant soybeans showed no overall positive effect and Bt corn was associated with returns declining by 3.4 per cent.

A recent study coordinated by the National Center for Food and Agricultural Policy in the United States, however, concluded that an expanded use of GM crops would provide significant economic benefits, with positive impacts on yields, reduced grower costs and pesticide reductions (Gianessi et al. 2002). The study examined 40 case studies in which GM cultivars have been developed, or are being developed, to manage agricultural pests in 27 crops, covering 47 states. The study drew upon a number of existing studies as well as interviews with researchers. As an example, the report stated that the average increase in net income from Bt cotton compared to conventional varieties in 2000 was US$20 an acre, taking into account technology fees.

Limitations of these estimates

Despite the usefulness of these estimates, there are several limitations that need to be noted.

First, many studies only cover periods of one or two years, with the long-term farm effects of GM crops less well known. The EC (2000), for example, noted that many of the studies it reviewed only compared farm-level and short-term profitability. The report emphasised that there are important yearly fluctuations in yields and the prices of inputs and commodities, and complexities in isolating the farm effects of biotechnology, which make short-term analysis difficult. There are also benefits that may take some time to impact on farm productivity, such as benefits from less soil erosion due to reduced tilling practices or less soil compaction from fewer tractor movements for applying chemicals. In some areas, there are also signs that a decline in benefits can occur over time as weeds develop resistance to particular herbicides. For example, from 1998 to 1999, the EC (2000) noted an increase of between 15 and 25 per cent in the average pounds of herbicide per acre used for Roundup Ready GM soybeans. On the other hand, new and improved varieties of GM crops are being developed, which may in the future increase agronomic and other performance qualities.

Second, many studies focus on only one or two factors affecting net on-farm benefits, such as impacts on yields and/or chemical use, with few studies investigating net on-farm effects or profits from farm adoption of GM crops (Lesser 2000; Fernandez-Cornejo and McBride 2000; Foster 2001). Many studies do not account for the ‘convenience’ or management flexibility effects of GM crops, leaving the analysis partial and incomplete (EC 2000; Furtan and Holzman 2001). These ‘convenience’ effects can include reduced machine movements from fewer herbicide applications, greater flexibility in the timing of herbicide applications, and earlier adoption of no-till or conservation tillage (EC 2000). Herbicide-tolerant crops, for example, can require a less complex use of herbicides which can increase a farmer’s ability to expand acreage (Furtan and Holzman 2001). The EC (2000) argues that these factors appear a significant advantage, especially for herbicide-tolerant crops, and have played a key role in the rapid expansion of the sowing of GM crops. Indeed, their report notes a survey showing that 12 per cent of farmers chose to adopt GM soybeans due to planting flexibility. Unfortunately, calculating the economic benefits of these flexibility or ‘convenience’ benefits is difficult (Furtan and Holzman 2001). Their exclusion from many of the assessments of net farm benefits to date, however, suggests such estimates may undervalue the benefits farmers are receiving from some GM crops.

These potential gains may also be offset by additional management precautions associated with GM crop use. These include controlling the spread of GM plants, restricting the development of herbicide resistant plants, and treatment of land post-GM planting. In the United States, for example, Bt cotton farmers are required to plant either 20 per cent of their cotton area to conventional varieties using conventional pest control methods, or approximately 4 per cent to a conventional variety with no pest control (Marra, Pardey and Alston 2002). The long-term net effect of these labour and management flexibility factors, therefore, is uncertain (Fourteen and Holzman 2001).

Third, other potential benefits and costs that are not ‘productivity’-related can also impact in a non-trivial way on farm decision making, and these do not show up in many of the studies discussed here. Examples include reduced exposure to agricultural chemicals that may lower the private costs farmers face in producing any given amount of output.[3] These ‘non-productivity’-related benefits may help explain the considerable expansion in the use of some GM crops in the United

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[3] Similar arguments could be made for any benefits (costs) farmers receive from knowing their local community may also experience reduced (increased) chemical exposure, as long as the benefit (loss) affects production decisions.

States since the mid-1990s (EC 2000). In China, survey data found 22 per cent of farmers of non-Bt cotton reported an incidence of poisoning (such as headaches or nausea) after applying pesticides compared to only 4.7 per cent for Bt cotton growers (Huang et al. 2001).

Environmental factors can also play a role. The Cotton Research and Development Cooperation (2000), for example, reported that 55 per cent of respondents nominated environmental benefits as the principal reason for adopting Ingard Bt cotton in 1999-2000 in Australia (see also Marra, Pardey and Alston 2002). Unfortunately, measuring the value of these non-productivity factors to farmers can be difficult and no comprehensive study has yet been undertaken.

Finally, benefits and costs that do not enter farm decision making, so called ‘externalities’, are also not included in the above estimates of on-farm gains. Examples can include potential impacts on off-farm water flows (including downstream pollution) arising from farmers using more or less water or chemicals in response to particular GM crop characteristics. Marra, Carlson and Hubbell (1998), note the potential problem of insect resistance to Bt strains, not only for adopters of Bt cotton but also nearby users of sprayable Bt *(*Bt is used in some chemical pesticides which are sprayed onto crops as well as used in GM crops). Although these external impacts may significantly affect welfare, and long-term agricultural sustainability, they may not directly impact on supply-side decisions (at least in the short term).

2.4 Summary of net on-farm benefits

Given the array of evidence presented above, arriving at an estimation of productivity gains associated with the introduction of GM technology in the grains and oilseeds sectors in Australia is difficult. When determining what gains are appropriate for each crop, changes in yields, costs and returns must be considered. In summary, the main messages from the evidence presented above are:

- increases in yields for insect-resistant corn average about 6 per cent, but no significant cost savings are reported;
- lower yields, averaging about 5 percent, and costs falling about 10 per cent, imply net gains of about 5 per cent for herbicide-tolerant soybeans;
- higher yields averaging about 25 per cent and cost declines for insect-resistant cotton are shown, while lower yields (about 3 per cent) and costs are reported for herbicide-tolerant cotton; and
- small yield results for herbicide-tolerant canola, averaging only about 1 per cent, and little evidence of cost reductions.

These results are generalisations of studies which show considerable variability in effects across regions and growing conditions. An implication of the regional nature of farm effects is that 100 per cent GM crop adoption is not predicted as only some farmers (eg those troubled by certain pests) would find GM crops beneficial (ERS 2001b).

These crops are covered in two broad categories in the GTAP model: grains and oilseeds. Grains includes corn (as well as sorghum and barley) while oilseeds covers soybeans and canola and cottonseed (cotton used for non-consumptive purposes is included in the category plant-based fibres). Therefore, given the relative shares the individual crops represent in these two crop categories, the following productivity gains have been applied to the model:

- 7.5 per cent for GM grains; and
- 6 per cent for GM oilseeds.

The grains value is driven by the results of the corn studies. As stated above, average yield increases are about 6 per cent, with little costs savings found. However, given other factors not considered, such as convenience factors, this value appears to be understated. Therefore, it is increased to 7.5 per cent to be more representative of the total potential productivity gains to farmers in this sector.

The oilseeds sector is dominated by soybeans (averaging about 5 per cent gains) and canola (reporting much smaller gains). Cottonseed (experiencing much larger benefits) is only a small part of the sector. For the same reasons outlined above for grains, this value was increased to 6 per cent.

These estimates are consistent with those found in a number of other modelling studies (Anderson and Nielsen 2001a, Foster 2001, and Nielsen, Thiefelder and Robinson 2001). However, it should be kept in mind that these are only estimates of potential gains from adopting GM technology. Actual productivity gains could be substantially different, depending on, for example, the particular crop, soil conditions (ie regional variations), timing, and the development of the technology itself.

3 Consumer and regulatory frameworks

The success of GM crop technology will be influenced not only by the productivity improvements it offers, but also by consumer sentiment towards the technology and government regulations. Since consumer sentiment is assumed to influence government policy, lower consumer concern about GM foods could be expected to be associated with less stringent regulatory regimes, while higher levels of consumer concern could be expected to be associated with more stringent regulatory regimes.

However, government policy is not only influenced by consumer groups. Producer groups are also influential. The way such interests work out is a matter of political economy – concentrated interests often dominate over diffuse interests, so regulatory outcomes often reflect the preferences of concentrated groups. Where there is a cohesive and strong coalition of producers that favours GM technology as well as low public concern about GM products, it is likely that regulation of GM foods will be minimal. Where there is strong organised consumer opposition to GM technology, the call for regulation is likely to be greater. Of course, long term interests may coincide eg in the wish to see reduced pesticide use.

In this chapter, some of the reasons behind consumer concern about GM foods are presented, to indicate how these concerns might impact on regulation. Evidence is also presented on the costs associated with different regulatory regimes.

3.1 Consumer attitudes

Differences between countries in consumers’ attitudes towards GM products will be reflected in their regulatory regimes, with consequent impacts on international trade.

Consumer attitudes vary significantly between regions, as they are influenced by several factors, including:

- information available to consumers about GM food, which is likely to vary with health and environmental safety concerns, and community understanding of the technology;

- consumer choice concerns;
- consumer confidence in food safety authorities; and
- income levels.

Some of these factors (such as information availability) could be relatively easily addressed and thus the impacts short-lived. Others (such as confidence in food safety authorities) could be more entrenched and take longer to overcome. Thus consumers attitudes, and the regulatory response to those attitudes, will differ both across regions, and over time.

Information and safety

Food safety and health concerns, as well as environmental concerns, also affect the amount of information consumers have about biotechnology. The level of understanding of that information will play a major role in determining consumers' attitudes toward GM foods. Results of surveys seem to indicate that as awareness of the existence of new technology increases, so do consumers' concerns. However, as consumers move from being 'aware' to being 'informed', they can often become more comfortable with the new technology (see appendix C for details on consumer survey results).

Consumer anxieties are associated with a perception that they are consuming untested or unfamiliar food, risks associated with the potentially allergenic and/or toxic properties of GM foods, and the environmental risks associated with growing GM crops.

Application of GM technology is progressing in an environment of increasing consumer awareness regarding all kinds of food safety. In such an environment, misinformation can impact significantly on consumer beliefs about food safety and lead consumers to believe that the risks associated with GM foods are greater than those associated with non-GM foods. Any risks perceived by consumers may have severe impacts on demand, especially where an alternative is available.

For example, some people believe allergens could be inserted unknowingly into GM foods, which may lead consumers to fear extra risks from consumption, thereby affecting demand. However, GM foods have the same potential allergens and toxins as their conventional counterparts, unless they have been specifically removed in the genetic modification process (ANZFA 2000). In Australia, as in most countries adopting GM technology, the food safety authority ensures that naturally occurring toxins in GM foods are not significantly higher than recommended limits for conventional foods. Any new proteins occurring in GM foods are also checked to ensure they are non-allergenic and non-toxic (ANZFA 2000).

Accidental contamination of non-GM foods with GM material through inappropriate handling and/or transport is also a concern for some consumers. The possibility that consumers who choose to eat non-GM food could be exposed to GM food accidentally stems from difficulties in identifying GM contamination by observation. The StarLink controversy (box 3.1) demonstrates the potential for large economic and welfare losses to arise from GM contamination accidents.

Box 3.1 **GM accidents – the StarLink controversy**

StarLink is a GM corn variety developed by Aventis that was approved in 1998 by the US Environmental Protection Agency for animal consumption only. It was given a zero-tolerance rating for human consumption because it contains an insecticidal protein that shares characteristics with known human allergens, and does not break down easily in the human digestive tract.

Either through cross-contamination of non-GM corn with StarLink in the field, or through co-mingling during handling, transport and/or storage processes, StarLink corn accidentally entered the US supply of corn for human consumption. It was detected in taco shells on supermarket shelves in September 2000.

While StarLink corn represented only around 0.5 per cent of total US corn production, a much larger proportion of the total corn supply was contaminated with StarLink. The US Government issued a recall of all StarLink seed and products and Aventis identified around 11 million tonnes of contaminated corn that required containment. This corn was subsequently redirected to animal feed uses.

The StarLink contamination accident is estimated to have cost the US Government around US$ 20 million in purchases of contaminated corn seed. However, because Japan banned StarLink imports for *any* use, the cost to the US corn industry as a whole was much greater, since all exports of corn to Japan, representing 30 per cent of total corn exports, were disrupted. Concern over StarLink contamination also spread to other US corn importing countries, such as Korea and Taiwan. Ironically, the StarLink contamination accident appears to have dented international confidence in GM food more severely than domestic US consumer confidence.

Source: Foster (2001).

Contamination accidents such as StarLink can dampen down demand not only for the particular commodity affected, but also for any secondary products made using contaminated inputs, and for GM food in general. Consumers may believe that if unapproved and potentially allergenic GM material could contaminate non-GM corn, then it is possible that other potentially harmful GM material could also make its way into food destined for human consumption. In the past, such accidents have been used by anti-GM lobbies to influence consumer opinion about the safety of GM food and the imperfect nature of segregation.

Adverse environmental effects from the cultivation of GM crops is another public concern (ERS 2001). The effects of new technologies on the environment often take time to identify, and sometimes, their results are irreversible. Some consumers may reject GM food if they perceive any risk of environmental damage from the cultivation of GM crops.

Consumer choice

In addition to consumer safety, consumer choice may also be placed at risk by the potential for cross-pollination between GM crops and related non-GM crops. In some cases, it is very difficult to segregate the different varieties. This, combined with an associated difficulty in detecting any cross-contamination quickly, means that GM varieties could mix with large proportions of overall production. Cross-contamination may mean non-GM and organic farmers could no longer classify their crops as GM-free or organic. Such a scenario may reduce the wellbeing of both producers and consumers in those sectors, depending on the size of export markets and the strength of consumer attitudes to GM food in those markets.

Consumer confidence in food safety authorities

Trust in food safety regulators differs substantially between nations and may explain some of the variation in consumer concerns about GM foods. Much of the anxiety surrounding GM foods in Europe may be explained by recent health scares, such as the Bovine Spongiform Encephalopathy (BSE) crisis, foot and mouth disease and e-coli contamination. These incidents have seriously affected European consumers’ faith in food safety regulators and government authorities. A survey in 2001 found only 26 per cent of European consumers believed that government authorities tell the truth about food safety (ERS 2001).

By contrast, trust in food safety regulation is much higher in the US, where 76 per cent of the population expressed a ‘great deal’ or a ‘fair amount’ of confidence in food safety authorities (ERS 2001). A reason for this may be that the serious health scares that deeply affected Europe have not occurred in the United States.

Where confidence in food safety regulators has been lost, consumers become more risk averse. Where ‘tried and true’ alternatives to GM food exist, consumers will be cautious and purchase familiar products. This helps explain why acceptance of GM food is much lower in Europe than in the US.

The NZ Government was recently criticised for allowing the planting and harvesting of imported corn seed that was contaminated with GM seeds (Reuters 2002). At the time, the NZ Government had a moratorium in place on the release of GM organisms into the environment. It subsequently reviewed this stance, following lobbying by biotechnology companies, to allow a threshold level of 0.5 per cent accidental contamination. Incidents such as this have the capacity to dent public confidence in food safety regulators (Environment Risk Management Authority ERMA).

Effects of income levels

Differences in consumer attitudes to GM crops are also likely to vary across countries on the basis of income. Most research into GM technology is undertaken by a small number of companies based in affluent countries, and is mostly focused on improvements that will benefit producers in wealthy countries.

Consumers in affluent countries are concerned about health problems such as obesity, cancer and heart disease, and are likely to favour developing biotechnology for treating these human diseases rather than for improving food productivity. They also tend to be more concerned about the potential environmental impacts of GM crops. Consumers in low income countries, on the other hand, are concerned about food security, malnutrition and infectious diseases, and so are more likely to want biotechnology to be used for developing pest-resistant and hardier crops that improve food supply (Pinstrup-Andersen and Cohen 2001). Moreover, potential long-term environmental and health risks will have less influence on low income consumers' purchasing decisions.

Wealthier consumers will accept GM food technology only if it shows a tangible benefit with very low risk. Low income consumers, on the other hand, are highly price conscious, so their purchasing decisions will depend on price differentials between GM and non-GM foods (Portmann and Tucek 2001).

Lowering food production costs will have a much bigger impact on low income consumers than on more affluent consumers. Pinstrup-Andersen and Cohen (2001) report that the use of biotechnology in food production to increase productivity and reduce unit costs will improve low income consumers' purchasing power by as much as 19 per cent, compared to only 0.33 per cent for high income consumers. This is chiefly because the budget share of food in low income countries is 50–80 per cent of total disposable income, whilst in high income countries, this budget share is between 10–15 per cent (Pinstrup-Andersen and Cohen 2001).

Furthermore, costs of food processing in developed countries are much greater than in the developing world, where final food products are much closer to the raw product. Thus, reducing the cost of producing the basic product through biotechnology will deliver GM producers in low income countries proportionately greater cost savings than GM producers in high income countries. Lower production costs would be expected to lead to reduced prices, and thus there would be a proportionately greater price incentive for low income consumers to purchase GM food than for high income consumers in the developed world.

However, the higher price of GM seed, as compared to conventional seed, may present a cost barrier for many producers in low-income countries. Moreover, to the extent that producers must return to the supplier for new seed each year they wish to grow a GM crop, conventional crops may remain favourable, since producers have the option of saving seed from conventional crops for replanting the following year.[1]

Nevertheless, GM technology may be more likely to be accepted in low income countries than in high income countries because it has the potential to benefit a larger section of the population. In low income countries, 50–80 per cent of the population rely on agriculture for a living, whereas in industrialised countries, this figure is only 2–5 per cent (Pinstrup-Andersen and Cohen 2001). Therefore, any benefits associated with growing GM crops (such as lower pesticide use) entail health and cost benefits for a larger share of the population in low income countries than is the case in high income countries (ABSP 2002).

In summary, this section suggests several issues relating to the impact of income on GM purchasing decisions. First, differences in health needs across low and high income countries will determine demand for particular GM foods in specific regions. Second, a lower price for GM food will have a more significant impact on demand in low income countries than it will in high income countries. Third, potential long-term risks (ie environmental) associated with GM foods that provide some other benefit (ie vitamin enrichment) are less likely to lower demand for GM food in low income countries than in high income countries. And finally, low pesticide GM crops are more likely to be accepted in low income countries because they will benefit a larger section of the (predominantly rural) population.

Evidence on consumer attitudes

As indicated above, there are many potential influences on consumer demand for GM foods, but insights into current and future consumer attitudes toward these

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[1] However, some non-GM crops also require re-purchase of seed each year.

foods are difficult to obtain. While surveys provide a good indication of attitudinal trends toward consumption of GM foods, they often report opinions that may not represent actual purchasing behaviour because they are based on stated rather than revealed preferences (RIRDC 2001). Observed price movements and anecdotal evidence on consumption patterns is therefore also provided, to help piece together a more accurate picture of consumer responses to GM foods.

Consumer surveys

Surveys provide an indication of trends in consumer attitudes and can help explain observed demand. Overall, survey data (see appendix C) indicate:

- there is greater acceptance of GM food technology where it is used specifically to improve foods;
- consumer resistance is lower where a direct benefit from consumption is easily identifiable; and
- there is considerable variance in consumer responses to several GM food issues, both through time, and between countries:
    - US consumers have the most relaxed views about the use of biotechnology in food production, and this attitude has been consistent over time:
    - European consumers are more cautious about GM food, and this caution has been strengthening over time; and
    - Australian consumers’ attitudes to GM food fall between the attitudes held by US and European consumers, with resistance appearing to decline over time.

However, the notion that producer lobbies play a key role in influencing demand has also been advanced. This suggestion has been made with particular force in relation to the EU, where proposed GM regulations have been described as not only scientifically unjustified, but unnecessarily trade-distortive, because of the high costs associated with segregation (ICTSD 2001).

Observed price differences — GM and non-GM foods

Depending on supply conditions, negative perceptions of GM foods would be expected to produce price premiums on non-GM varieties. However, ERS (2000a) reports that demand for non-GM maize and soybeans in the US is limited, and that there is only patchy evidence of price premiums for non-GM grains and oilseeds. This may be because negative perceptions of GM food are not severe enough to affect actual purchasing decisions, or because there is still considerable supply of non-GM products for most crops, which means that scarcity has not yet forced price rises to materialise in the United States.

Other evidence, however, suggests that negative attitudes *have* been revealed in purchasing decisions. The European Commission (EC 2000) reports that many food processors and retailers in Europe have attempted to restrict the use of GM food as a result of negative consumer sentiment. For example, Safeway and Marks and Spencer have banned GM foods to placate consumers concerned about GM ingredients (Swadling 2000). There are also reports that consumers in Japan and Korea have paid price premiums for corn from countries other than the United States in the wake of the StarLink corn incident (Dann 2000).

In addition, ERS (2000) reports that marketing initiatives such as the 'Pure Fresh Green' program allowed the United States to export non-GM and organic soybeans to Japan at a considerable price premium (although the actual amount was not reported). This willingness to pay more for non-GM products is evidence of consumer resistance to GM soy in the Japanese market, and has important ramifications given the large share of soy-based ingredients in final foods.

Other evidence from Brazil (the world's second-largest producer of soybeans and the only country in the Americas to reject GM crops and food) suggests that GM-free soy exports are receiving price premiums of between 50 and 100 per cent in Europe and Japan. Those products with traceability testing receive higher premiums than products that have only been certified by origin (Reuters 2002). Such premiums attest to considerable concern about GM food among European and Japanese consumers.

As the largest producer and consumer of GM foods, North America has a significant role in determining supply and demand for GM crops, as well as prices. It is unlikely that price premiums for non-GM products will arise in the domestic market however, as North American consumers are not so acutely aware and apprehensive about potential health issues associated with GM foods. The extent to which non-GM premiums arise in the international market will partly depend on other nations' (such as China and India) adoption of GM technology, as this will help determine the share these goods command in international markets.

However, the protection of non-GM markets in risk averse regions such as the European Union and Japan, may imply a trend toward price premiums for non-GM products in those regions. The size of these markets, and degree of consumer resistance, will ultimately determine the size of any potential price premiums in those markets.

3.2 Regulations

The role of regulation in biotechnology is primarily to protect human, animal and plant health and safety, and to ensure broader environmental protection. Pursuit of these goals is complicated by a lack of consensus on the nature of the risks, the level of government involvement necessary to manage the risks, and the degree of compliance with international rules and standards regarded appropriate. This section discusses each of these issues and how they affect a region's approach to regulation. It also provides empirical estimates of the potential costs of these regulatory approaches.

Approach to regulation

Biotechnology regulation is complicated by the lack of a clear consensus on the long-term effects of this technology on human and environmental health. While scientific evidence to date shows no adverse impacts on human health, long-term evidence is still to be collected. Environmental impacts of the technology are even more contested. Therefore, regulators must determine the best approach for dealing with a new technology that has the potential to increase farm yields, lower potentially harmful chemical use, and improve product quality, while at the same time protecting consumer, animal and plant health from potential unknown long-term side effects.

Substantial equivalence and the precautionary principle

There are two broad philosophies that may be used to determine an approach to the regulation of GM crops. These are *substantial equivalence* and the *precautionary principle.*

Broadly, the precautionary principle approach justifies regulators taking action to avoid possible negative outcomes, notwithstanding scientific uncertainty, and without the need to specify what negative outcomes might occur. Proposed regulation of GM crops in the EU provides an example of the application of the precautionary principle. The EU's current policy stance is that GM products are new goods, and policy-makers are obliged not to approve products for release until they are shown to pose no danger to human or environmental health (Runge, Bagnara and Jackson 2001). Therefore, GM foods are subject to separate, and higher, standards than conventional food products (Paarlberg 2001).

A regulatory approach based on the substantial equivalence view, on the other hand, treats genetically modified and conventional crops as no different in a fundamental sense. Therefore, food derived using genetic engineering is ‘substantially equivalent’ to traditional foods if its composition, nutritional value, metabolism, intended use and level of undesirable substances contained therein are the same (OECD 2000).

In the United States, for example, the Food and Drug Administration (FDA) requires new foods derived using gene technology to receive pre-market approval only if their genes are not substantially equivalent to those already found in the conventional food variety (Paarlberg 2001).

The difference in the two regulatory rationales leads to substantially different policy frameworks. The precautionary approach will, necessarily, impose higher standards and greater costs on GM crop development. The substantial equivalence approach calls for no differentiation in the approval processes between GM products and any new ‘conventional’ crop or food product, and thus no government-imposed cost differential. This should encourage greater research and product development than regulation developed under the precautionary principle.

The actual form regulation takes will depend on current and pending trends in food safety, concerns for consumers’ ‘right to know’, environmental impacts, intellectual property and research developments, the political strength of lobby groups, and public perceptions of the reliability of regulatory bodies.

Trends in food safety

As consumers’ concern about GM foods has grown, so too has the demand for information on the foods they consume. The overall trend is toward greater disclosure of sources, methods of production and the content of processed foods. In addition, the increasingly global nature of the food supply chain has put pressure on governments to enhance and harmonise food safety standards.

Foot and mouth disease, BSE and disputes over hormone injected beef have raised the level of concern in many countries and increased the demand for greater traceability in the food supply chain. ‘Traceability’ can take several forms, but in the case of GM foods, it is not clear what form this should be. Segregation systems generally deal with segregating one crop from another and do not involve high levels of precision. Identity preservation (IP) systems, on the other hand, require documentation to guarantee certain traits or qualities are maintained throughout the supply chain. These standards are more rigorous and more costly to apply.

Together, segregation and identity preservation (SIP) allows buyers to verify the grade, variety or type of product they are purchasing. SIP systems and related labelling are not new or unique to GM crops, however. They are already used to distinguish different grades of commodity crops and higher value varieties (EC 2000).

Both the private sector and governments have an interest in ensuring traceability to guarantee food safety and quality control. The private sector is mostly concerned with ensuring segregation and traceability as a means to differentiate products when there are undetectable quality differences. In such a case, traceability lends credence to certain claims of product 'superiority', such as vitamin enrichment or organically grown. The main goal of traceability for the public sector is to ensure accurate record-keeping in the interest of public health. In lieu of any private market incentives, governments will have an interest in providing consumers with access to information about food safety and quality. Traceability will also play a role in ensuring the government's ability to recall products in the case of unforeseen food safety or environmental problems.

SIP systems may be categorised as either 'process standards' or 'performance standards'. Performance standards are usually preferred over process standards because they allow firms to determine the most efficient mechanism for compliance with food safety or environmental regulations (ERS 2002). Where regulation involves mandated food safety performance standards, GM foods face the same regulation as all other food products. Where there are process attributes (such as non-GM) that are valued by consumers, food suppliers have an incentive to market those attributes without the need for regulation. However, with no market incentives, this information will not be provided voluntarily.

Whether mandatory or voluntary labelling regimes are adopted will have a significant impact on who bears the cost. Unless labelling schemes are coupled with high consumer demand for non-GM products and strict segregation requirements, mandatory labelling costs will probably fall on non-GM producers and consumers. This is because if consumers are indifferent between GM and non-GM products, GM producers have no incentive to segregate, in fact, they probably have an incentive to remain indistinguishable from non-GM commodities and products. Even if GM producers were to label their products 'may contain GM ingredients' or 'contains GM ingredients', it may still fall upon non-GM producers to certify that their products are indeed non-GM.

International regulatory regimes

International standards are designed to ensure that domestic regulations are based on sound scientific principles, recognising that measures ostensibly adopted to pursue human and environmental protection could be disguised barriers to trade, and could be discriminatory. Examples include World Trade Organisation (WTO) rules, specifically the technical barriers to trade (TBT) and sanitary and phytosanitary (SPS) standards. Both the TBT and SPS agreements acknowledge the importance of harmonising standards internationally so as to minimise or eliminate the risk of sanitary, phytosanitary and other complex technical standards becoming trade barriers.

Other international agreements or forums under which GM products fall include the Codex Alimentarius (Codex), the Cartagena Protocol on Biosafety (Biosafety Protocol), the International Organisation for Standardisation (ISO), and the OECD. These agreements and forums typically relate to harmonising food safety and food product laws and to protecting consumer health. They are also concerned with promoting fair practices in food trade by ensuring that regulations do not create unnecessary obstacles to trade or permit member governments to discriminate by applying different requirements to different countries where the same or similar conditions prevail (unless there is sufficient scientific justification for doing so).

Whichever form of regulation is imposed by a region, there will be costs associated with it. However, where international standards relating to GM foods are not consistent with domestic standards, these costs will be much larger. This is particularly true for nations with minimal domestic regulations that wish to export to regions with stricter controls on GM products. The issue currently at hand is whether the various national systems relating to GM foods, especially those proposed by the EU, violate these international standards[2]. Those countries using the precautionary principle when developing domestic regulation of GM foods could find themselves in dispute with those adopting the more lenient substantial equivalence approach — the potential for long and costly trade disputes is real.

Costs of regulation

By adding to the costs of supplying GM and non-GM crops, proposed and established regulations can alter trade flows and economic welfare. Broadly, costs of regulation are associated with:

- requirements covering the research, development and application of GM crops including pre-release approval in many countries for the use of GM seeds, and pre-market assessment for food products containing GM ingredients; and
- labelling of food products containing GM ingredients — mandatory labelling regulations have been introduced in Australia, New Zealand, the European

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[2] Of most immediate concern are standards under the Biosafety Protocol, due to come into effect some time in 2003.

Union, Japan, and the Republic of Korea (see appendix D for outline of different regional approaches to regulation).

The following section reviews the potential cost implications of these regulations. In particular, it focuses on the costs associated with regulating the application of GM crops, and the costs of SIP and labelling. Reviewing the costs of potential SIP and labelling regimes for GM and non-GM crops is particularly important. It has been argued that under certain circumstances, these costs can more than outweigh the potential agronomic benefits offered by GM crops (Foster 2001).

Costs of regulating the research and application of GM crops

Several costs are associated with meeting regulatory approval to release GM crops into the environment and for their subsequent use in food. Many of these costs are met by the developers or promoters of GM crop seeds, and as such, are reflected in seed prices and technology fees paid by farmers. These seed and technology costs were briefly considered in chapter 2.

Other regulatory costs may be imposed at the farm level. These may include requirements for farmers to use buffer zones to ensure the protection of the natural environment or other farmers' properties from cross-contamination with GM material. Consequences of cross-contamination can include the development of weedy relatives or resistance to existing pest management strategies (see section 3.1). In 2000, the US EPA specified requirements for farmers planting Bt corn to maintain 'refuges' (areas of non-Bt corn) covering at least 20 per cent of the area planted to Bt corn. Buffer zones are also required for all GM crop trials in Australia to limit the spread of GM pollen.

Costs of labelling and identity preservation for GM and non-GM crops

Whether the call for labelling the GM status of agricultural products is driven by government regulations or consumer demand for product information, there is a demand to verify the origin of food ingredients to determine their GM status. SIP regimes provide this verification. The EC (2000), for example, argues that for consumers to be confident in labelling systems, there is a need for products to be segregated throughout the processing system, with a SIP regime to distinguish products according to their GM content or whether GM technology has been used in their production.[3]

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[3] While noting that SIP is not mandatory for compliance with Australia's GM food laws, Australia New Zealand Food Authority (ANZFA) (undated) suggests that evidence that a food or ingredient is, or is not, from a GM source may come from a paper trail of verifiable

In the case of crops, the need for SIPs can come from the potential for accidental mixing of GM and non-GM crops, through pollen dispersal, cross pollination, seed dispersal or inadequate separation of GM and non-GM crops or products during processing, transport or distribution (Department of Human Services South Australia 2001).

Preserving the identity of crops can be achieved by testing regimes and/or implementing processes for on-going segregation across the supply chain. At the production stage this requires buffer zones between GM and non-GM crops. The appropriate size of such buffer zones will depend on whether the crop is open-pollinating (such as canola or corn) or self-pollinating (such as cotton or soybeans) and, if open-pollinating, how pollen is transferred between plants. At the storage, handling and transportation stages, SIP can involve separate storage bins, particular times for crop movements, and cleaning of transportation containers. An example of a generic SIP system is provided in appendix E (table E.1).

SIP costs include costs associated with separate transport and storage facilities or the need to clean these between GM and non-GM crop uses. Costs can also include losses of economies of scale and, where necessary, documentation and verification processes which can involve testing regimes. Leading Dog Consulting and Peter Flottmann and Associates (2001) (the ‘Leading Dog Report’) argue that the most significant segregation costs appear to be associated with the ‘re-shuffling’ or changing of the grain handling system, rather than from equipment cleaning, dedicated use of equipment (on farm or in the transportation) or from testing.

However, the costs of SIP for GM commodities also depends on the degree of segregation already existing in the market. For example, Australian grain producers have substantial infrastructure currently in place for segregation. In addition, the Australian Government established a program in 2000 to assess the requirements and costs of segregating GM products to ensure their traceability. It committed A$3.65 million over four years to the project (Foster 2001).

SIPs for GM and non-GM crops will therefore introduce new costs to agricultural production, depending on the degree to which products are traded through a bulk commodity system. The size of these additional costs, however, depends on the crop concerned, the volume of production going through SIP systems and, importantly,

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documentation including IP. ANZFA (undated) also notes that required information on the GM status of food will need to be carried from growers, processors, suppliers and importers to manufacturers and retailers along the supply chain, and that IP may be particularly useful when negative claims such as ‘GM-free’ are made. The ACCC (2001) also emphasises that a ‘GM-free’ claim leaves no room for ambiguity, and thus a product labelled as such that contains any percentage of novel DNA and/or novel protein may be misleading under Australia’s Trade Practices Act.

the threshold level of contamination accepted. It is expected that costs will increase exponentially rather than linearly for tolerance levels approaching 0 per cent (EC 2000).

The importance of tolerance levels was also highlighted by the ERS (2000). It noted that at a 1 per cent or lower tolerance level for GM contamination, only 5 per cent of grain elevators in the United States could achieve segregation without major new investments. The same threshold could potentially double transportation costs in the United States (compared to only modest transport cost increases if tolerance levels were set at 5 per cent or higher).

The size of SIP costs has been estimated in a number of studies (Buckwell et al. 1999; Bullock et al. 2000; ERS 2000). Many of these studies have focused on the costs of segregating non-GM from GM crops for US suppliers to sell products to export markets such as the EU. Buckwell et al. (1999), for example, give a number of examples of SIP costs for different products under different SIP arrangements. They find, where tolerances of GM residue were up to 1 per cent, that additional costs were approximately 10 per cent of farm gate prices. They suggest that this 10 per cent cost increase is probably the most likely estimate of the additional costs of SIP, given that the direction of most labelling regulation is to allow up to 1 per cent tolerance of GM material.

Buckwell et al. (1999) also examined GM canola in Canada and found that the additional costs of SIP were around 6–8 per cent of farm gate prices (although no specific threshold was given). The authors also report findings of SIP costs from three case studies of crops offering enhanced benefits for consumers (unrelated to GM technology). Costs were found to range between 5–15 per cent of the farm gate price.

A study by the EC (2000) covering non-GM and specialty soybean, corn, canola and sunflower in the US, Canada and European Union, shows results of similar magnitude, with the additional costs of SIP ranging from 10–15 per cent of sale price. The study estimated that SIP would increase grain prices at the farm gate by 6–17 per cent. It argues that because this range of cost estimates corresponds to the experience with existing SIP systems for value-added market segments, it can be taken as a reliable estimation of SIP costs.

In Australia, Leading Dog Consulting (2001) estimated that, given present testing technology and SIP systems, costs will increase by around 10-15 per cent through the supply chain. The report notes that in the United States, the estimated average total cost of segregation (including testing) for both soybeans and corn is 12 per cent of the sale price.

It has been argued, however, that where segmented markets already exist, the arrival of GM crops does not change the basic handling system, so estimates of costs associated with regulatory compliance are overstated. Moreover, SIP and labelling regulation costs are expected to fall over time after initial up-front costs are incurred. As experience grows, testing procedures improve, and economies of scale are reached (assuming segregation activities expand) (Buckwell et al. 1999). Leading Dog Consulting (2001) notes there is already evidence in some food chains that SIP costs become significantly lower as supply chain capabilities develop and more suppliers seek to provide that service (although no estimates were given).

3.3 Summary and modelling implications

Consumer responses

The evidence presented above suggests that consumers' attitudes to GM foods are varied and changing. Consumers' concerns about GM products and their consumption depend on income levels, food safety controls, and information on GM technology and products. The recent introduction of the technology makes it difficult to arrive at long-run assumptions when modelling consumer attitudes.

However, drawing on evidence of consumer responses to GM crops and foods discussed in this chapter (see also appendix C), it is apparent that US consumers are the most accepting of GM crops. By contrast, European consumers are becoming increasingly concerned, while Australian consumers are becomingly less concerned. Consumers in some parts of Asia (eg. Japan) also have concerns about consuming GM foods.

To differentiate consumer responses to GM food between regions, and to reflect the smaller GM markets in the EU, Australia, and some parts of Asia (as compared to US markets), a 25 per cent reduction to current demand for GM in those regions was modelled to represent the section of the population averse to GM food consumption.

Survey results (appendix C) indicate that anywhere between 47 and 80 per cent of consumers perceive GM as risky or unacceptable, depending on the region. However, this does not necessarily translate directly into the same percentage that would refuse to buy products derived from it. For example, in 2000, 50 per cent of consumers surveyed in the US indicated a negative attitude towards the trend to GM food (Portmann and Tucek 2000). Yet, the United States is the largest consumer of such goods. Therefore, a modest estimate of consumer resistance is adopted, namely 25 per cent.

No consumer resistance was modelled in the United States, Canada, China or the rest of the world. The reasoning behind this was discussed in section 3.1 – North American consumers reportedly make less distinction between GM and non-GM crop varieties, while developing regions (which form the bulk of the rest of the world category) are more sensitive to price than to production methods.

While few studies have attempted to model the implications of GM foods, Anderson and Nielsen (2001b), and Anderson, Nielsen and Robinson (2000), incorporate a consumer preference shift using the GTAP model. They also model a 25 per cent reduction in Western Europe’s demand for imported GM cereal grains and oilseeds.

Since consumer attitudes to GM foods form the basis of recommendations made by consumer lobby groups to the government, differences across regions in consumer acceptance of GM crops will play a significant role in explaining differences in policy and regulatory responses to GM foods. The degree to which consumers oppose or accept GM food in each region will have implications for the stringency of regulations adopted in each region, and therefore on the costs of regulating GM commodities.

Regulatory responses

A number of considerations complicate the regulation of GM goods. In particular, the global nature and high volume of trade in these commodities mean that it is important for any domestic regulations to comply with international regulations and standards. Environmental considerations impose added complications on the international standards set by organisations such as the WTO. These include considerations such as biodiversity, and domestic standards in areas such as pesticide use and weed control. Given the important role of crops in the food chain, there are also matters stemming from food safety and consumer preferences to take into account. Finally, there is the technical nature of the GM development to consider, which generates issues on patent rights and scientific ‘certainty’.

Evidence on how these considerations affect a region’s approach to regulation is mixed. However, a general trend is that some regions (such as the EU and Japan) are more concerned about food safety issues, and are risk adverse, resulting in more stringent approaches to regulation. This implies greater costs of producing GM crops in these regions. Other regions (such as the United States and Canada) have been less affected by non-biotechnology food safety scares, and demonstrate a more aggressive adoption of the technology, leading to less regulation and lower costs to producers. Australia has adopted a relatively risk averse stance, but unlike the EU and New Zealand, has provided a process for the future commercialisation of GM crops.

Given the ambiguous evidence on price premiums, the trend toward greater food safety and farm accountability, and the mixed approaches to regulation across the world, regulation costs on both GM and non-GM producers are imposed in the model. However, two scenarios regarding the total burden borne by producers due to GM food regulation are imposed. As shown in section 3.2, studies indicate such regulation could raise farmers' costs by as much as 17 per cent. However, for some markets (such as grains) the necessary infrastructure to support the regulation is already in place.

Regions with greater consumer resistance to GM foods were assumed to have lower threshold levels for contamination (ie. regulations that allow for less than 1 per cent 'accidental' inclusion of GM product before the product must be labelled as containing GM material) and to therefore require more stringent SIP systems than regions with higher threshold levels.

Two scenarios with respect to regulation costs were implemented — the 'large' regulation cost scenario corresponds to an assumption of higher regulation costs, while the 'small' scenario corresponds to an assumption of more modest regulation costs. Therefore, depending on whether the 'large' or 'small' assumption about regulation costs was imposed, regions that have introduced, or are considering introducing, low threshold levels for GM food contamination, such as Australia, New Zealand and the European Union, were, respectively shocked by a 10 or 5 per cent increase in production costs associated with regulation. Korea and Japan, which are considering higher threshold levels (but whose current systems call for 3 and 5 per cent respectively), were given either 5 or 3 per cent shocks, depending on the level of regulation costs assumed. The remaining regions (North America, China and the rest of the world) which exhibited lower consumer resistance to GM, were assumed not to implement any additional domestic regulations on GM segregation. Table 4.3 contains a summary of the shocks imposed across different scenarios.

4 The model and assumptions

This chapter outlines some of the theory behind the Global Trade Analysis Project (GTAP) model to help explain the results. It explains the extensions that were made to the database and model theory for the purposes of this paper. The chapter also outlines the simulations that were undertaken with the modified model to capture some of the potential economic effects on Australia of different consumer and regulatory responses to GM crops across regions.

Three scenarios are described: the first implements productivity improvements associated with GM crops; the second introduces consumer resistance to GM food and associated regulatory responses; and the third scenario is included to estimate the effects of GM crops under a steady state policy environment. Finally, some expected results from the scenarios are presented based on standard economic theory.

4.1 GTAP Model

Theory

The global computable general equilibrium (CGE) modelling framework GTAP is used in this paper. The production side of this model assumes a constant returns to scale production technology and perfect competition. Each commodity is produced by a distinct sector, which uses intermediate inputs sourced both domestically and internationally. Imported and domestic intermediate goods are assumed to be imperfect substitutes (the Armington assumption), which is represented by a constant elasticity of substitution (CES) function. Firms thus decide on the source of their imports, which determines the composite price of imports, and then based on this price, they determine the mix of imported and domestic goods. Armington intermediate composites are then used in fixed proportions with a value-added composite CES nesting of primary factors (land, skilled labour, unskilled labour and capital) to produce final outputs.

Prices reflect perfect competition in production, capital formation and trade. Therefore, sellers earn zero pure profits and costs determine revenues. The assumption of constant returns to scale in production is significant because it implies that the percentage change in the price of any commodity will simply equal the weighted sum of the percentage changes in the prices of inputs.

The demand side of the model has three sectors — private households, government and savings. At the macro level, household consumption, government consumption and net (of depreciation) savings in each region are a variable share of regional income. These demand aggregates vary in response to changes in regional income and prices (McDougall 2002). Households are assumed to consume a CES composite of domestic and imported commodities and income and price elasticities of demand are specified for each region, potentially allowing a detailed representation of demand conditions (Hertel 1997). There are two possible investment allocation mechanisms: either the expected rate of return on capital is equalised in all regions; or the percentage change in investment is equalised in all regions.

Trade is modelled as a series of import and export flows defined by commodity and region of origin/destination. Armington elasticities are defined as regionally generic across all agents, which means that import demand equations differ only according to their import shares. Careful definition of imports and exports categorised by agent is important where import intensities of the same commodity vary greatly across uses, because it allows trade payments to be traced to specific sectors of the economy (private households, government or firms) (Brockmeier 1996).

Prices, regional incomes and quantities of non-endowment commodities are endogenous, while all policy variables, technical change variables and population are exogenous to the model (Hertel et al. 1997). Capital is allocated across regions so as to equate rates of return. Labour is assumed to be perfectly mobile between regions, and therefore fast to adjust changes, whereas land is defined as a ‘sluggish’ endowment commodity.

4.2 Extensions

Database

The standard 1997 GTAP database identifies 57 commodities and 66 regions. For the purposes of this paper, the database was aggregated to emphasise those regions and commodities most important to Australian trade and the GM food debate. Thus, the final database aggregation accounted for ten main commodities (manufactures, services, transport, livestock, processed meat, wheat, grains, oilseeds, other agricultural produce and other processed foods) and seven regions of trade relevance to Australia (see table 4.1).

To analyse the implications of various regions' stances on GM crops for Australian trade, the database was modified to distinguish GM crops from non-GM crops. The largest GM crops are soybeans, canola, maize and cotton. Given that cotton (other than cottonseed) does not enter the food supply, the paper concentrates on the first three crops. These crops are included in two commodities in the GTAP database: oilseeds and grains. The grains sector contains maize, sorghum and barley while the oilseeds sector contains soybeans, cottonseeds and canola. Wheat was not split into GM and non-GM varieties because, as yet, it is not grown commercially as a GM crop anywhere in the world.

While environmental concerns are of importance in designing policy, it is consumer resistance to the consumption of GM products in the food supply that is driving much of the current and proposed legislation. That is, some consumers are concerned about the direct and indirect effects of consuming fresh and processed GM foods as well as meat and dairy products where livestock have been fed with GM crops.

To date, most GM foodstuffs enter the food chain as additives in highly processed foods, such as oils, which often have little traceable GM substance when they reach the final goods stage. As stated in chapter 3, regulation currently under consideration in the EU would require these goods to be labelled, but as at this time, no country requires labelling when GM traces have been removed from the product. In Australia, only those products still containing traces of GM are required to be labelled. Thus, there are currently many processed foods for sale that have been derived from GM and that do not require labelling.

Splitting the database to include processed foods purchased by consumers would be difficult. It would require estimations of the percentage of ingredients derived from GM crops that go into the production of each processed food commodity, as well as the amount of GM material that remained (and would thus be subject to regulation) once processing was complete. The GM input split would be even more difficult to calculate for produce such as meat, where livestock may have been fed on GM grain. Thus, these 'end user' types of food are not included in the analysis presented here. The database was therefore split to include only GM and non-GM crops. This split was based on currently reported market shares.

As discussed in chapter 1, James (2001) reports estimated market shares for particular GM crops by region. Huang et al. (2001) report shares for China. These market shares are presented in tables 4.1 and 4.2 as the assumed production shares. All the initial relationships in the model, such as shares of inputs, exports and destinations, as well as intermediate input usage, were assumed to hold equally for GM varieties and non-GM varieties. Each country's share of world production and exports for the two sectors are also provided in the tables.

Table 4.1 **Grains shares**

Region	*Current share of world grains*[a]		*Assumed production shares*[b]	
	% Production	% Exports	% GM	% Non-GM
Australia	1	2	10	90
New Zealand	0	0	0	100
North America	39	50	40	60
China	10	7	10	90
Japan	0	0	10	90
Korea	0	0	10	90
EU	14	23	10	90
Rest of the World	36	18	15	85

[a] Based on shares in GTAP 1997 database.

[b] Authors' estimates based on James (2001) and Huang et al. (2001).

Table 4.2 **Oilseeds shares**

Region	*Current share of world oilseeds*[a]		*Assumed production shares*[b]	
	% Production	% Exports	% GM	% Non-GM
Australia	0.5	1	10	90
New Zealand	0	0	0	100
North America	25	59	65	35
China	9	2	15	85
Japan	0	0	10	90
Korea	0.5	0	10	90
EU	12	10	10	90
Rest of the World	53	28	15	85

[a] Based on shares in GTAP 1997 database.

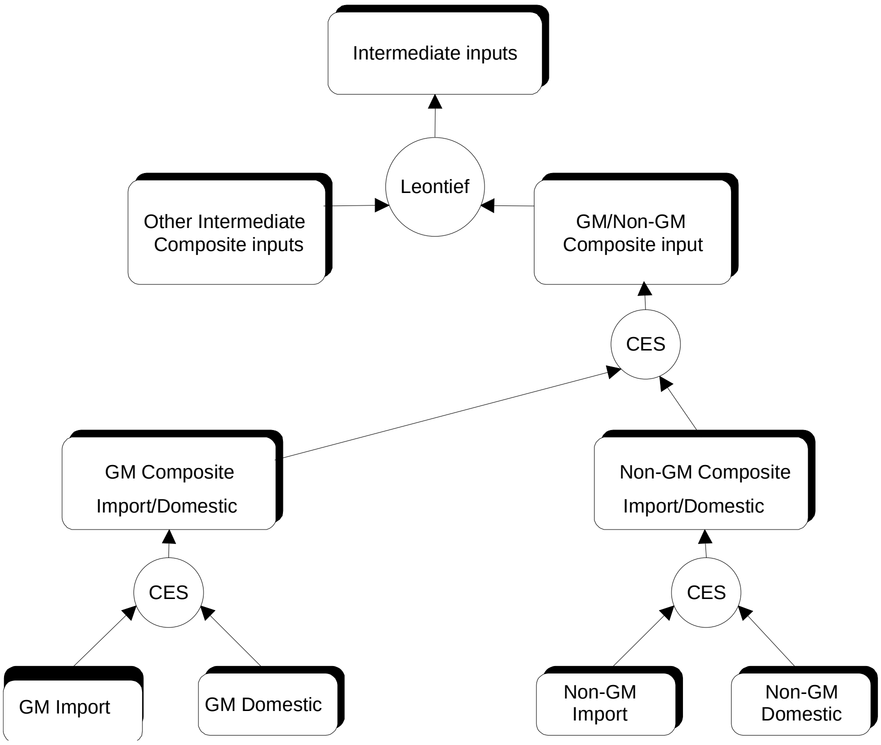
[b] Authors' estimates based on James (2001) and Huang et al. (2001).

Model

The model theory was extended to introduce substitutability between GM and non-GM varieties in both consumption and production. A CES nesting of GM and non-GM grains and oilseeds was added to the production function so that firms' decisions about whether to use GM or non-GM intermediate inputs of grains and oilseeds in production was based solely on their relative prices (see figure 4.1).

This nesting was placed after the import/domestic substitution nesting, such that firms choose between imported and domestic products and then between GM and non-GM products. The GM/non-GM nesting produces a composite which feeds into demand for intermediate goods in the same way as other intermediates.

Figure 4.1 **Production nesting**



A CES nesting of GM and non-GM crops was introduced into the consumption module in a similar way, except households were assumed to first choose between GM and non-GM grains and oilseeds varieties and *then* between the imported or domestic product (see figure 5.2). New shift variables were also introduced into the model to allow consumers to differentiate GM and non-GM varieties by factors other than price. For example, these variables could be used to represent consumer resistance to GM produce stemming from food safety concerns (where resistance does not vary according to price).

4.3 Scenarios

Productivity

An output-augmenting technical change shock was applied to the GM oilseeds and grains sectors to reflect the productivity gains associated with the use of GM technology. Chapter 2 outlined the evidence on productivity gains presented in the literature and the following assumptions were adopted:

Although uniformity of productivity response to GM technology is not supported in practice — productivity responses have been shown to vary both inter-regionally and within regions depending on land fertility, water supply, soil type and other factors — the scale of modelling in GTAP makes more disaggregated productivity responses impractical. Applying uniform productivity increases is seen as an acceptable mode of representing averages observed within regions, and has been undertaken by Nielsen, Thierfelder and Robinson (2001), Anderson and Nielsen (2001a) and Foster (2001). However, these productivity increases should be seen as indicative since actual gains could be substantially different.

Consumer and regulatory responses

Consumer resistance to GM crops in Australia, New Zealand, the European Union, Korea and Japan was simulated using two separate mechanisms. First, the substitution parameters between GM and non-GM grains and GM and non-GM oilseeds were lowered to represent a decrease in their perceived substitutability in these regions. These parameters determine the degree to which consumer demand increases or decreases in response to a relative price change between varieties.

Second, consumer resistance to GM produce was simulated with the introduction of a preference shift variable. The variables for both imported and domestic GM grains and oilseeds were shocked to represent the fact that no matter how cheap GM crops may become, some consumers may simply not want to consume them (for food safety, environmental or other reasons). The degree of consumer resistance was indicated by a 25 per cent consumer preference shift away from GM in the European Union, Australia, New Zealand, Korea and Japan.

North America, China and the rest of the world are assumed to remain price sensitive and unaffected by consumer preference shifts. The reasoning behind this assumption is discussed in chapter 3 — North American consumers reportedly make less distinction between GM and non-GM crop varieties, while developing regions are more sensitive to price than to production methods.

When applying the regulation shocks, the issue of who will bear the costs of the regulation arises (see section 3.2). Under the precautionary principle, GM sectors are required to bear the cost of regulations because the technology is deemed to be ‘untested’ and therefore, potentially hazardous to the consumer. Under substantial equivalence, there is no need to impose additional standards to deal with the entry of GM products; rather the market should determine if the additional costs of product differentiation are warranted. That is, consumers will indicate what information they want — for example, whether they want to know if a product *is* genetically modified or *is not* genetically modified — through their willingness to pay price premiums. Therefore, which sector will bear the costs of regulation under substantial equivalence will depend on consumer demand for information and product differentiation and their willingness to pay for it (see chapter 3).

Another relevant issue when discussing the imposition of regulation costs is the general trend toward increases in food safety. As stated earlier, with many of the current food ‘scares’ such as Bovine Spongiform Encephalopathy and foot and mouth disease, there is a trend towards consumers demanding improved traceability systems across the entire food chain, regardless of the GM status of the good. If this is indeed the case, then all producers along the food supply chain, from the farmer to the grocer, will need to provide evidence of where the product came from, how it was grown, how it was transported, etc. Thus, the regulation surrounding GM foods will not be as great an *additional* burden to food producers as it would have been had there not already been an emerging trend toward product identification.

Given the trend toward greater food safety and farm accountability, and the mixed approaches to regulation across the world, this paper imposes regulation costs on both GM and non-GM producers. However, two scenarios regarding the total burden borne by producers due to GM food regulation are imposed. As shown in chapter 3, studies indicate such regulation could raise farmers’ costs by as much as 40 per cent. However, for some markets (such as grains) the necessary infrastructure to support the regulation is already in place. Thus, estimated increases of 5 per cent (Japan and Korea) and 10 per cent (Australia, New Zealand and the EU) are presented in the ‘large’ scenario and increases of only 3 and 5 per cent respectively are presented in the ‘small’ scenario. As stated in chapter 3, the remaining regions (North America, China and the rest of the world), which exhibited lower consumer resistance to GM, were assumed not to implement any domestic regulations, and were therefore not shocked.

Costs associated with regulations to introduce segregation and identity preservation (SIP) systems for GM and non-GM grains and oilseeds were simulated using two mechanisms. First, domestic regulations were modelled using a negative input-augmenting technical change shock to represent the increased costs associated with compliance to the new regulation (where appropriate). In order to comply with regulation, firms must incur:

- additional non-labour input costs (such as additional packaging material, and specialised or dedicated transport systems, for example);
- primary input costs (such as additional handlers to ensure commodities remain separate, technical personnel to test for potential cross contamination, and buffer zones to prevent cross-contamination that add to the acreage required to produce the same level of output); and

- capital costs (specialised equipment for segregation and technical equipment for testing and monitoring cross-pollination, for example).

Thus, the amount of inputs of transport, manufactures, services and primary factors needed to produce a given level of GM and non-GM grains and oilseeds are increased to represent the impact of GM regulations.

Since imports must comply with domestic regulations in order to be sold in the domestic market, an additional mechanism captures the full impact of GM regulation. Without import regulation on GM and non-GM grains and oilseeds that ‘matches’ domestic regulations, imports would become relatively cheaper compared to domestic products and the balance of trade would deteriorate as agents’ substitute towards imports. Thus, the second mechanism used to simulate the cost of GM regulations to importers was a negative shock to import-augmenting technical change. This shock represents an increase in the effective price of imports into regulated regions due to additional production requirements (ie SIP), and an expansion in the value of exports required to meet demand.

Policy evolution

There are several conceivable outcomes concerning the economy-wide and international impacts of GM technology over time. Barring an unforeseen health scare, or serious environmental consequences, it is likely that the occurrence of GM ingredients in the food supply will increase. The extent to which this increase in GM ingredients spreads throughout the global food chain, the extent to which it is accepted in all consumer markets, the rate at which this acceptance takes place, and the reaction of many developing countries (notably China and India) to this technology, will all play a role in determining the ultimate outcome.

A series of simulations are implemented in an attempt to put forth a likely scenario for the various factors affecting the direction of GM crop production. The scenario, termed ‘policy evolution’, presents a conservative estimate of change, given available information and opinions expressed by those in the industry. It is one of a number of likely outcomes and does not purport to be the ultimate ‘forecast’ of GM adoption. Most notably, it does not include the adoption of any additional crops (an obvious next step) but rather, concentrates on the possible evolution of policy and demand for the two GM products in question (grains and oilseeds).

The policy evolution scenario abstracts from other world trends. That is, it does not implement forecasts for GDP growth or income levels or any likely changes in consumers’ consumption bundles. This is done to isolate the effects of changes in attitude towards GMs on trade and domestic output over time[1]. The policy evolution scenario makes two alternative assumptions for Australia. The first is that Australia's market share for GM crops stays at the current level (ie 10 per cent). The second assumes that Australia increases its uptake of GM crops at the rate of North America, ultimately achieving a similar market share (ie 60 per cent).

The first assumption is that the productivity gains outlined above will begin to decline. This could happen, for example, if some resistance to pesticides and herbicides were to develop, which would make GM crops less effective and lead to increased spraying. However, it is expected that industry efforts to counteract this declining productivity would be undertaken. Thus, productivity growth will not be eliminated, but would gradually decline to a steady state rate of around 2 per cent.

It is assumed that consumer resistance will decline over time, but there will continue to be some consumers (mostly located in developed countries such as the European Union and Japan) who refuse to eat GM foods. However, this niche market is assumed to be small and an expansion of the existing organic market.

The aim of the policy evolution simulation is to obtain an indication of the steady state effects of GM crops on the market. As indicated in previous chapters, consumer resistance to GM foods is expected to lessen over time. GM may be more widely adopted if consumers accept health risks associated with GM consumption as minimal and no adverse health effects actually occur. Also, as the second generation of consumer-oriented modifications (such as enhanced flavouring or longer shelf life) are introduced and GM food becomes more widely available, it is reasonable to assume that consumers will, in general, view GM foods as just another extension in the varieties available for purchase (see appendix C).

The policy evolution simulation therefore assumes that although regulations may still be in place, the cost of those regulations will decline over time, in line with more relaxed consumer sentiment. Moreover, it is expected that over time, by moving along a learning curve, producers will become better at implementing regulatory requirements. In addition, as the market expands, economies of scale will evolve that allow costs to be spread over a greater amount of output. Finally, as consumers become more accepting of GM goods, certain restrictions may be removed and SIP systems may be relaxed.

The policy evolution simulation involves a series of comparative static simulations where developments are traced over several periods. While this is not a dynamic simulation in the strict sense, it does provide an indication of the possible 'steady

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[1] One adjustment was made to the database to reflect future events and that was the implementation of policy changes agreed to by countries under the Uruguay Round.

state' economic outcomes in a world where GM crops are part of the food chain, there is a small niche market for non-GM goods, and regulation associated with GM foods is no different to that applied to all other food products.

The first part of the simulation, 'period one', is based on the current policy environment. That is, consumers view GM and non-GM crops as imperfect substitutes and, in certain regions, there is a segment of the market (25 per cent) that refuses to eat GM foods under any conditions. Regulations increase costs to farms by 5 to 10 per cent, depending on the threshold of allowable 'accidental contamination' in each region. Productivity gains are 6 per cent for oilseeds and 7.5 per cent for grains.

In the second part of the simulation, 'period two', consumers are assumed to be more accepting of GM foods in the market place and begin to see them as closer substitutes to conventional foods. Thus, the elasticity of substitution parameters are raised above their period one values. However, there is still a core resistance to the technology, so the 25 per cent of consumers resistant to GM remains the same. By the second period, firms will have incurred many of the 'set up' expenses associated with regulation. Thus, implementation of the regulations only increases costs by 3 to 7 per cent, depending on the rigour of domestic regulation. Productivity gains continue to occur at the same rate as above.

In the third part of the simulation, 'period three', it is assumed that consumers have witnessed no adverse health effects associated with GM technology. Second generation products are assumed to have been introduced into the market place and more and more consumers make decisions based strictly on price. Thus, elasticity parameters are again raised, and the share of the market continuing to resist GM under any circumstances falls to 15 per cent. In response to reduced consumer resistance to GM food and improved economies of scale due to market expansion, costs of regulation are assumed to fall to between 2 and 5 per cent. Productivity gains continue to occur.

The final part of the simulation estimates some likely 'steady state' economic outcomes once GM technology is firmly in place and accepted by all but a small group of consumers. Regulations are assumed to have been relaxed, but general concerns for food safety remain. However, these concerns are not particular to GM foods and thus they attract no special attention. In this case, substitution elasticities for GM grains and oilseeds are the same as for non-GM grains and oilseeds, and there are no additional regulation costs imposed. Ten per cent of consumers are assumed to remain resistant to GM food. Productivity advances still occur at a higher rate for GM technology than conventional farming methods. Thus, a 2 per cent long-term productivity gain associated with GM technology is assumed.

Table 4.3 provides a summary of the three simulations.

Table 4.3 **Simulation summary**

	Production Gains		*Consumer Demand*	*Regulation cost*[(b)]	
	Grains	Oilseeds		Large[(c)]	Small[(d)]
Simulation					
	%	%	%	%	%
Productivity	7.5	6	n.a	n.a	n.a
Regulatory	7.5	6	-25	10/5	5/3
Policy evolution[(a)]	7.5→2	6→2	-25%→-10	10→0	5→0

n.a - not applicable.

a Run under two sets of assumptions for GM market share in Australia: Current (10 per cent) and increase (60 per cent).

b Regulation costs associated with GM crops only.

c Assumes Australia, New Zealand and the EU receive 10 per cent increases in production costs associated with regulation, while Korea and Japan receive 5 per cent cost increases.

d Assumes Australia, New Zealand and the EU receive 5 per cent increases in production costs associated with regulation, while Korea and Japan receive 3 per cent cost increases.

4.4 Summary

Sectors that supply inputs to the GM sectors, as well as those that buy GM products as inputs, will be affected by the productivity improvements associated with the use of GM technology. As demand rises for GM grains and oilseeds, the demand for inputs into these sectors will also rise. The competitiveness of downstream users of GM goods will also improve. For example, lower input costs could be experienced in processed food production as traditional maize is substituted out in favour of lower cost GM maize. This shift into GM inputs in one sector may however have consequences for mobile factors of production which could, in turn, affect other sectors in the economy.

There is both a direct and an indirect (downstream) effect associated with the adoption of GM technology. The direct result of output-enhancing GM technology is that regions adopting GM crops will gain from lower input costs; the more a region adopts the productivity enhancing technology, the greater the input cost reduction. The downstream or indirect effect will depend on the degree of substitutability between GM and non-GM products. When consumers (both households and firms) are relatively indifferent between GM and non-GM produce, the prices of non-GM crops will decline (along with the prices of GM crops) as consumers substitute toward cheaper GM food varieties. The lower the degree of substitutability, however, the weaker this indirect effect will be. The net effect in each region of these direct and indirect effects is theoretically ambiguous, however, and must therefore be estimated empirically.

Consequences for trade flows will depend on preferences for GM versus non-GM crops in foreign markets. As productivity improves in the GM sectors, world prices for GM products will decline, and this will benefit net importers of these goods (so long as they are indifferent between GM and non-GM goods). For exporters of GM products, lower prices may enable an expansion of trade volume, depending on price elasticities and preferences in foreign markets. In markets resistant to GM technology, lower priced GM crops will not significantly affect food prices because they are unlikely to be adopted.

When regulation costs are introduced into the model, producers’ decisions must incorporate the costs of compliance, not only with domestic regulations, but with those imposed in export markets. If gains in production efficiency associated with GM technology do not outweigh the additional costs of regulation under given demand conditions, producers in some regions are likely to avoid GM technology. This is more probable in regions that impose strict domestic regulations on GM crops, because such regulations would have long-run implications for the development, use and acceptance of GM technology in those regions, and therefore on their ability to remain globally competitive.

5 Results

As explained in the previous chapter, various scenarios were implemented to explore the potential consequences of the adoption of GM technology in grains (which includes corn but *not* wheat) and oilseeds (which includes canola, soybeans and cottonseed) production. This chapter discusses the results of these scenarios, taking each application in turn, and building on the results of the previous scenario. The first section reports the results from the productivity simulation. It shows the impact on Australia's output, exports and imports attributable to a productivity increase in the production of GM oilseeds and grains.

The second section shows the results of the two regulation scenarios. The first assumes that GM crops continue to meet resistance, and the cost of regulation is high — either 5 or 10 per cent depending on the stringency of the regulations proposed or in place. The second scenario assumes greater acceptance by consumers, and lower regulation costs of 2 and 5 per cent.

Finally, the outcomes of two sets of 'policy evolution' simulations are examined. These are based on a series of comparative static simulations which examine the potential outcome of a gradual change in consumer resistance and of a reduction in regulation costs, holding all other effects constant. The first set of simulations looks at the outcomes if Australia maintains its current market share of GM crops. The second set examines the same evolution of policy, but assumes that Australia increases its adoption of GM crops to attain the level currently seen in North America. North American markets have been the most accepting of GM technology and thus provide a good example of the rate at which these crops would be adopted in the absence of regulatory and consumer impediments.

5.1 Productivity simulation

Productivity shocks, of 7.5 per cent and 6 per cent to GM grains and oilseeds respectively, were applied to generate a set of results prior to any regulation or consumer considerations. Australia currently produces no GM crops for domestic food supply (although some GM inputs are approved for import). If crop production were to experience an increase in productivity due to GM technology and if there were no barriers due to regulation or market resistance, producers would be able to raise output (with the same number of inputs) and this would, in turn, reduce the price of GM crops to both intermediate and end users. A reduced price would induce increases in their use. Thus, it is expected that under this scenario both outputs of GM crops, and the demand for GM crops as inputs, would increase.

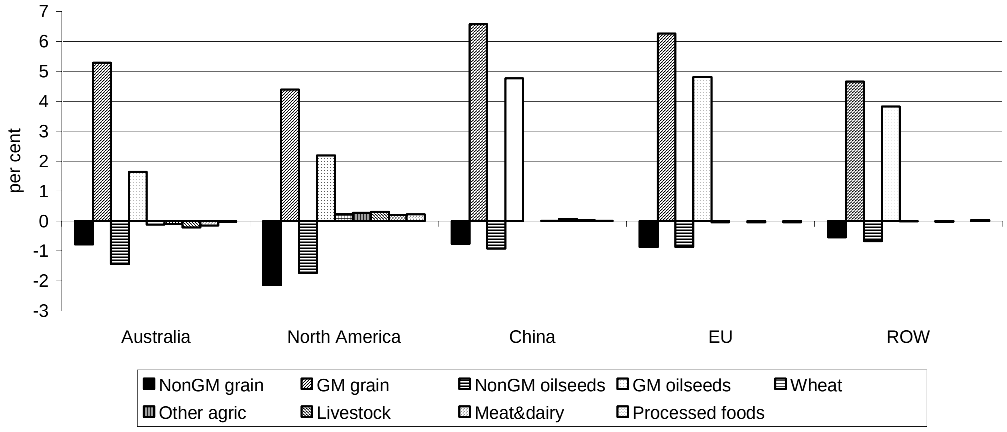
Changes in output and exports resulting from the modelling for major crop producing regions are examined below. Changes in imports for Australia's important export markets are then discussed. These results are shown in figure 5.1.

Output

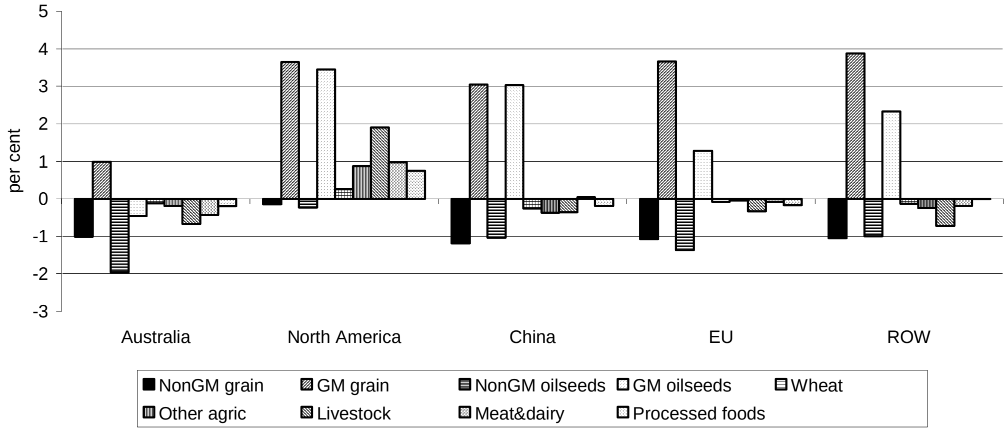
As expected, the results show that production of GM crops increases across the board at the expense of conventional crops. This occurs to the greatest extent in China and the European Union, and to a lesser extent in Australia. The larger markets for grains and oilseeds currently existing in China and the European Union explain this discrepancy. North America, already producing relatively large amounts of GM crops, experiences the smallest shift toward GM technology. Output in sectors other than GM-affected crops appears to be relatively unaffected by the productivity change, with small increases in North America, small declines in Australia and virtually no change in the other regions. The pattern of production gains across regions typically reflects the degree of GM uptake already in place. For example, North America experiences an expansion in the output of industries using GM inputs (such as livestock, meat and dairy and processed food). Other regions, such as Australia, simply experience an increase in the production of GM final goods, since their other industries currently have little or no GM inputs, and so do not benefit. However, over time, as the use of GM inputs increases, gains (in the form of lower input costs) would be expected to be more widespread across industries for the currently non-GM producing regions.

Figure 5.1 **Productivity simulation results**

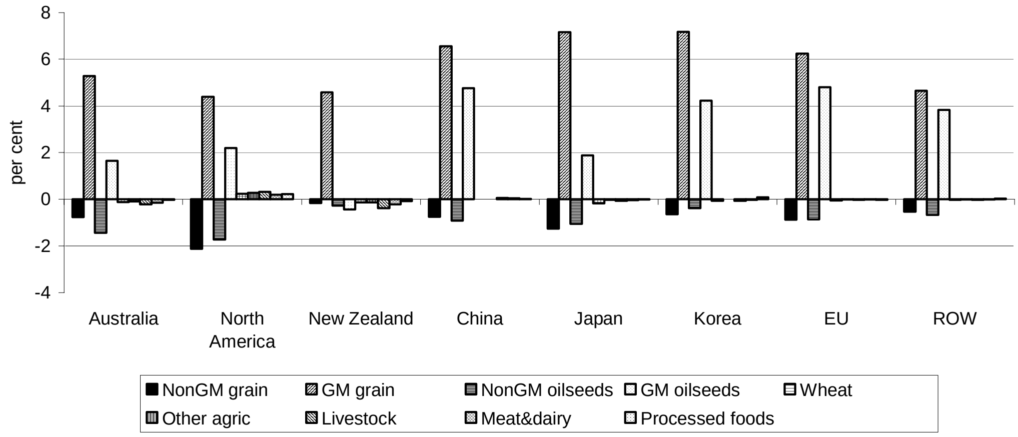
Changes in output



Changes in exports



Changes in imports



Exports

The results indicate that export changes follow much the same pattern as output changes. Most regions experience an increase in GM food commodity exports. Australian exports of GM grains increase while GM oilseeds exports decline. This is explained by Australia's small market share for overall oilseeds exports (less than 4 per cent) and the small share of GM varieties in overall oilseeds output (10 per cent). The productivity gains in the larger oilseeds producers, such as North America and China, dominate export growth in this market.

Not surprisingly, the model indicates that the largest producer of GM crops, North America, gains the most in terms of exports volumes from the assumed productivity changes. North America currently accounts for half of all grains exports and almost 60 per cent of all oilseeds exports. Exports of other agricultural commodities from this region are anticipated to increase, as are exports of livestock, meat and dairy and other processed foods. As GM commodities represent a relatively large share of inputs in these industries in North America, the region gains a comparative advantage in production of several commodities as a result of the productivity increases in the GM sectors.

Changes in crop exports across the remaining regions largely reflect their relative standing in terms of world agricultural trade. Exports increase in China and the European Union, both of which are large grains exporters (about 7 and 23 per cent of current total grains exports, respectively). As expected, exports in conventionally-produced grains and oilseeds decline in every region, as the market for these crops contracts.

Imports

Imports of GM goods increase for most regions. The seemingly large percentage increases in GM grain imports to Australia and New Zealand are calculated from very small bases, given that neither country imports much oilseeds or grains (less than 1 per cent of global imports of these commodities). Therefore, changes in absolute values for these countries are small. On the other hand, regions such as Korea, Japan and the EU, which are large importers of grains and oilseeds, significantly expand their imports of these commodities.

Imports of conventionally produced oilseeds and grains decline in most regions, but substantially so in North America. This is consistent with the increase in the output of GM crops in this region. Imports of conventional crops are replaced by cheaper domestic GM crops. Imports of other agricultural produce, livestock, meat and dairy and processed food also fall for this region, as consumers shift to cheaper domestically produced food and livestock (as a result of cheaper GM inputs). Other regions experience a slight increase in the imports of these goods and again, this reflects the flow-on effects of the large productivity gains in North America.

Under this scenario, Australia experiences virtually no changes in any of the total macroeconomic variables, including total imports and total exports. The major change takes place in the composition of trade, concentrated in the two GM producing sectors. GM grains and oilseeds imports increase significantly (7.5 and 5.4 per cent respectively) with much smaller increases in livestock and meat and dairy imports. However, exports of GM grains increase (1 per cent). When looking at the resulting shifts in trade for Australia, however, it must be noted that these crops represent only a small part of Australia's agricultural trade figures (accounting for about 3 per cent and 2 per cent of agricultural exports, respectively). Thus, given these small percentages, it is not surprising that Australia's total trade position does not change much under this scenario.

However, as noted in chapter 1, these crops represent an expanding area of agricultural exports for Australia. Therefore, while the results presented here show relatively small effects on total trade figures, they have implications for potential export growth of these crop markets. If these crops were to become major exports for Australia, not adopting GM technology may potentially place Australia at a comparative disadvantage.

Welfare

An overall measure of economic welfare changes is given by the equivalent variation, shown in table 5.1.[1] Overall, world welfare improves under the assumption that GM technology is associated with greater productivity. Consistent with the results outlined above, those economies already producing GM crops gain more than those not producing GM crops prior to the productivity shock. Therefore, North America has the largest increase in economic welfare, although the EU and the rest of the world (ROW) also experience large gains. Japan and China gain to a lesser extent; Japan from cheaper imports and China from an overall improvement in exports.

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[1] Equivalent variation is an economic welfare measure that describes the minimum amount that a party that gains from a particular change would be willing to accept to forgo the change. A positive value indicates a welfare improvement. The equivalent variation of a party that loses from a change is the maximum they would be willing to pay to prevent the change.

Table 5.1 **Welfare effects of productivity simulation**

Region	*Equivalent variation*		*Decomposition of welfare results, contributions of*[a]		
		Total	*Allocative effects*[b]	*Technical change* [c]	*Terms of trade* [d]
	US$Million	**% total**	**US$Million**	**US$Million**	**US$Million**
Australia	-6	-0.1	3	13	-22
North America	2480	58.0	-29	2700	-230
New Zealand	-11	-0.2	-1	0	-10
China	219	5.1	27	168	23
Japan	175	4.1	38	4	153
Korea	57	1.3	11	5	43
EU	530	12.4	265	219	64
ROW	824	19.3	74	785	-35
Total World	4268	100.0	388	3894	-14

[a] Does not include miscellaneous factors affecting Equivalent variation.

[b] Measures changes in welfare associated with changes in resource allocation that occur as a result of policy shifts. If a policy shift causes economic activity to move closer to an undistorted equilibrium, this represents a gain in allocative efficiency. If a policy causes economic activity to move away from an undistorted equilibrium, this represents a loss.

[c] Measures changes in welfare associated with changes in production technology.

[d] Measures changes welfare associated with changes in the relative price of exports and imports for a region. Where export prices rise more quickly than import prices, or export prices fall less quickly than import prices, there is a terms of trade gain for that region which is welfare enhancing.

Source: Author estimates

Australia, however, suffers an overall small welfare decline under this scenario. This is a reflection of the small share of total output these crops represent. As shown earlier, as GM productivity increases, Australia’s domestic production is too small to take advantage of this increase. Therefore, while domestic production switches into GM technology, imports become more competitive and increase. The traded price of both GM and non-GM crops falls, so export prices fall as well. The net result is an economic welfare loss stemming from a decline in the terms of trade. The small GM production base means the resulting allocative and technical benefits of the production switch do not overcome this terms of trade effect. However, it is reasonable to assume that as GM production expands, domestic prices will fall and imports will decline, reversing the terms of trade effect and increasing allocative and technical benefits.

North America’s reported total economic welfare increase of US$2.48 billion comes entirely from increased productivity (technical change), with allocative efficiencies actually declining and terms of trade deteriorating. The decline in North America’s terms of trade comes from the fact that exports are increasing at a reduced price, while the decline in imports is not enough to offset this. This leads to an overall decline in the terms of trade.

5.2 Regulation

This section presents the results of the second scenario, where consumer resistance and regulation costs are imposed. As described in chapter 4, regulation costs were imposed in Australia, New Zealand, and the European Union at a rate of 10 per cent, and in Korea and Japan at five per cent — representative of differences in the stringency of regulations in different regions. These costs are imposed on both domestic production and imports. As explained above, two different scenarios are developed regarding these costs. The first (‘large’) scenario assumes that all regulation stems from the introduction of genetic modification and that market shares for these products remain relatively small. The effect of these assumptions on output, exports and imports are shown in the three panels in figure 5.2.

The second scenario (‘small’) assumes that regulation results not only from the introduction of genetic modification, but also from a more general trend toward increased food safety (that is, at least part of the regulation costs would be imposed regardless of the introduction of GM commodities). Moreover, as the market for GM commodities expands, regulation costs are spread over an increasingly larger output base and economies of scale are achieved. Thus costs are imposed at the 5 and 3 per cent levels (depending on the level of regulation imposed). The impact on output, exports and imports for the ‘small’ scenario are shown in the three panels in figure 5.3.

Under the ‘large’ scenario, regulation costs are higher than assumed productivity gains. Therefore, in those regions incurring regulation costs, output gains experienced by the GM sector are expected to be reduced, if not reversed to outright declines. When regulation costs are lower (‘small’), productivity improvements should maintain an increase in output; but increases are expected to be lower than under the productivity scenario.

Output

As expected, imposing regulation costs in the modelling has very little impact on the output of GM and non-GM crops in regions unaffected by changes in domestic regulation (figure 5.2). While output of GM crops increases by the same amounts as under the productivity simulation, the declines in non-GM crop output are not as large. For example, output of non-GM oilseeds fell by 0.7 per cent in the ROW under the productivity scenario. When regulation costs and consumer resistance to GM crops are added, output of non-GM oilseeds fell by only 0.6 per cent. North America continues to increase its production of GM commodities at the expense of non-GM commodities, and also increases its output of related industries such as processed food and livestock.

Regions imposing regulations experience an overall change in output patterns. In these regions, domestic output growth of GM crops is typically smaller than previously observed, and there are smaller reductions in non-GM output. Non-GM grains output in Australia changes from a decline of 0.8 per cent in the productivity simulation, to 0.15 per cent in the 'large' costs simulation, while there are smaller increases in grains produced in the GM goods sector (output growth falls from 5.3 per cent to 3.7 per cent). Regulation costs reduce the price differential between the two crops brought on by the productivity gains imposed earlier, lessening the switch to GM production. The same pattern is observed in the EU results, except that in this case, the gains to the EU grain market improve. This stems from an expansion in intra-EU trade brought about as a result of the regulation.

Changes in the oilseeds output are similar for both Australia and the EU. Non-GM oilseeds production increases in both regions (a reverse from the declines experienced in the productivity scenario). Domestic output of GM oilseeds in both regions rises as well. Because productivity gains in oilseeds are assumed to be smaller than in grains, regulation costs have a larger impact on prices, especially import prices. Therefore, the switch to domestic production is greater in the oilseeds sector than in the grains sector.

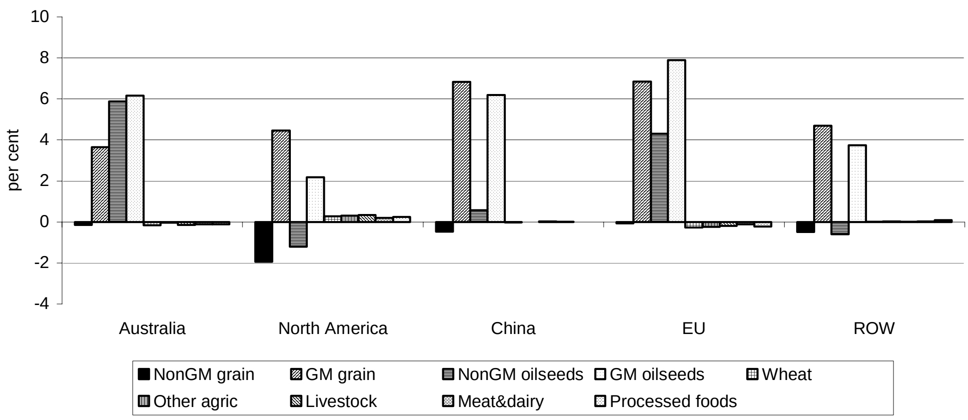
In related or 'downstream' industries such as livestock and processed food, Australia and the EU experience slight declines in output. This is the same trend identified earlier in the productivity scenario. As the costs of regulations in Australia and the EU increase the domestic price of crops, they also increase the domestic input cost to downstream markets, and the higher the regulation costs imposed, the stronger this effect will be. As input prices rise in regulated regions, output in the downstream markets of unregulated regions such as North America (and to a lesser extent the ROW) increases. This is consistent with the fact that, having a larger share of crops experiencing an increase in productivity and no associated increase in domestic regulatory costs, inputs to these secondary markets are cheaper and thus these industries expand.

When the regulation costs are assumed to be smaller (see figure 5.3), the overall pattern remains the same but the individual changes are smaller. For both oilseeds and grains, the regulatory costs no longer overtake productivity gains. Thus, the large increase in the production of non-GM oilseeds observed in Australia and the EU (and to a lesser extent, China) are no longer apparent. There is still an increase in the production of non-GM oilseeds in the EU and Australia, but these increases are much smaller.

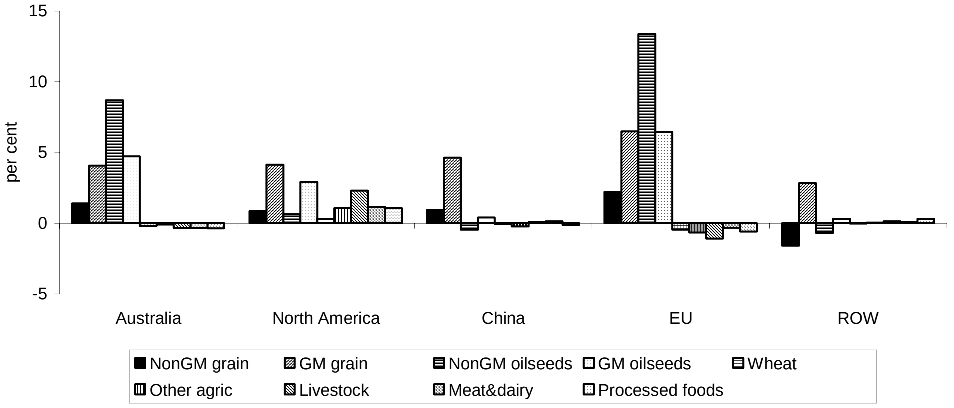
Figure 5.2 Regulation costs simulation results in GM and GM-related sectors

10 and 5 per cent costs imposed

Changes in output



Changes in exports



Changes in imports

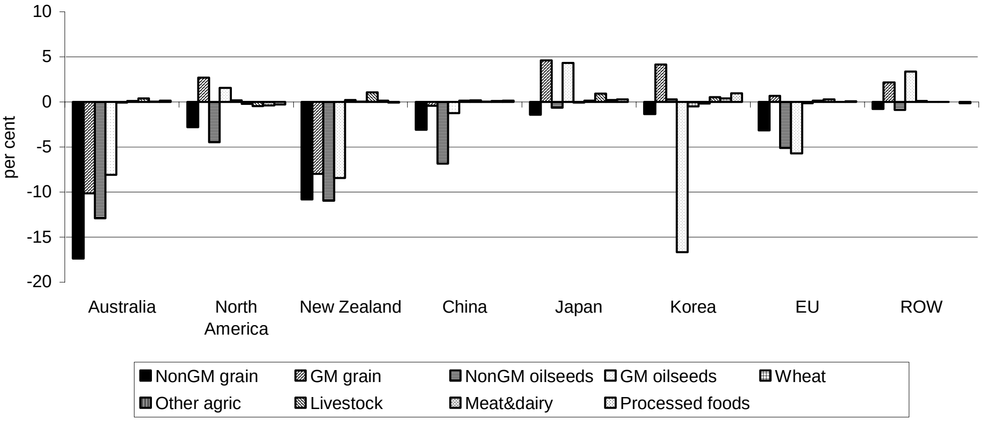
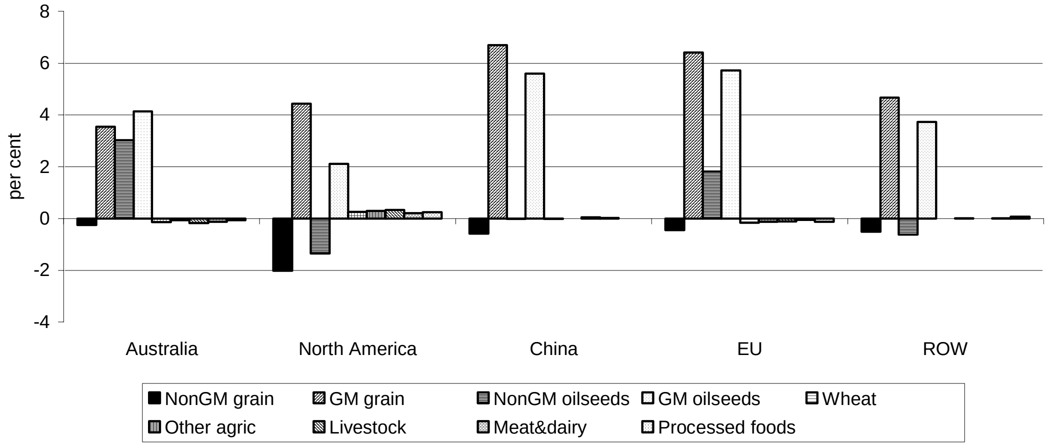


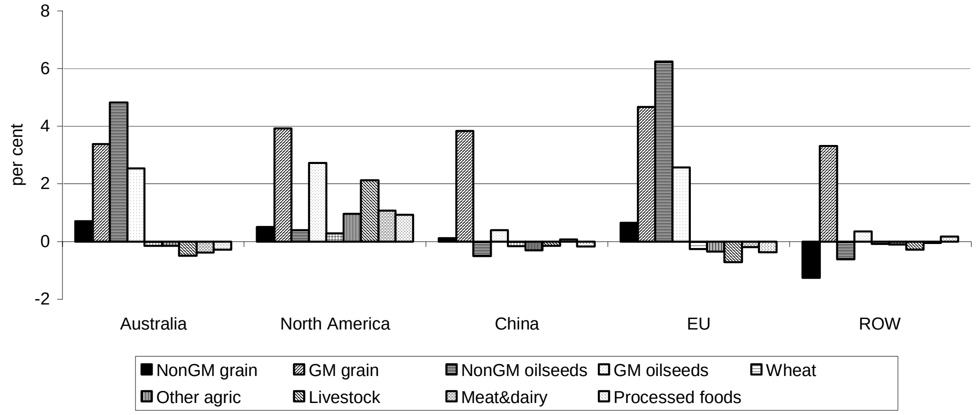
Figure 5.3 **Regulation simulation results**

5 and 3 per cent costs imposed

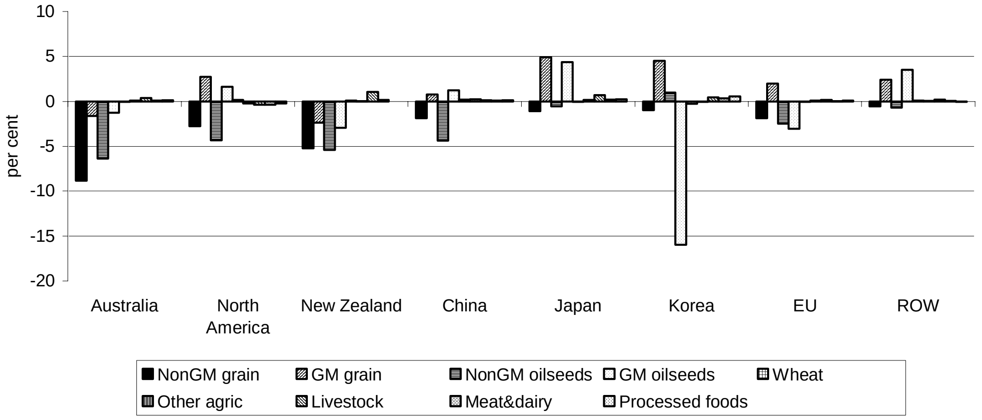
Changes in output



Changes in exports



Changes in imports



Exports

When ‘large’ regulation costs are imposed, Australia’s exports of all four crops (GM and non-GM) increases. This increase goes almost entirely to other regulated regions such as Japan and Korea; although there are also relatively large increases in non-GM oilseed exports to the EU. It must be kept in mind that these increases are off very small bases — as stated above, Australia accounts for only 1 per cent of total world oilseeds exports. The impact this has on Australia’s canola market depends on the share of canola in the oilseeds commodity category. Given that most of the oilseed crop for Australia is made up of canola, the expansion in oilseeds exports from Australia could represent a significant increase in demand for non-GM canola in the EU. The large expansion observed in EU exports is mainly a function of increased intra-EU trade.

North America and China (which are assumed not to incur domestic regulation costs) experience gains in all GM and non-GM export commodity markets (with the exception of China’s non-GM oilseed exports). Thus, it would appear that these regions are expanding trade both to regulated and unregulated regions. The ROW shows the more traditional pattern of expanding GM exports and declining non-GM exports. This implies their trade growth is mainly to unregulated regions.

The downstream benefits of increased productivity in large GM-producing regions is also evident in the export results. North American exports of livestock, meat and dairy and processed foods increase more than in the productivity scenario. Exports of these secondary commodities increase as the stringency of regulation in other regions grows because domestic regulation decreases the price competitiveness of regulated regions’ secondary commodities. Thus, exports of these goods from North America become more competitive under the ‘large’ scenario than exports from Australia and the EU. The ROW experiences a similar trend in exports to that of North America, although the gains are smaller.

Overall, it would appear that agricultural exporting regions experiencing consumer resistance and regulation of GM crops (namely, Australia and the EU), increase their exports of non-GM crops to each other and to other regulated regions (such as Japan and Korea) while non-regulated regions increase their exports of both commodities, as well as increasing exports of secondary commodities.

When regulation costs are assumed to be smaller, export patterns are similar, but the magnitude of the results is not as great for the regulated regions (see figure 5.3). This is especially true for Australian oilseed exports which do not experience the same large increases to the EU market as they do under the ‘large’ scenario. This is because when regulation costs are smaller, regulated regions do not rely so much on exports to one another, since unregulated regions still find it worthwhile to supply them.

Imports

Australian imports of both types of grains and oilseeds decline when regulation costs are introduced. While regulation costs are imposed on both domestic production and imports, the price of domestic crops falls at a greater rate than the price of imports for Australia. This is because applying regulation costs to imports places them on a more equal footing with Australian domestic products.

Most of the regions imposing GM regulation encounter a decline in imports. The only exceptions are Japan and Korea, where Japan continues to increase its imports of GM grains and oilseeds, but at a lesser rate than previously observed. Here, Japanese domestic prices fall less than imported prices (for example, GM grains import price fall 3.9 per cent but domestic prices only fall 1.9 per cent.). The difference in domestic price changes and import price changes reflect the relative market share of the good as well as the influence of GM output. Japan has very little domestic grain production so imports will remain competitive. Korea increases its imports of GM grains while substantially decreasing the very small amount of GM oilseeds it previously imported. North America and ROW experience increases in their imports of GM commodities, but this is due primarily to intra-regional trade. That is, Canada and the United States increase imports from one another and from the ROW, while the ROW increases its imports of these commodities from North America.

Figure 5.2 also shows that the largest increase in imports of secondary commodities such as livestock and processed foods is in the Korea. These imports are coming mainly from North America, where large productivity gains make GM inputs cheaper and thus downstream commodities very attractive.

When regulation costs are assumed to be lower, there is less differential between domestic and imported prices. Thus, the decline in imports is not as great. However, increases in imports of downstream goods from North America remain, as these goods are only indirectly affected by regulation.

Welfare

Overall measures of economic welfare decline when ‘large’ regulation costs and consumer resistance are added to the productivity gains modelled already (table 5.2). The EU experiences the largest decline in welfare as a result of regulation.

However, this is largely a result of import losses stemming from intra-EU trade. Japan has the lowest economic welfare measure after the EU with a total decline of US$235.5 million after productivity gains, consumer resistance and regulation are all taken into account. This loss comes from the adverse effect on technical change due to the increased costs of regulation.

As explained in the previous chapter, regulation costs are modelled as adverse technical change effects. That is, under the regulation simulation, it is more costly for the firm (or farmer) to produce each level of output, given the costs of regulatory compliance. This is represented by large losses in technical change in all regions imposing some regulation (table 5.2). Prior to the regulation costs, New Zealand fared the worst of the regions examined. However, once the costs of regulations and consumer resistance are added, Australia, Japan, Korea and the EU — in short, all regulating regions — experience larger economic welfare declines. The differences in welfare reductions depend on the size of the market on which the regulation is being applied. Thus, Australia suffers larger economic welfare declines than New Zealand because GM regulation requirements apply to a larger proportion of output in Australia than in New Zealand. However, Australia’s losses are much lower than Japan, Korea and the EU, which all have larger markets subject to regulation.

North America’s economic welfare gains are higher under this scenario than the productivity scenario, mainly because of terms of trade effects. Where previously North American exports experienced a price decline that reduced welfare, the introduction of regulation costs elsewhere reduces these negative welfare effects. This is because the costs of regulation are reflected in a higher export price for North America, as these costs (or spending as the case may be) are incurred domestically. Therefore, the price of its exports does not fall to the same degree as in the productivity scenario, leading to a smaller welfare decline resulting from changes in terms of trade. In addition, domestic prices in North America fall more than import prices, leading to a larger decline in imports.

When regulation costs are assumed to be ‘small’, overall economic welfare losses are not as great for Australia compared to the ‘large’ scenario (table 5.3). While the terms of trade effect has become negative (due to the smaller reduction in imports), the negative effect of the regulation on technical change has declined, leading to an overall smaller welfare loss for Australia. Given that regulation costs were modelled as higher costs to producers, the negative welfare implications due to deteriorating allocative effects are not surprising.

Table 5.2 Welfare effects of regulation simulation

Regulation costs of 10 and 5 per cent

Region	*Equivalent variation*		*Decomposition of welfare results, contributions of*[a]		
	Total		*Allocative effects*	*Technical change*	*Terms of trade*
	US$Million	**% total**	**US$Million**	**US$Million**	**US$Million**
Australia	-17	-1.1	-3	-18	5
North America	2551	172.5	-29	2700	-148
New Zealand	-8	-0.5	-1	-3	-4
China	84	5.7	-4	64	27
Japan	-235	-15.8	139	-424	60
Korea	-127	-8.5	181	-318	11
EU	-1547	-104.6	-551	-1034	43
ROW	778	52.6	-5	785	5
Total World	1479	100.0	-273	1752	-1

[a] Does not include miscellaneous factors affecting Equivalent variation.

Source: Author estimates

Not captured in these economic welfare measures, however, are any potential gains that arise from increased consumer confidence resulting from this regulation, or increased market confidence from overseas buyers. Consumers' welfare may actually rise if they believe such regulation ensures product safety and that claims made (such as 'GM Free') are accurate. The reputation of 'clean and green' is believed to have bolstered Australian beef exports, for example, during the recent foot and mouth disease outbreak in the EU. This benefit will only be captured in these calculations to the extent that they transfer into price premiums.

Table 5.3 Welfare effects of regulation simulation

Regulation costs of 5 and 3 per cent

Region	*Equivalent variation*		*Decomposition of welfare results, contributions of*[a]		
	Total		*Allocative effects*	*Technical change*	*Terms of trade*
	US$Million	**% total**	**US$Million**	**US$Million**	**US$Million**
Australia	-10	-0.3	-0	-2	-7
North America	2529	89.7	-23	2700	-182
New Zealand	-9	-0.3	-1	-2	-7
China	139	4.9	9	106	26
Japan	-70	-2.5	100	-253	98
Korea	-53	-1.9	113	-188	24
EU	-510	-18.1	-146	-407	54
ROW	803	28.5	35	785	-12
Total World	2819	100.0	87	2739	-6

[a] Does not include miscellaneous factors affecting Equivalent variation.

Source: Author estimates

5.4 Policy evolution

This section reports the results of the policy evolution simulations. The first policy evolution simulation assumes Australia’s current GM market share (ie 10 per cent), while the second assumes GM market shares are increased to be in line with those currently in place in North America (ie around 60 per cent). As described in chapter 4, regulation costs and productivity gains associated with GM technology are gradually reduced until a ‘steady state’ is achieved. The steady state results for each of the two policy evolution scenarios are presented below. Changes in outputs for grains and oilseeds sectors are presented first under assumptions of current GM market shares and then for increased GM market shares (figure 5.4); changes for exports under both assumptions are then discussed (figure 5.5); followed by changes in imports (figure 5.6). Finally, changes in the output, exports and imports of downstream sectors are presented, for Australia only, under each market share assumption (figure 5.7).

Output

The first panel in figure 5.4 shows the changes in output of GM and non-GM grains and oilseeds for the main crop-producing regions under the assumption of current market share. In all five regions examined, the output of non-GM crops falls and the output of GM crops increases. As regulation costs come down and consumer resistance abates, Australia increasingly switches from non-GM crop production into GM crop production. The declines in non-GM output are offset by increases in GM output, so Australia experiences only a very small increase in total grains and oilseeds output. Growth in GM oilseeds output tends to be lower than grains across regions. North America shows the greatest tendency to reduce non-GM crop production, while China shows the greatest tendency to increase GM crop production. This trend implies that China could potentially surpass North America as the largest producer of GM grains and oilseeds.

When an increased adoption rate of GM crops in Australia is exogenously imposed on the model, the gains in output stemming from a change in market conditions (ie productivity changes and fall in regulation costs) are smaller than under the current market share scenario. However, when larger market shares for GM crops are is assumed, the declines in the non-GM sector are larger as more pressure is placed on this now smaller, less productive, part of the sector.

Figure 5.4 **Steady state of policy evolution simulation results**

Change in output

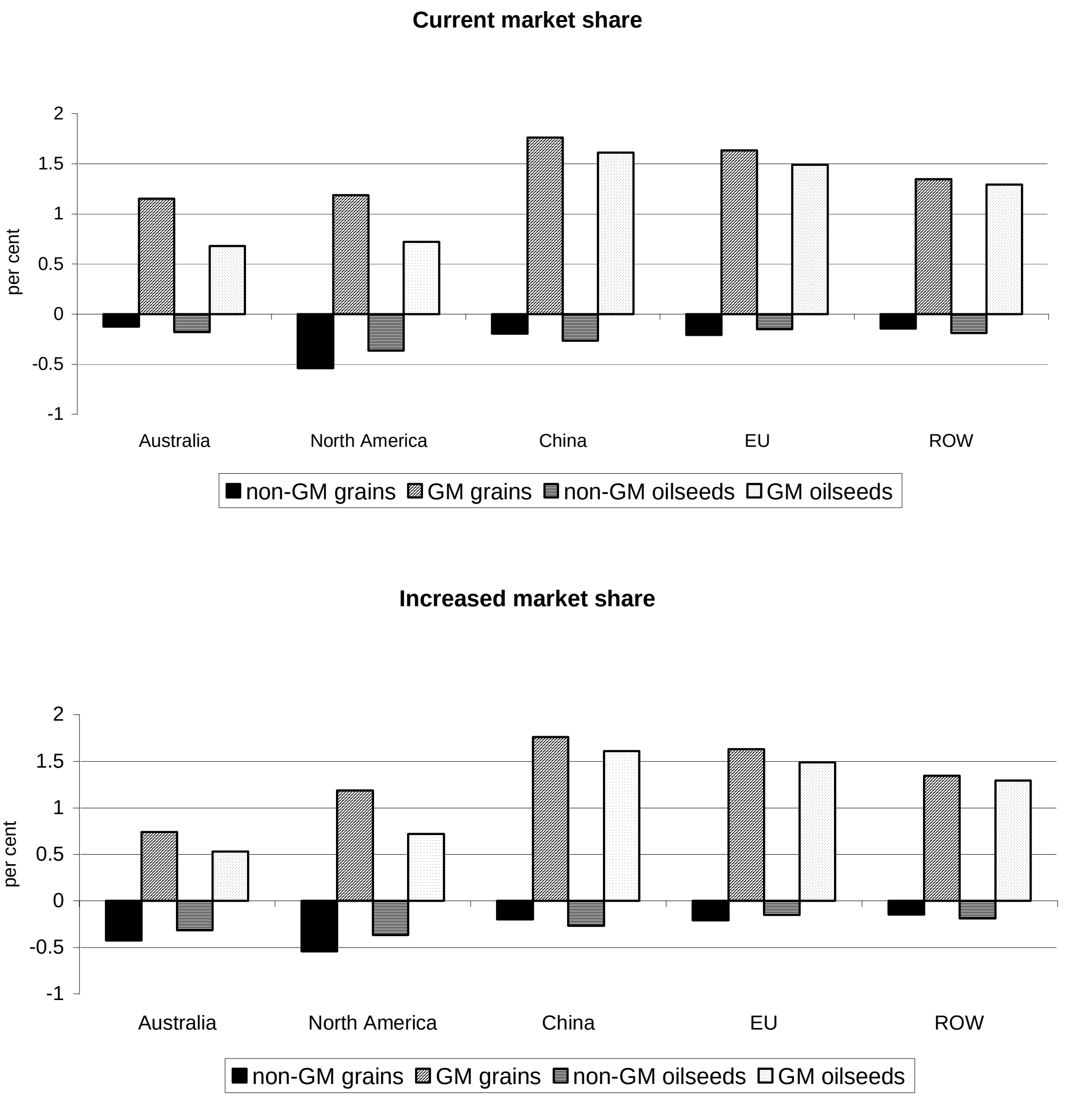
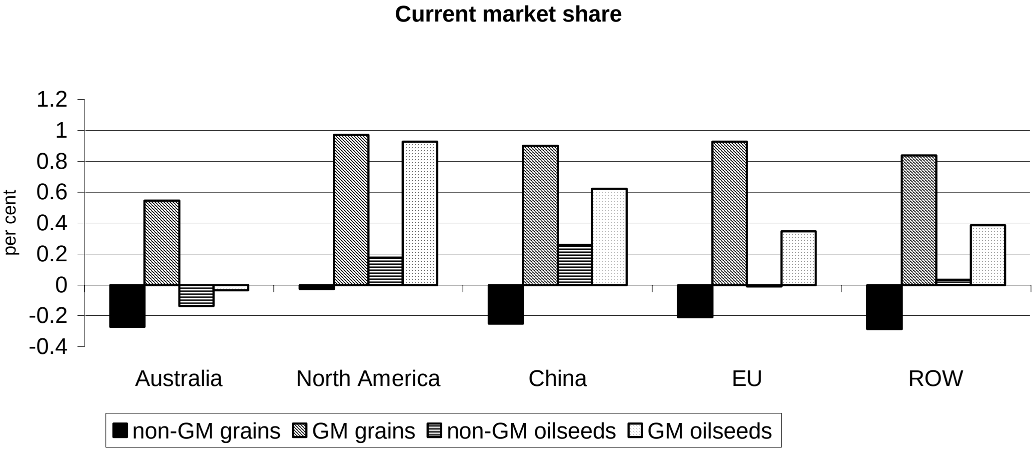


Figure 5.5 Steady state of policy evolution simulation results

Change in exports



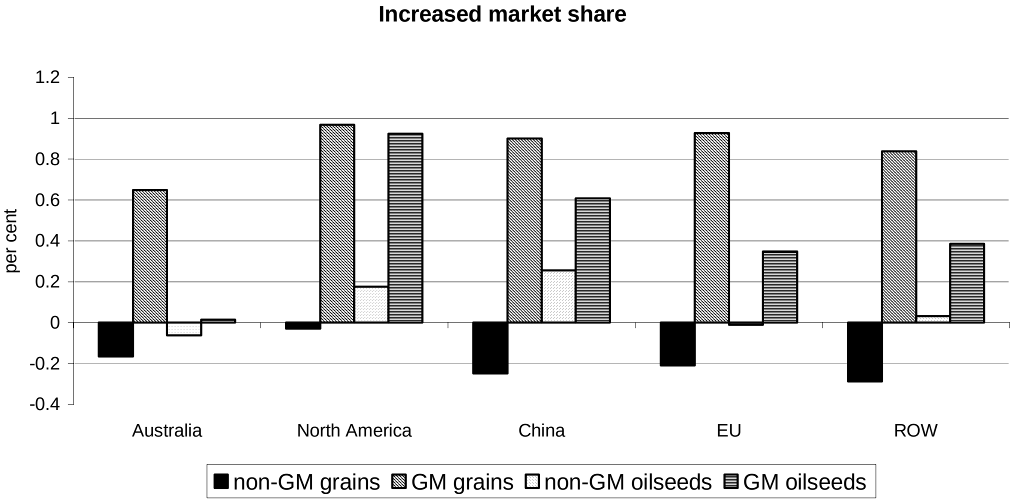
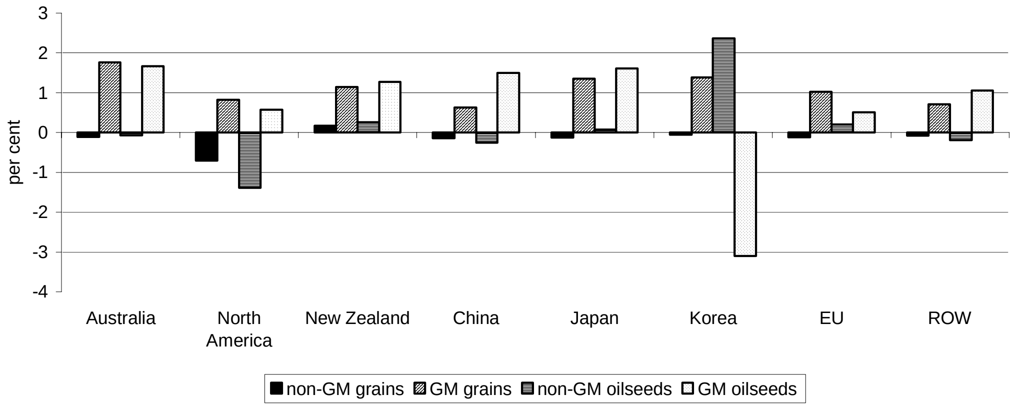


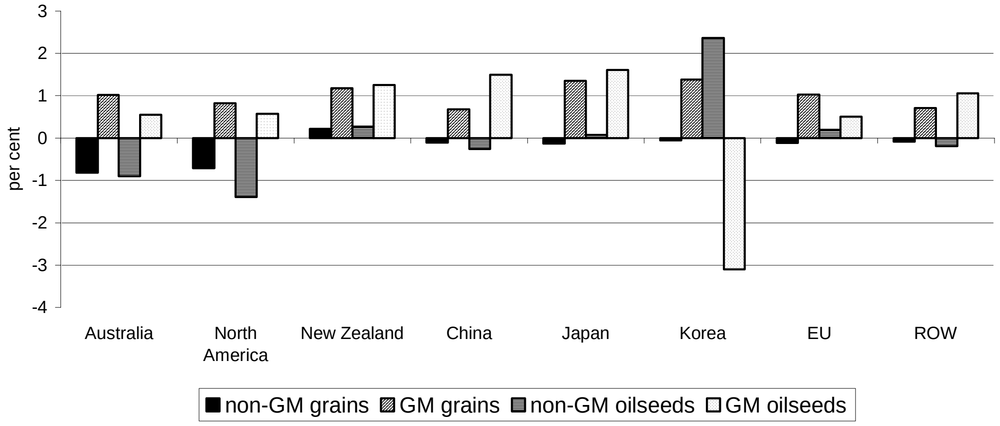
Figure 5.6 **Steady state of policy evolution simulation results**

Changes in imports

Current market share



Increased market share



Exports

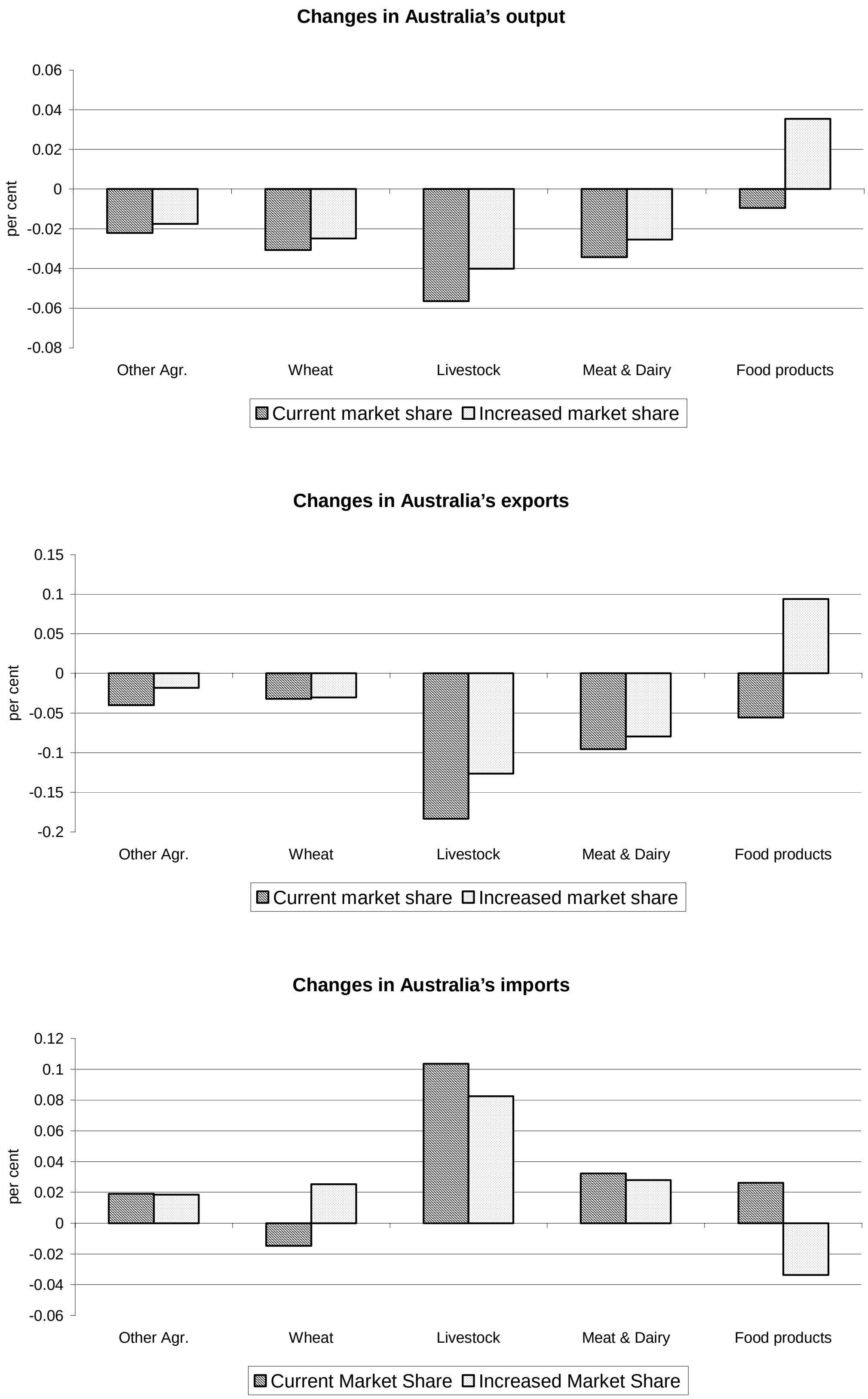
Assuming current GM market shares, Australia’s exports of non-GM grains and both GM and non-GM oilseeds fall, but by less than 0.5 per cent (figure 5.5). Exports of GM grains grow, albeit only slightly. As the discrepancies in regulation costs between regions diminish, trade across the formerly regulated and unregulated regions increases. Australia’s export growth declines compared to the previous regulation simulation. This is because when regulation costs were high, Australia had significant trade to the European Union, Japan and Korea. However, when regulations are removed, these regions increase their trade with North America and the ROW, which have relatively higher shares of the (assumed) more productive GM crops.

The assumption that Australia increases its market share of GM grains changes its steady state export position marginally; and this is greater for grains than oilseeds. With a larger GM market share, the decline in exports of non-GM grains is smaller and the export of GM grains is larger, leading to an overall increase in grain exports. This occurs because a larger portion of Australia’s production is assumed to come from GMs, and thus a larger portion of total output experiences productivity increases. Under the assumption of current market share above, increases in GM grains exports were not enough (given their small output base) to overcome the declines in non-GM exports. Thus, total grain exports fell slightly in that scenario.

In the steady state, the export of GM oilseeds becomes positive when increased GM market share is assumed. It declines under the assumption of current market share. With a larger GM market share, Australia is able to take advantage of productivity gains in this sector and maintain a small increase in exports over the long run, which come at the expense of North America. The very small increases in GM oilseeds exports are too small to have an appreciable impact on Australia’s overall growth in total oilseeds exports, however.

Figure 5.7 Steady state of policy evolution simulation results

Downstream industries



Imports

As shown in figure 5.6, imports of both non-GM crops fall for Australia, and as regulations costs decline, GM crop imports increase (mainly from North America). Australia’s total oilseeds imports increase slightly (about 0.1 per cent) in the steady state, while grains imports remain largely unchanged. Most regions show small gains for GM grain and small losses for non-GM grains. This is consistent with the long-run assumptions of no regulation costs or consumer resistance and a small productivity improvement in GM sectors.

When Australia is assumed to maintain its current market share and regulation costs are reduced, imported GM crops compete more effectively with domestic non-GM output and thus imports of GM grains and oilseeds rise. When a larger market share for GM crops in the domestic economy is assumed, domestic output is more competitive with imports and the effect is for import growth to be much lower under this scenario.

Downstream industries

Figure 5.7 shows the changes in Australia’s output, exports and imports of GM-related products under the two different GM market share assumptions. Overall, the changes are very small, all less than 1 per cent.

Output declines in the livestock and meat and dairy sectors observed under Australia’s current GM market share assumption are larger than when increased market shares are assumed. This is because increased market shares mean more GM inputs are used in these downstream sectors, making them more competitive than they were, and leading to smaller output declines. As stated, however, these differences are very small. For similar reasons, Australia’s food products output increases under the higher GM market share assumption, whereas it declines under the current market share assumption. Again, this is because the use of more GM inputs makes the final product price lower, in both domestic and foreign markets.

In the steady state, when GM-related regulation costs are assumed to be zero, meat and dairy and wheat exports remain virtually unchanged across the two scenarios, while livestock and other agricultural exports experience smaller declines under the increased market share assumption. Processed food exports expand under the assumption of increased GM share and decline under the assumption of current market shares in the steady state. These results again stem from the greater input cost advantages reaped by downstream sectors when the GM market share is higher.

The changes in imports for downstream sectors under the current and increasing market share assumptions are, again, all very small. Livestock has the largest increase in imports under both scenarios. When GM market shares are assumed to increase, processed food imports actually decline. As with the grains and oilseeds results shown above, domestic production, which is more efficient when using more GM inputs (given that GM technology is assumed to be more productive), displaces imports.

Welfare

The table of welfare results (table 5.4) presents the steady state simulation for all regions.[2] These results are based on assumptions of general consumer acceptance of the GM crops modelled and no specific regulation tied to the production of these crops and food. GM crops still enjoy productivity gains, but these are capped at 2 per cent. Non-GM crops are guaranteed at least a 10 per cent market share (under the assumption that a niche market develops similar to that already in place for organic foods). This assumption implies that either the organic market expands or that some consumers continue to view GM food as distinct and not substitutable for either non-GM or organic.

The only region experiencing an economic welfare decline in the steady state is New Zealand. This stems from a terms of trade decline, which occurs in a similar fashion to that outlined above for Australia. However, all other regions show economic welfare gains. North America and Australia both experience terms of trade declines. Although North American exports increase, the prices received for its exports are declining (given the productivity of its GM sectors) much faster than the prices of its major imports, which are not affected by productivity improvements to the same degree. Thus, its terms of trade decline. In addition, the existence of a niche market for non-GM crops causes a loss to North American allocative efficiency. Again, this stems from the rather large share of North American output attributable to GM.

Even though the higher market share scenario assumes Australia’s grains and oilseeds sectors adopt GM crops at the same rate as North America, Australia still does not experience the same large technical change benefits. While the market shares are similar, North America still produces a larger absolute amount of both crops and is a much larger player in the world market for oilseeds and grains than

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[2] The results presented for Australia in table 5.4 are under the assumption of increased market share. The difference in total welfare outcomes under the two assumptions for other regions is minimal. For Australia the results under current market share assumptions are: allocative efficiency, -0.66; technical change, 3.7 and terms of trade, -6.2, all in millions of US$.

Australia. Thus productivity improvements (technical change) are larger in North America than they are in Australia.

Consistent with earlier findings, those regions producing relatively large amounts of GM products gain the most. China, ROW and the EU were assumed to have relatively large initial market shares of GM crops, and therefore, they gain significantly from the technological improvements experienced in these sectors. Japan, a large food importer, gains significantly from cheaper imports (of GM commodities), which improves its terms of trade and leads to economic welfare gains.

Table 5.4 **Welfare effects under policy evolution simulation**

Steady state

Region	*Equivalent variation*		*Decomposition of welfare results, contributions of*[a]		
		Total	*Allocative effects*	*Technical change*	*Terms of trade*
	US$Million	**% total**	**US$Million**	**US$Million**	**US$Million**
Australia[b]	9	0.8	-0	16	-7
North America	616	53.6	-18	693	-69
New Zealand	-3	-0.3	-0	0	-3
China	60	5.2	6	47	6
Japan	48	4.2	8	1	44
Korea	24	2.1	11	1	13
EU	140	12.2	64	67	15
ROW	255	22.2	27	225	2
Total World	1149	100.0	98	1050	1

[a] Does not include miscellaneous factors affecting Equivalent variation. [b] Under assumption of increased GM market share.

Source: Author estimates

5.5 Conclusions

The results presented here indicate that the adoption rate of GM technology in the grains and oilseeds sectors will not have a major impact on Australia's trade under various scenarios. The result is consistent with two recent studies by ABARE. Foster (2001) reports that Australian production of total grains falls by 0.1 per cent and its total output of oilseeds falls by 1 per cent with the introduction of GM technology. The results of the productivity simulations presented here (which, like the ABARE study, assumes no regulations) show grains market output falling by 0.16 per cent and oilseeds by 1.1 per cent.

Looking specifically at canola, ABARE (Nelson et al. 2001) reported an estimated increase in total output resulting from GM adoption of almost 10 per cent by 2005. While this study does not examine canola specifically, gains for oilseeds output (about 3 per cent) were found in the first productivity scenario. However, this was a single period gain.

Under the original productivity increase scenario, Australian exports of both non-GM oilseeds and grains fall, as do GM oilseeds. Only GM grains exports increase. The fall in exports is because the world market share of non-GM crops declines in response to the introduction of more productive GM crops. Australia, producing mostly non-GM crops, is not in a position to capitalise on the GM productivity increases to a large extent. While movement into the GM sector is observed in Australia, as a result potential productivity increases, general export market improvements will only occur once a GM sector is more firmly established.

When estimates of regulation costs and consumer resistance are considered, output of non-GM grains declines less as consumer resistance guarantees a larger market share for these crops. At the same time, growth in domestic output of GM grains is smaller. These results holds under both ‘large’ and ‘small’ regulatory cost scenarios for Australia.

The model suggests that the markets for downstream sectors (such as livestock and processed foods) would also be affected. Under the assumptions made in the model, these sectors are regulated only indirectly. Those regions experiencing no additional regulation costs, that also have sizeable GM markets, gain most. Thus, North America, in particular, would increase its output and exports of livestock, meat and dairy, and processed foods. This would come at the expense of regions such as Australia.

All of these results are based on comparative static simulations, that is, a one-off shock to the system. One of the most difficult aspects of predicting the effects of adopting GM technology is the fluid nature of the debate surrounding GM crops and food. Consumer attitudes are constantly evolving, new regulation is being proposed almost every day across the world, and importantly, biotechnology is being applied to an ever increasing range of crops and foods.

One possible series of changes has been modelled in this paper. It assumes that consumer resistance will abate, expanding potential markets for GM goods. As such, regulation costs will fall. These assumptions were modelled firstly under the premise that Australia maintained its current market share of GM goods (about 10 per cent), and secondly, assuming Australia increased adoption rates to the same levels as seen in North America (about 60 per cent).

The results of these scenarios imply that, if Australia does not increase its adoption of GM technology, its markets for oilseeds and grains are likely to stagnate, and may even decline. Even when increased adoption rates are assumed, overall gains to Australia are small, while slight declines are observed in downstream industries. However, it is the long-term implications of these trends that are important. If Australia remains at its current GM production levels, and most of its trading partners adopt GM, Australia could potentially lose market share over the long run, both in its primary crop markets and in downstream markets, such as livestock and processed foods.

However, several notes of caution apply. The results presented here assume that Australia, for the most part, maintains its overall position in world trade of grains and oilseeds. If aggressive market expansion were to occur, the potential losses for Australia from non-adoption of GM technology may increase. However, this assumes that no ‘GM free’ price premiums develop in the marketplace. If a significant number of consumers would be willing to pay a premium for non-GM production, Australia could be in a good position to take advantage of this market. However, if ‘GM-free’ is relegated to a niche market, Australia may find itself competing against large agricultural exporters such as the EU, for a relatively small number of consumers.

Finally, if GM technology spreads into other markets, notably wheat, the implications for Australia would be much greater. Given that many expect GM wheat to be commercially available within the next year or so, this is an important future area for research.

6 Conclusion

GM crops have the potential to affect Australian and global trade by improving crop productivity, making agricultural production more sustainable, and expanding the range of agricultural products. Concerns over the acceptability of GM products by some consumers, and the regulatory responses adopted by countries, may also substantially influence trade flows.

The rapid adoption of GM crops to date suggests that benefits are accruing to farmers using GM technologies. Although empirical evidence of on-farm benefits is mixed, the balance appears positive. Along with on-farm performance of GM crops, consumer attitudes and acceptance will be critical to the ongoing use of the technology, both by driving product demand and shaping regulatory responses at the national and international levels. While consumer attitudes are still evolving, some regional disparities are apparent — acceptance is fairly high in the United States but much lower in the European Union, for example.

Results from the modelling undertaken in this paper suggest that:

1. Australia’s **overall trade position** would only be significantly affected by the expansion of GM technology into the non-wheat grains and oilseeds sectors if current market conditions change. This is supported by modelling of several different scenarios, which show that there are only slight impacts on Australia’s trade position:
   - absolute changes to Australia’s import and export flows as a result of *productivity* gains in the non-wheat grains and oilseeds sectors are relatively small; and
   - when regulation costs and consumer resistance are added to the model, total trade effects are still small and Australia’s economic welfare declines slightly.

2. **The composition of trade** will alter in favour of GM commodities at the expense of their non-GM counterparts, both in Australia and globally.

3. **Downstream sectors** such as livestock and processed foods (that use GM crops as inputs) are affected by the adoption of GM grains and oilseeds under the scenarios considered. Australia’s exports of downstream industries fall slightly,

while imports increase. Regions with sizeable GM markets that experience no additional regulatory costs benefit most.

4. If consumer resistance is assumed to abate, the total trade impacts remain small whether Australia maintains its current adoption rates or increases them to the levels of North America. However, if Australia does not increase its adoption of GM technology, its markets for oilseeds and non-wheat grains are likely to stagnate. By contrast, if Australia increases its adoption rates, small *increases* in output and exports are observed in the GM sectors, with slight declines remaining in downstream industries.

The results imply that over the longer term, the expansion of GM technology into non-wheat grains and oilseeds sectors could have significant impacts on Australia's trade position. This is because the *cumulative* effects of the small declines in market shares of non-wheat grains, oilseeds and downstream sectors could potentially be important. More importantly, it is the potential losses in future market opportunities for Australian non-wheat grains and oilseeds that could be significant.

The overall imprint GM crops will leave on agricultural production and trade in the Australian and global contexts remains to be seen. Technological, consumer and political developments worldwide will continue to shape the prospects of these crops. Opportunities for further research in this area include modelling an expanded set of GM commodities — the inclusion of wheat would be of particular interest — and analysing long-run modelling scenarios, to complement the static analysis undertaken in this, and most other, papers.

A Applications of gene technology in crops

Gene technology can be applied in a number of ways to create new or modified crops. These applications are often distinguished according to whether crops are ‘first generation’ or ‘input trait’, ‘second generation’ or ‘output trait’, or ‘third generation’.

A.1 First generation or ‘input trait’ crops

Examples of the ‘first generation’ of GM crops include pest resistant *Bt* cotton which uses a soil bacterium (Bacillus thuringiensis) that produces toxins against insects, and herbicide-tolerant soybeans which have been developed to resist non-selective herbicides, including glyphosate (mainly by using genes isolated from micro-organisms) (Green and Salisbury 2001). Cotton plants with both insect resistance and herbicide tolerance have also been commercialised. Other ‘first generation’ crops in the pipeline include fungus resistant potato and wheat (EC 2000). GM crops with more complex traits, such as drought resistance, are also underway. So far, the vast majority of commercially-released GM crops, and most field trials, have related to these first generation applications aimed at providing on-farm benefits.

A.2 Second generation or ‘output trait’ crops

A ‘second generation’ of GM crops is also on the horizon. These crops are aimed at providing new value-enhanced or ‘output’ traits that improve the quality of the product to food producers or consumers. They may improve nutrient content, flavour, processing or storage characteristics. Examples include high oleic soybeans that contain less saturated fat than conventional soybean oil, high sucrose soybeans that improve food quality by improving taste and digestibility, and potatoes resistant to browning.

A.3 Third generation crops

A ‘third generation’ of GM crops is also underway. These products can be used for industrial or medical purposes to replace or enhance existing systems. Examples include biologically-based plasticisers and lubricants, pharmaceuticals, and nutraceuticals or ‘functional foods’ (where food crops contain pharmaceutical properties such as disease-preventing micronutrients). An innovative example of a GM crop used in industrial production is that of *Cynara Cardunculus-thistle* which is grown in Spain for electricity generation. Examples of nutraceuticals are Vitamin A supplemented rice which can assist in reducing the incidence of blindness, and canola oil with high beta carotene content.

B Field trials approved in Australia

There have been 107 applications for field trials of GM organisms in Australia as at June 2001. There have also been four commercial releases of GM organisms that have been approved in Australia. Table B.1 lists GM plants used in field trials and commercial releases in Australia. Table B.2 gives examples of the locations of deliberate releases of GM organisms (including field trials and commercial releases). Table B.3 lists GM food products approved for sale in Australia and table B.4 lists GM food products pending approval, both as at August 2002.

Table B.1 **Genetically modified plants deliberately released into the environment within Australia as at August 2002**

Crop	*Trait*	*Crop*	*Trait*
Canola	Modified plant architecture	Cotton	Insect resistance
	Herbicide tolerance		Herbicide resistance
	Herbicide resistance		Herbicide tolerance
	Fungal resistance		Tolerance to water logging
	Insensitivity to daylight hours	Wheat	Herbicide tolerance
	Lowered anti-nutritional content		Herbicide and ampicillin resistance
	Altered nutritional characteristics	Barley	Herbicide tolerance
	Reduced seed pod shattering		Starch breakdown
Sugar cane	Increased sugar production or altered juice colour	Oilseed poppy	Increased alkaloid production
	Leaf scald disease resistance	Subterranean clover	Herbicide resistance
Field peas	Insect resistance		Improved nutritional quality
	Nutritional quality	White clover	Alfalfa mosaic virus resistance
Pineapples	Control of flowering		Virus resistance
	Biochemical alteration	Lupins	Herbicide tolerance
Papaya	Antiobiotic resistance		Nutritional value
	Fruit quality		Herbicide tolerance, disease quality, colour bioassay selection (β-glucuronidase gene)

(continued on next page)

Table B.1 (continued)

Crop	*Trait*	*Crop*	*Trait*
Lettuce	Virus tolerance and antibiotic tolerance		Herbicide tolerance, seed tolerance, colour bioassay selection
Apple	Antibiotic resistance		Virus resistance
Grapevines	Reduce colour of the fruit	Tomato	Herbicide tolerance
Indian Mustard	Herbicide tolerance		

Source: GTR (2002e).

Table B.2 Examples of locations of deliberate releases of genetically manipulated organisms in Australia as at August 2002

State	*Organism*	*State*	*Organism*
Australian Capital Territory	Barley	**South Australia**	Barley
	Clover		Canola
	Field pea		Field pea
	Pseudomonas		Indian mustard
	Wheat		Wheat
New South Wales	Canola	**Tasmania**	Canola
	Clover		Oilseed poppy
	Cotton		Potato
	Field pea	**Victoria**	Canola
	Indian mustard		Clover
	Pseudomonas		Grapevine
Northern Territory	Cotton	**Western Australia**	Canola
Queensland	Apple		Clover
	Canola		Cotton
	Cotton		Field pea
	Indian mustard		Lupin
	Lettuce		Oilseed poppy
	Papaya		
	Pineapple		
	Sugarcane		

Source: GTR (2002a).

Table B.3 **Genetically modified foods approved as at August 2002**

Product	*Application number*
Glyphosate tolerant soybean	A338
Insect resistant cotton	A341
Insect resistant corn Mon 810	A346
Glyphosate tolerant cotton 1445	A355
Glyphosate tolerant corn	A362
Glyphosate tolerant canola GT73	A363
High oleic acid soybeans	A387
Colorado Potato Beetle resistant potato	A382
Colorado Potato Beetle resistant potato with resistance to potato leaf roll virus	A383
Colorado Potato Beetle resistant potato with resistance to potato virus Y	A384
Insect-resistant corn (Bt-176)	A385
Insect-resistant glufosinate ammonium	A386
Glufosinate ammonium tolerant corn T25	A375
Glufosinate ammonium tolerant canola topaz & glufosinate ammonium tolerant canola with fertility traits	A372
Glyphosate tolerant sugarbeet GTSB77	A378
Cotton resistant to bromoxynil	A379

Source: Food Standards Australia New Zealand (2002).

Table B.4 **Genetically modified foods pending approval as at August 2002**

Product	*Application number*
Canola resistant to bromoxynil	A388
Insect-resistant, glufosinate ammonium corn	A380
Glyphosate tolerant corn	A416
Insect resistant cotton	A436
Insect resistant , glufosinate ammonium corn	A446

Source: Food Standards Australia New Zealand (2002).

C Consumer surveys

Survey data published by Economic Research Service (ERS) (2001) provide a cross-section of studies and illustrate the variance in consumer responses to several GM food issues, both through time and between countries. These surveys provide only a general trend in attitudes, as they were not conducted across similar sample populations.

The results in table C.1 indicate some initial consumer resistance to agricultural GM technology. In those countries where results are available over time, consumer acceptance (resistance) initially decreases (increases), then slightly improves (lessens). For example, around 66 per cent of respondents in a 1993 Australian survey reported they would eat GM foods (equivalent to around 33 per cent resistance) (Kelley 1993). This figure fell to 25 per cent in 1998 (or around 75 per cent resistance). However by 2001, it had increased to 50 per cent acceptance (around 50 per cent resistance). The initial decline in consumer acceptance, followed by a gradual improvement, may be linked to increasing consumer awareness over the period — when consumers were unaware of the potentially negative adverse effects of GM technology, there was little resistance. However, as knowledge increased, so did resistance. Over time, as a fuller picture emerged of both the costs and benefits of the technology, this downturn in consumer acceptance began to level out.

While consumer acceptance of biotechnology for agricultural purposes is somewhat higher in the United States than for other regions, such as Europe and Japan, it does appear to weaken over time. For instance, while 54 per cent of respondents to Hoban, Woodrum and Czaja’s 1988-89 survey indicated that plant GM was desirable, and another 23 per cent indicated they were neutral on the subject, by 2000, 50 per cent of respondents to their survey held a negative view of GM food (Hoban, Woodrum and Czaja’s 1992; Portmann and Tucek 2000).

Table C.1 **Consumer attitudes toward biotechnology in agriculture**

Responses from multiple surveys across countries and time

Country	*Year*	*Question/issue*	*Response*
Australia	1993	Would you eat genetically modified foods? (Kelley 1993)	56–66% said yes, depending on the food
Australia	1998	Willing to eat genetically modified foods? (Biotechnology Australia 2001b)	25% said yes
Australia	2001	Willing to eat genetically modified foods? (Biotechnology Australia 2001b)	50% said yes
United States	1988/89	Plant GM (asked to assume not harmful to humans or environment)(Hoban, Woodrum and Czaja 1992)	54% said desirable 23% said neutral 23% said undesirable
United States	1999	Biotechnology used in agriculture and food production (Gallup 1999)	51% strongly supported or moderately supported
United States	1999	Would they be more or less likely to buy a food because it was genetically modified? (*The Economist*)	57% said less likely
United States	2000	Trend toward GM food (Portman and Tucek 2000)	50% negative
United Kingdom	1998	GM products (Greenberg 1998)	51% said unacceptable
Germany	1999	Would they be more or less likely to buy a food because it was genetically modified? (*The Economist*)	95% said less likely
Japan	2000	Trend toward GM food (Portman and Tucek 2000)	80% negative
Europe	2000	Trend toward GM food (Portman and Tucek 2000)	60–80% negative

Sources: Biotechnology Australia (2001b); ERS (2001); Portman and Tucek (2000).

However, these survey outcomes depend on the specific questions asked. Hoban et al. (1992) refer to *plant* genetic modification, and ask respondents to assume that it is not associated with harmful impacts on human health or the environment. By contrast, Portmann and Tucek’s study refers to GM *food*, which implies a more direct link to human consumption.

Table 3.2 shows results from international surveys that specifically ask respondents to consider their opinions on biotechnology when it is used to *improve* foods. These results show some differences from table C.1. In particular, 82 per cent of Japanese respondents in the Hoban et al. (1996) survey indicated that they either supported or strongly supported biotechnology used to develop improved crop varieties. This contrasts strongly with Portmann and Tucek’s (2000) finding, reported in table C.1, that 80 per cent of Japanese consumers surveyed had a negative view of GM foods. Again, the Hoban et al. (1996) study refers specifically to biotechnology used to *improve* crops, whereas Portmann and Tucek ask about the trend towards GM foods.

The results in table C.2 indicate that American consumers are supportive of GM food technology, and this view has been consistent over time. Australian consumers' support for biotechnology to improve foods diminished at first, but recovered between 2000 and 2002 for genetic modification of foods that specifically improved taste. Results for Europe in 1996 indicated some support for genetic modification of foods that involved a change in product characteristics. However, the Portmann and Tucek (2000) results showed 60–80 per cent of European consumers viewed GM food negatively (table C.1).

Table C.2 **Consumer attitudes toward biotechnology to improve foods**

Responses from multiple surveys across countries and time

Country	*Year*	*Question/issue*	*Response*
Australia	1993	Genetic modification to change food characteristics (Kelley)	64–82% said 'good idea' depending on the food
Australia	2000	Would you buy GM foods if they tasted better? (Biotechnology Australia 2002)	41% said yes
Australia	2002	Would you buy GM foods if they tasted better? (Biotechnology Australia 2002)	51% said yes
United States	1992 1994 1997	Biotechnology used in agriculture and food production to improve foods (Hoban 1998)	66% support " "
United States	1995	Biotechnology used to make foods taste better, stay fresh longer, prevent disease (Hoban 1996)	75% support
United States	1997 02/1999 10/1999 05/2000	How likely to buy produce genetically modified by biotechnology to taste better or fresher? (IFIC 1999 and 2000)	55% likely/somewhat likely 62% " 51% " 54% "
Japan	1995	Biotechnology used to develop improved crop varieties (Hoban 1996)	10% strongly supported 72% supported
Europe	1996	Genetic modification to change food characteristics (*Eurobarometer* 46.1)	53% said useful 47% said risky 40% said morally acceptable

Sources: Biotechnology Australia (1998,2001b); ERS (2001).

Consumer attitudes to pest or herbicide resistant GM plants are shown in table C.3. By contrast with earlier evidence, US consumers' favourable attitudes to this type of GM crop fell over time. However, the 2000 results indicated that 69 per cent of consumers would still be likely to purchase such food.

The Environics and The Investment Funds Institute of Canada studies highlight the inconsistencies displayed by consumers in surveys. The Environics study reports that in 1999, 78 per cent of consumers favoured the use of biotechnology to grow pest resistant crops. Yet, in the same year, only 67 per cent indicated a willingness to buy such crops.

Consumers’ responses in Europe exhibit increasing concerns over time. While 68 per cent of respondents to the *Eurobarometer* (1996) survey regarded genetic modification to make crops disease resistant was useful, and 63 per cent said it was morally acceptable, the Washington Post survey of French consumers in 1999 found that consumer support had slipped to 52 per cent; US consumers were 78 per cent in favour or somewhat in favour.

In Australia, consumer attitudes to GM foods have also changed over time. Surveys undertaken by Biotechnology Australia in 1998 and 2001 suggest resistance to GM food in Australia may be declining. They reported that from 1998 to 2001, Australians’ willingness to eat GM foods increased from 25 per cent to almost 50 per cent (Biotechnology Australia 2001b). Another survey found that those amenable to buying GM foods, if they tasted better, rose from 41 per cent in 2000 to 51 per cent in 2002 (Biotechnology Australia 2002). Biotechnology Australia (2001b) also found that while there was still resistance to GM foods in Australia, concerns rank lower than other consumer health concerns such as food poisoning, food tampering and pesticide residues on food.

Table C.3 **Consumer attitudes toward biotechnology to make plants pest or herbicide resistant**

Responses from several surveys across countries and time

Country	*Year*	*Question/issue*	*Response*
United States	1992	GM used to make cotton plants resistant to herbicide (Hoban 1993)	70% said acceptable
United States	1999	Do you favour the use of biotechnology to grow pest-resistant crops that require fewer farm chemicals? (Environics, *The Washington Post* 1999)	78% favour/somewhat favour
United States	1997	How likely to buy produce modified by biotechnology to be protected from insect damage and require fewer pesticides (IFIC 1999 and 2000)	77% very/somewhat likely
	02/1999		77% "
	10/1999		67% "
	05/2000		69% "
Europe	1996	Genetic modification to make crops disease resistant (*Eurobarometer* 46.1)	68% said useful 53% said risky 63% said morally acceptable
France	1999	Do you favour the use of biotechnology to grow pest-resistant crops that require fewer farm chemicals? (Environics, *The Washington Post* 1999)	52% favour or somewhat favour

Source: ERS (2001).

D Regulatory regimes

D.1 National regulatory regimes

Different countries have developed different approaches to the regulation of GM foods. This section discusses Australia's regulatory system and outlines the approaches of its major trading partners.

Generally, countries have either applied new legislation or adapted existing legislation to account for the introduction of GM products. This broadly reflects the two dominant views of biotechnology: that it creates something brand new (more akin to the precautionary approach); or that it is simply another development in food and food production (more akin to the substantial equivalency approach).

Australia and New Zealand

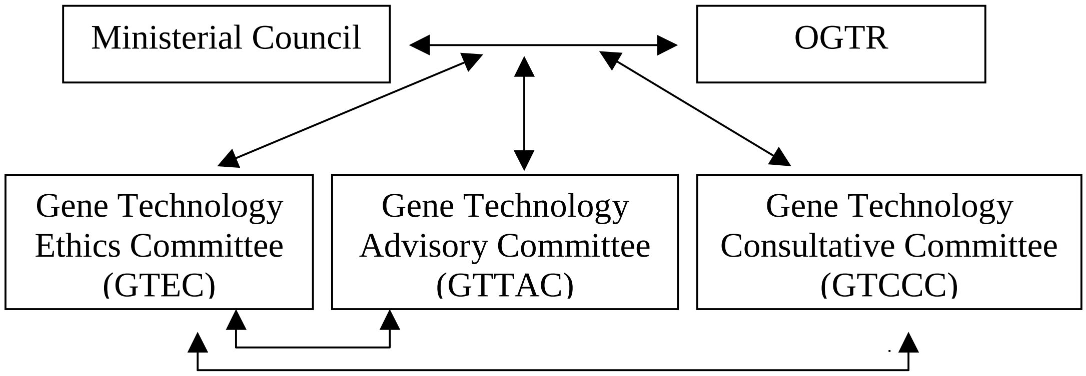
Australia developed specialised legislation to deal with the introduction of GM crops. The *Gene Technology Act 2000* was created by the Office of the Gene Technology Regulator (OGTR or the Regulator). The OGTR regulates live, viable GM organisms and thus is responsible for the regulation of field trials and the commercial releases of GM crops in the Australian environment. Other important GM regulatory authorities are the Australia New Zealand Food Authority (ANZFA), which jointly regulates food products with New Zealand, the Australian Quarantine Inspection Service (AQIS) and the Therapeutic Goods Administration (TGA).

The *Gene Technology Act 2000* established three advisory committees to assist in the development of regulation for GMOs:

- the gene technology technical advisory committee (GTTAC), which provides scientific and technical advice to the Regulator and the Ministerial Council;
- the gene technology community consultative committee (GTCCC), which advises the Regulator and Ministerial Council on matters of general concern to the community in relation to GM organisms; and
- the gene technology ethics committee (GTEC), which provides advice to the Regulator and Ministerial Council on ethical issues relating to gene technology.

Box D.1 outlines the relationships between these committees, the Regulator and the Ministerial Council.

Box D.1 **Technology committee structure**



Source: Office of Gene Technology Regulator (2002g)

The OGTR and the Ministerial Council work together to form policy principles and guidelines. The Regulator assesses applications for licences to deal with GM crops and prepares risk assessments and risk management plans. This is a lengthy process (taking several years) and requires public consultation.

In May 1999, ANZFA adopted Standard A18 to regulate the sale of food and food ingredients, other than additives and processing aids, that are produced using gene technology. The regulation provides a general prohibition against the sale of food products using gene technology, unless specifically approved. Processing aides and additives are regulated under Food Standards A16 and A3, respectively.

The principal regulatory concern is to ensure that foods are safe. Standard A18 covers two areas with respect to GM foods. The first area requires GM foods to be subject to rigorous and extensive pre-market safety assessments to ensure public health and safety. The second area relates to specific labelling provisions for GM foods.

ANZFA exhibits a ‘cautious approach’ to foods deemed to involve scientific risk prior to granting permission for sale. The pre-market assessment must show that GM foods have the benefits of conventional foods but pose no additional risks. Each safety assessment is undertaken by a senior scientist, usually a molecular biologist, who works in coordination with other ANZFA scientists with complementary expertise, particularly in toxicology. In addition, ANZFA draws on an external panel of experts to examine the safety assessment for scientific rigour and to identify further issues which may need to be addressed. Safety assessments are performed on foods derived from each individual type of GM plant or animal.

Once food commodities have been assessed by ANZFA and approved by the scientific committees, they may be used as ingredients in other foods without requiring further approval. The safety assessment of GM foods is divided into four main parts: description of the genetic modification; general safety issues; toxicological issues; and nutritional issues.

Since December 2001, all GM foods are required to be labelled to indicate the origin and nature of the characteristic or property modified where:

- the modification resulted in one or more significant compositional or nutritional parameters having values outside of the normal range of values for the existing equivalent conventional food or food ingredient; or
- the level of anti-nutritional factors or natural toxicants are considered to be significantly different in comparison to the existing equivalent conventional food or food ingredient; or
- the food contains a new factor known to cause an allergenic response in particular sections of the population; or
- the intended use of the food or food ingredient is different to the existing equivalent conventional food or food ingredient, (ANZFA 2001).

One of the key issues associated with labelling is the allowable threshold level for accidental inclusion of GM ingredients. ANZFA currently imposes a 1 per cent threshold for unintentional contamination.

New Zealand currently has a moratorium on new commercial releases of GM products for the next two years. However, laboratory and field trials are permitted to continue.

European Union

The European Commission (EC) regards GM commodities as new technology where scientific knowledge is still very limited. It states:

> In cases where scientific evidence is insufficient, inconclusive or uncertain, and where possible risks are judged to be unacceptable, risk management measures should be based on the precautionary principle. (EC 2002, p. 16)

Current regulation of GM crops in the European Union is contained in Directive 2001/18/. However, there is a proposal to supplement this directive to make the procedure for approval more transparent (EC 2001). This proposal strengthens existing rules for risk assessment and introduces mandatory information disclosure to the public as well as general rules for labelling and traceability at all stages of the supply chain. In addition, mandatory requirements for long-term monitoring of the interaction of GM crops and the environment is required. Approvals for GM products will be limited to a maximum of ten years upon which consultation with the Scientific Committee becomes mandatory.

There are currently 18 GM products approved for release in the European Union, with a defacto moratorium on new authorisation. Some member states have invoked a clause to temporarily ban GM maize and oilseed from the market. As yet, there is no specific regulation on GM animal feed. However, eight GM products have been authorised in accordance with the previous Directive for use in feed.

The European Union (since 1997) requires mandatory labelling to indicate the presence of GM material in a product. Minimum ‘adventitious contamination of GM material’ in food is set at 1 per cent. Under the new European Union proposals, any food product made from a GM crop must be labelled as such, even if the genetic material is removed during manufacturing. The proposals also restrict the term ‘GM-free’ to products where the complete absence of GM material (including food from animals fed on GM feed or produced with GM processing agents) can be guaranteed through all stages of production. The proposed EC standards are considered quite restrictive and, as currently drafted, are opposed by many other countries such as the United States, Canada, Argentina and Australia.

North America

Health Canada, the Canadian Food Inspection Agency, and Environment Canada all play a role in regulating GM foods in Canada. Pre-market notification is required for all foods derived from biotechnology. Guidelines for safety assessment are based on the OECD’s substantial equivalence test and are described as ‘flexible’ (Mackenzie 2000).

Approval of GM foods in Canada follows a three step process:

- a review of the development of the modified plant itself;
- consideration of dietary exposure; and
- examination of nutritional and toxicological data.

Once this safety assessment is made, GM foods enter the market place in the same manner as traditional food products and remain subject to the same post-market standards applicable to all foods in Canada.

Since 1994, 43 GM plant products for food and seven GM plants for animal feed have been approved in Canada (MacKenzie 2000).

The United States has had regulatory oversight for GM foods in place the longest. The first environmental release of a GM crop in the United States occurred in 1983 following approval by the National Institute of Health. Regulatory responsibility falls to Food and Drug Administration (FDA), the Environmental Protection Agency (EPA) and the US Department of Agriculture (USDA). In general, the regulatory framework is based on the idea that existing food safety regulations are sufficient to cover biotechnology and that products, not processes, should be regulated. GM products are not considered fundamentally different from their non-modified counterparts and thus, regulatory oversight authority is exercised only where there is evidence that the risk posed by the introduction of GM products is unreasonable.

Currently, 53 foods have been approved for consumption by the FDA and 52 different animal feeds have been approved by USDA (FDA 2002).

Japan/Korea

In Japan, GM products (including feed) must be assessed as ‘safe’ by the Ministry of Health and Welfare (MHW) and the Ministry of Agriculture, Forestry and Fisheries (MAFF). The risk assessment process is based on the concepts of substantial equivalence espoused by the OECD. These guidelines will most likely be replaced by a mandatory system to deal with increased international trade in GM foods and to take into account mandatory labelling requirements currently proposed in Japan. To date, 40 crops and nine food additives have been evaluated as safe by the MAFF (MAFF 2001).

As of April 2001, the manufacture, sale and import of GM food products that do not conform with stated safety standards will be prohibited. Labelling requirements, as of this date, also apply to all products with a threshold of ‘accidental contamination’ of 5 per cent.

Korea’s Food and Drug Administration (KFDA), which assesses and manages food safety, has established guidelines that require producers to show that foods developed with biotechnology pose no health risks to humans. However, Korea is currently considering changing the status of these guidelines to a system of mandatory regulations.

China

According to a recent report (Huang et al. 2002), China is developing the largest plant biotechnology capacity outside North America. While this technology is currently regulated by the Office of Genetic Engineering Safety Administration, China is considering legislation to further regulate biotechnology in agricultural production.

China currently requires importers of agricultural biotechnology products to apply for official safety verification approval from China's Ministry of Agriculture. It has announced that it will produce detailed regulations regarding new technology imports, but has yet to do so. This has caused a great deal of uncertainty in the market. However, in March 2002, China announced an agreement with the United States in which temporary measures were adopted requiring less paperwork and shorter approval times. This allowed the resumption of US GM soybean imports, which had halted in light of the previous regulatory ambiguity.

Rest of the world

Many other countries either have in place, or have under consideration, regulation regarding GM foods. The governments of the Philippines, Indonesia and Thailand have all announced an intention to regulate the import of GM products. India recently approved the commercial release of three GM cotton hybrids. This is significant because India is currently the third largest producer of cotton in the world, but if current yields improve, its position would likely change, as India currently has the largest area of land under cotton cultivation (nearly 9 million hectares) (Reuters News Service 2002).

E Examples of SIP systems

Table E.1 **Example of a SIP system**

A generic system for bulk grain commodity-processed food manufacture

Production stage	*Checkpoint*	*Procedure*
Agricultural production on-farm	Site history	Check the planting site and site history to avoid potential emergence of volunteer crop plants of a different type.
	Site location	Observe any necessary separation distances to avoid unacceptable levels of successful cross pollination between crops of different types.
	Sowing of seed	Ensure that seed is of acceptable seed purity.
	Harvest	Maintain identification and segregation of identity preserved crop from crops of other types through all harvesting processes.
	All agricultural equipment	Clean before use according to specified cleaning procedures or use only for one particular crop type.
Local off-farm storage	Transport vehicles	Clean before use according to specified cleaning procedures or use only for one particular crop type
	Storage facilities	Clean before use according to specified cleaning procedures or use only for one particular crop type.
Post-storage prior to shipping or wholesale storage	Transport vehicles	Clean before use according to specified cleaning procedures or use only for one particular crop type
	Storage facilities	Clean before use according to specified cleaning procedures or use only for one particular crop type
Processing	Storage facilities for identity preserved crop and other identity preserved ingredients	Clean before use according to specified cleaning procedures or use only for specified inputs.
	Processing equipment	Clean before use according to specified cleaning procedures or use only for specified inputs. Maintain identification and segregation through all processing steps.

(continued on next page)

Table E.1 **(continued)**

Production stage	*Checkpoint*	*Procedure*
Food manufacture	Storage and on-shipment	Clean before use according to specified cleaning procedures or use only for specified processed products.
	Storage and conveyance of non-GM processed fraction and *all potentially GM ingredients*	Clean before use according to specified cleaning procedures or use only for specified ingredients.
	Production and packaging line	Clean before use according to specified cleaning procedures or use only for specified ingredients. Maintain identification and segregation through all production and packaging steps.

Source: Department of Natural Resources and Environment (Victoria) (2001).

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