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Global responses to GM food technology:

Implications for Australia

A report for the Rural Industries Research and Development Corporation

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Foreword

This report estimates the likely economic effects of alternative responses abroad (and at home) by producers, consumers and policy makers to new genetically modified (GM) products with particular emphasis on the effects on Australian farmers, agribusinesses, rural researchers and RDCs.

New agricultural biotechnologies, including those that involve genetically modified organisms (GMOs), have great potential for farmers (and ultimately consumers) in Australia as elsewhere. However, consumers and community groups are concerned about their potentially adverse food safety and environmental impacts. Government responses in various countries to those concerns include banning field-trials, production and/or use of GMOs, mandating strict GMO labelling laws and even banning GM consumption and imports. Even the threat of such action has non-trivial impacts on agricultural product markets and hence on agricultural research agendas.

The complex question of whether Australia should adopt GM technology, assuming it increases the risk that consumers abroad will not buy Australian foods produced with that technology, requires empirical analysis and an understanding of the global economic system. This study uses a global economic model (GTAP) and separates GM-free and GM-inclusive markets within each country being modelled to provide estimates of global and national impacts of GM adoption under various policy scenarios. The results provide insights into why various countries have adopted different GM policies, and how adoption and regulation abroad as well as at home alter national benefits. In particular, model results indicate there would be gains to Australia from GM adoption if consumers are relaxed about consuming food that may contain GMOs, even if the European Union ban on GM food imports were to continue. If Northeast Asia were to copy the EU's policy response and ban imports from GM-adopting countries, however, Australia's gain from adopting GM crops may be fully eroded. The authors also note that in all the cases they consider, Australia's gain from GM crop adoption is much less than North America's as a percentage of national GDP, and those Australian gains go to non-farm households at the expense of farmers via lower domestic food prices.

This project was funded from RIRDC Core Funds, which are provided by the Federal Government. The report is an addition to RIRDC's diverse range of over 900 research publications, forms part of our Global Competitiveness R&D program. That program aims to identify important impediments to the development of a globally competitive Australian agricultural sector and to support research that will lead to options and strategies to reduce these impediments.

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Abbreviations

AUS	Australia
ARG	Argentina
BSE	Bovine spongiform encephalopathy
CAP	Common Agricultural Policy (of the EU)
CGE	Computable general equilibrium
CHN	China
DNA	Deoxyribose nucleic acid
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organisation (of the UN)
FDA	Food and Drug Administration (of the US)
GATT	General Agreement on Tariffs and Trade
GEMPACK	Software package used to solve GTAP model
GM	Genetically modified
GMO	Genetically modified organism
GTAP	Global Trade Analysis Project
IFIC	International Food Information Center
IND	India
IP	Intellectual property
NGO	Non-government organization
NOP	National Opinion Polls
OECD	Organisation for Economic Cooperation and Development
R&D	Research and development
RIRDC	Rural Industries Research and Development Corporation
SIP	Segregation and identity preservation
SPS	Sanitary and phytosanitary
TBT	Technical barriers to trade
UK	United Kingdom
UN	United Nations
UNEP	United nations Environment Programme
US	United States
WHO	World Health Organization (of the UN)
WTO	World Trade Organization

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Executive Summary

Genetically modified organisms (GMOs) have great potential for farmers and ultimately consumers in Australia and around the world. Benefits for producers include greater productivity and less occupational health and environmental damage (e.g., fewer pesticides), while benefits to consumers include lower food prices and, potentially, enhanced attributes (e.g., 'nutriceuticals'). Protagonists argue that genetic engineering also entails a more-controlled transfer of genes because the transfer is limited to selected genes, whereas traditional breeding risks transferring unwanted genes together with the desired ones.

Despite these potential benefits, some consumer and community groups are concerned about their potentially adverse impacts on food safety (e.g., 'Will they cause cancer?') and the environment (e.g., 'Will they lead to pesticide-resistant superweeds?). Numerous governments are responding to those concerns, typically in very conservative, command-and-control ways such as banning the production and/or use of GMOs or mandating strict GMO labelling laws. Countries exporting food products fear that food-importing countries will discount or deny access to their products if even a subset of their farmers adopt GM technology. Indeed the European Union has a moratorium – in place since October 1998 – on the approval of GM products for domestic production or importation. As a result, the US share of the EU's maize imports has fallen to virtually zero (from around two-thirds in the mid-1990s), as has Canada's share of EU canola imports (from 54 per cent in the mid-1990s). The GM-adopting countries have lost market share to GM-free suppliers (particularly Brazil for maize and soybean and Australia and Central Europe in the case of canola).

Food-exporting countries such as Australia need to weigh the potential economic benefits from biotechnology development against any net negative environmental risks associated with producing GM crops, any additional costs of segregation and identity preservation through the supply chain, any discounting and/or loss of market access abroad for conventional counterparts to those specific crops which may contain GMOs, and any discounting and/or loss of market access abroad for other farm products because of what GM adoption does for Australia's generic reputation as a 'clean, green, safe food' producer. In addition, Australia has to decide whether to participate in the current and possible future WTO dispute settlement cases on GMOs, bearing in mind the risks this issue brings to the rules-based global trading system in general and the WTO's farm trade reform agenda in particular.

All of Australia's crop and livestock producers, as well as consumers of these products, have a direct economic interest in this issue. The adoption of GM technology has been most widespread in the production of maize, soybean and canola (key livestock feed ingredients globally), as well as cotton. As of 2002, GM varieties accounted for one-quarter of the area planted to those crops globally (and 4.3 per cent of all arable land), having been close to zero prior to 1996. But most of it is grown in Argentina, Canada and the United States, where that GM share is more than 60 per cent. Production costs in those countries have been lowered by more than 5 per cent, thereby lowering livestock feedgrain costs and hence weakening the comparative advantage of Australia's competing grass-fed livestock industries (since products from animals fed GM feedstuffs are not considered to contain GMOs). GM rice and wheat are also possibilities in the near future.

Neither the magnitude nor the signs of the economic effects of GM adoption by some countries and boycotts by others can be determined without empirical data and a model of the affected markets. This research uses the GTAP model of the global economy to estimate the production, trade, national economic welfare and real farm household income effects in Australia and other countries of GM adoption. These GTAP modelling results improve on earlier results in two respects: by distinguishing between GM-free and GM-inclusive products, and by generating real farm household income effects of technology adoption and of consumer and government responses under various scenarios. The latter results allow speculation as to the motivation of governments in the US, EU and East Asia in adopting different GM policies.

As mentioned above, maize, soybean and canola have enjoyed the highest rate of adoption of GM food varieties globally. The potential global benefits of GM adoption in maize, soybean and canola is estimated to be substantial (US$4.0 billion per year) if there were no adverse reactions elsewhere. However, as an exporter Australia would gain, but only slightly, from adopting GM varieties of these crops because the gain from higher crop productivity would be almost fully offset by an adverse terms of trade change. The EU moratorium, which acts as an increase in farm protection there, causes the EU to be worse off by $3.1 billion per year (less whatever value EU consumers place on having avoided consuming GM products), and reduces by two-thirds the gain to the GM adopters. It improves welfare for food-importing regions of the rest of the world and Australia only very slightly.

If GM varieties of rice and wheat were also to be released, quite possibly China and India would then become GM adopters too. Since they account for 55 per cent of the world's rice market and 30 per cent of the wheat market, the economic welfare effects of adding these two extra countries and commodities are dramatic. The conservatively estimated global economic welfare gain if there is no policy response is $ $4.3 billion if rice and wheat are added and China and India join the GM-adopting group, almost double the current gains from GM crop adoption. In this case if Australia chooses not to adopt GM varieties, any gain in market access because of the EU's GM moratorium is almost fully offset by the greater decline in international prices caused by the moratorium. Australia's crop production and exports are reduced more, not less, as a result of the EU moratorium.

On the other hand, if there were no EU moratorium and Australia adopted GM technologies, its crop production would expand instead of contracting. While domestic consumption of crop and livestock products also would increase because of lower domestic prices, those estimated increases are not enough to prevent crop export earnings from rising instead of falling. Hence net economic welfare for Australia would be US$28 million per year higher as a result of GM adoption, less any negative value domestic consumers place on not knowing if they may be consuming GM products.

With the EU moratorium, the net economic welfare benefit to Australian producers and consumers of GM adoption in this case is estimated to be US$15 million per year. While that is $13 million less than if there is no EU moratorium, it still represents a net gain from joining the adopters of GM varieties of these four crops even if the EU moratorium remains in place. However, the average Australian farm household income would decrease with GM adoption – even with rice and wheat included – if the EU moratorium remains.

What should Australia do? The consumer legislation on GMOs devised by the health ministers of the Australian and New Zealand governments is relatively strict by world standards in terms of tolerance of unintended GMO material in foods sold in Australia, but it is more tolerant with respect to products in which GMOs are no longer detectable. Controls on Australian production of GM crop varieties were already severe by North American and Argentinean standards, but they are now constrained even further by domestic consumer legislation. This has been well illustrated by the recent debates over whether to approve GM canola production in Australia: production is unlikely to be approved unless and until an effective segregation and identity preservation system is in place to allow co-existence of non-GM and GM varieties. Even then, several States of Australia have continued to delay approval because they perceive insufficient economic benefit from GM crops to warrant the cost of the necessary co-existence system (which will fall more on non-GM producers, the smaller the share of GM varieties in total output) and the expected loss that would result from a downgrading of their status as a 'clean, green, safe food' supplier domestically and abroad.

These cautious approaches were understandable while only maize and soybean were ready for adoption. The production ban is less defendable for canola now that GM varieties for Australian conditions are available, and will be even less so if and when suitable GM rice and wheat varieties are ready for release and the concerns of consumers in Europe and elsewhere fade, making adoption of these products more economically beneficial. In revising Australian consumer and producer regulations for dealing with GMO issues as information and views evolve, the following points might be kept in mind:

- Attitudes towards GMOs (and many other attributes of food) are continually changing as greater information becomes available to consumers, so the optimal consumer regulation will change over time;
- In particular, consumer attitudes towards GMOs will become more differentiated as second-generation GM varieties come on stream that exhibit product attributes specifically desired by consumers;

- The optimal regulation for domestic sales depends to some extent on the costliness of a segregation and identity preservation (SIP) system (since consumers will bear part of its cost), the benefits of which also depend on the consumer legislation that is still developing in Australia's export markets abroad;
- The demand by consumers for foods with (or without) specific attributes will continue to grow, so 'GMO-ness' is but one of many reasons why consumers may be willing to pay for SIP systems in the supply chain;
- Hence it may make less sense in the future for a region to forego the productivity gains in GM varieties if the main reason for that stance is to avoid the costs of a SIP system, and particularly if the region does not have the funds or organizational capacity to promote itself as a GM-free region;
- Comparative advantages of each region and of Australia as a whole in various (GM and non-GM) crops will continue to change not only because of changing consumer attitudes but also as countries alter their consumer, producer and trade policies and as new GM crop varieties appear;
- Where price premiums for non-GM varieties exist they are small, meaning that the market for certified non-GM foods may simply become a niche market similar to the market for organics products;
- Crop varieties suited to particular regions rarely appear as manna from heaven but rather as a result of a concerted and targeted R&D investment, so adopting a GM-free status will likely lead to a bias toward more-traditional research which will tend to be slower and hence less rewarding;
- Rural research and development corporations can help to counter such tendencies by ensuring a portion of their portfolio includes GM technologies so that when markets become more accepting those technologies can be disseminated relatively promptly;
- Australia's biotech R&D industry – a potential export earner in its own right –will be held back the more Australia limits production of GM crops, and as a result many scientists may choose to migrate to more-stimulating research environments abroad;
- Industry groups can prepare appropriate technology stewardship strategies, which in turn will help investors who are thinking of developing SIP systems;
- Fortunately the GMO standards set by countries in East Asia, where much of Australia's food exports are destined, are less stringent than Australia's own standards; and
- Australia should oppose excessive standards abroad if they are protectionist in intent, for they may just be substitutes for traditional protectionist measures as multilateral rounds of trade talks lead to decreased use of traditional protectionist measures.

1 Introduction

1.1 What are the issues?

Genetically modified organisms (GMOs) have great potential for farmers (and ultimately consumers) in Australia as elsewhere. Benefits for producers could include greater productivity and less occupational health and environmental damage (e.g., fewer pesticides), while benefits to consumers could include lower food prices and enhanced attributes (e.g., 'nutriceuticals'). While traditional biotechnology improves the quality and yields of plants and animals through, for example, selective breeding, genetic engineering enables direct manipulation of genetic material. In this way the new GM technology accelerates the development process, taking years off R&D programs. Protagonists argue that genetic engineering also entails a more-controlled transfer of genes because the transfer is limited to a single or just a few selected genes, whereas traditional breeding risks transferring unwanted genes together with the desired ones.

However, despite those potential benefits, some consumer and community groups are concerned about their potentially adverse impacts on food safety (e.g., 'Will they cause cancer?') and the environment (e.g., 'Will they lead to pesticide-resistant superweeds?).

Numerous governments are responding to those concerns, typically in conservative, command-and-control ways such as banning the production and/or use of GMOs or mandating strict GMO labelling laws. Diverse regulatory responses to these technologies have both direct and indirect implications for the international market for these products. For example, the European Union has a moratorium – in place since October 1998 – on the approval of biotech products for domestic production or importation, even though it risks being at odds with the EU's multilateral obligations under WTO law. As a result, the US share of the EU's maize imports has fallen to virtually zero (from around two-thirds in the mid-1990s, close to the US share of world exports), as has Canada's share of EU canola imports (from 54 per cent in the mid-1990s). The fall has been less dramatic in the case of soybean products, but in all three cases the GM-adopting countries have lost market share to GM-free suppliers (particularly Brazil for maize and soybean and Australia and Central Europe in the case of canola). In addition, food markets and hence trade and agricultural research agendas anticipate and respond to these potential regulatory decisions. In particular, countries exporting food products fear that they will find food-importing countries discounting or denying access to their products if even a subset of their farmers adopt GM technology.

In response to frustration over the way the EU precautionary measures have been applied (e.g., some EU member states maintain national marketing and import bans on biotech products even though those products have been approved by the European Commission), the United States, Canada and Argentina successfully sought the establishment of a WTO Dispute Settlement Panel on 29 August 2003 to rule on the WTO consistency of the measures. This and subsequent GMO dispute cases are likely to challenge the WTO's agricultural trade liberalization process in the years ahead.

1.2 Why are these issues important to Australia?

These issues have potentially greater impact on food-exporting countries such as Australia than on food-importing countries. While the concerns of domestic consumers and environmentalists need to be taken into account, exporters such as Australia also need to weigh the potential economic benefits from biotechnology development by its scientists and potential productivity and environmental gains from GMO adoption by its farmers against at least four potentially offsetting factors:

- any negative environmental risks (net of environmental benefits) associated with producing GM crops;
- any additional costs of segregation and identity preservation (IP) through the supply chain;
- any discounting and/or loss of market access abroad for conventional counterparts to those specific crops which, notwithstanding the IP system, may contain GMOs; and

- any discounting and/or loss of market access abroad for other farm products because of what GM adoption does for Australia's generic reputation as a 'clean, green, safe food' producer.

In addition, Australia has to decide whether to participate in the current and possible future WTO dispute settlement cases on GMOs, bearing in mind the risks this issue brings to the rules-based global trading system in general and the WTO's farm trade reform agenda in particular.

Australian crop and livestock producers, as well as consumers of these products, have a direct economic interest in this issue. The adoption of GM technology has been most widespread in the production of maize, soybean and canola (key livestock feed ingredients globally), as well as cotton. As of 2002, GM varieties accounted for one-quarter of the area planted to those crops globally (and 4.3 per cent of all arable land), having been close to zero prior to 1996. But most of it is grown in Argentina, Canada and the United States, where that GM share is more than 60 per cent (Tables 1 and 2). Production costs in those countries have been lowered by more than 5 per cent, thereby lowering livestock feedgrain costs and hence weakening the comparative advantage of Australia's competing grass-fed livestock industries (since products from animals fed GM feedstuffs are not (yet) considered to contain GMOs). GM rice and wheat are likely to be available in the near future too. Indeed many farm products will soon have GM varieties. But the nature of these – and most other – agricultural technologies is such that the time between the first R&D investments until widespread adoption by farmers is long. Hence the Australian community (farmers, consumers, researchers and governments) must carefully consider appropriate ways to capitalize on these new technologies. These choices will depend on domestic food safety and environmental risks, but will also be affected by the various responses abroad to GMOs and the way these affect the unit value, volume and direction of food exports in the future.

Table 1: Area planted to GM maize, soybean, canola and cotton and seed value, selected countries and the world, 1996 to 2002

(million hectares and US$ million)

AREA (m. ha)	**1996**	**1998**	**2000**	**2002**	***GM share of total area (%), 2002***
Maize	0.3	8.3	10.3	12.4	*9*
Soybean	0.5	14.5	25.8	36.5	*51*
Canola	0.1	2.4	2.8	3.0	*12*
Cotton	0.8	2.5	5.3	6.8	*20*
Total, 4 crops	**1.7**	**27.8**	**44.2**	**58.7**	***22***
of which:					
United States	1.5	20.5	30.3	39.0	*62*
Argentina	0.1	4.3	10.0	13.5	
Canada	0.1	2.8	3.0	3.5	*66*
China	0.0	0.0	0.5	2.1	*5*
South Africa	0.0	0.0	0.2	0.3	
SEED VALUE ($m)					
Total, 4 crops	148	1970	3044	4066[a]	

[a] Of which 58% soybean, 21% cotton, 16% maize and 5% canola; and 72% of sales are in North America and 21% in South America.

Source: www.isaaa.org (see James 2003) and (for total areas) www.fao.org

Table 2: Shares of total area planted to maize, soybean, canola and cotton that is genetically modified, selected countries, 2001

(% of national area planted for each crop and for all 4 crops)

	Maize	Soybean	Canola	Cotton	***Weighted average for all four crops***
United States	26	70	20	67	***56***
(2002)	(34)	(75)	(54)	(71)	***(62)***
(2003)[a]	(40)	(81)		(73)	***(61)***
Argentina	25	85	na	7	***76***
Canada	19	20	61	–	***52***
China	–	–	–	45[b]	–
Australia	–	–	–	64	–
South Africa	4	–	–	19	–

[a] 2003 data for the US are from http://pewagbiotech.org/

[b] According to Huang and Wang (2002), this had risen from 30 per cent in 2000, suggesting that the estimate reported in Table 1 is for 2000 rather than 2001. Huang and Wang estimate that, as of 2001, nearly 5 million Chinese farmers were planting Bt cotton.

Source: www.isaaa.org (see James 2003) and (for total areas) www.fao.org

1.3 Outline of the report

As with many new technologies, there are both opportunities and risks associated with producers adopting, and consumers accepting, GM crop biotechnology. The challenge to managing this technologies effectively is to craft regulatory responses to manage the risks without unduly constraining opportunities to benefit from them. GM products will have impacts in three broad policy areas: food systems, the environment and global market competitiveness. How might this new technology affect the price and quality attributes of the resulting food, production externalities in the countryside, and farmers' competitiveness in global markets? Section 2 then summarizes attitudes of consumers towards GMOs in key countries including Australia, and the various ways in which governments have responded to those food safety concerns. This is followed in Section 3 by a parallel summary of information on and attitudes towards the environmental benefits and risks associated with producing GM crops in key countries including Australia, and the various ways in which governments have responded to those environmental concerns. The separation of consumption and production concerns assists the identification of appropriate citizen and governmental responses.

Clearly, governments can choose from among a diverse portfolio of regulatory responses to manage the opportunities and risks of new GM technologies. These regulatory choices have implications for both domestic and international food safety and environmental health, as well as for economic markets. Understanding the motivation for particular regulatory choices is crucial in order to develop an effective and efficient global system of regulations for these technologies. Section 4 discusses the international context for regulatory decisions, stressing the potential political economic motivations of various interest groups in influencing regulatory policy. Given the current WTO dispute over the EU moratorium, the WTO system for evaluating policies is described.

Neither the magnitude nor the signs of some of the economic effects of GM adoption by some countries and boycotts by others can be determined without recourse to empirical data and a model of the affected markets. Hence Section 5 develops several case studies of adoption in the coarse grains, oilseeds, rice and wheat markets. It first presents data on the importance of various countries in global production, consumption and trade in those products since the mid-1990s and the changing shares of different exporting countries in imports by the European Union. Those data are an input into the GTAP model of the global economy that is then used to explore the production, trade, national economic welfare and real farm household income effects of GM adoption in North America and elsewhere.

The new GTAP modelling results presented in Section 5 improve on earlier results in two respects. One is that the model now distinguishes between GM-free and GM-inclusive products; the other is that the impacts on factor rewards are used to draw implications of technology adoption and of consumer and government responses for the incomes of producers of these crops in key regions of the world (as an informal way of testing the hypotheses derived from the political economy analysis of Section 4). Results are presented for various scenarios. In one set of scenarios, GM adoption takes place in some countries (several different sets are considered) without any policy or consumer reactions in non-adopting countries. In another set, Western Europe not only refrains from using GM crops but also rejects imports of maize and soybean products from GM-adopting regions. A scenario also considers the case in which consumers express their preferences through market mechanisms rather than through blunter government regulations. The GTAP model's estimates of the impacts of these scenarios on farmer incomes allow speculation as to the motivation of governments in the US, EU and East Asia in adopting different GM policies. That in turn has serious implications for the global trading system, which are discussed at the end of that section. The report concludes in Section 6 by drawing out lessons for Australia.

2 Adoption of GM food by consumers

The potential to provide the world with better food at lower prices via genetic modification is enormous and expanding daily. Optimists see in GM technology potential solutions to food security and the alleviation of hunger among the world's poor, including 'hidden hunger' that results from inadequate levels of micronutrients in children's diets. The first generation of GM crops, which have enhanced productivity characteristics, has the potential to lead to decreases in food prices depending upon levels of farmer adoption. If GM crop technology lowers producers' costs of production per tonne, early adopters can expect a potential economic benefit if they are able to receive the same price as for the GM-free substitute. Initial productivity gains have varied widely by region, product, and type of GM technology. The nature of factor- or input-saving also has varied with the technology. In some cases yield increases have been non-existent or have been eroded by cost increases (including for new seed that has to be bought each year). But overall, beyond the first year or two when managerial practices may have to change, many farmers have found adoption to be economically worthwhile. After providing an extensive summary of empirical findings on the benefits and costs to farmers to date, Stone, Matysek and Dolling (2002, Table 2.2) conclude that it is reasonable to assume average total factor productivity gains from advances to date of 7.5 per cent for maize and 6 per cent for soybean. As more and more farmers adopt the new technology and output expands, the price of the product will fall, other things equal. Hence over time there will be a gradual transfer of the producer benefit from first-generation GM crops to consumers in the form of cheaper food.

The emerging second-generation GM foods are being targeted to directly benefit consumers, by providing desirable attributes. These products could contain enhanced macro or micronutrients such as vitamins, higher levels of health-promoting factors such as antioxidants, lower levels of anti-nutritional factors such as toxins, or raise the visual, taste, smell or storability qualities of products. For example, a GM variety of rice, 'golden rice', has been genetically engineered to contain a higher level of beta-carotene in the endosperm of the grain (Beyer et al. 2002). In contrast to the current commercial applications of biotech crops, this new rice variety would directly benefit consumers rather than producers. More specifically, if it was cheaper and/or more nutritionally beneficial (in place of less-nutritious staples such as maize and sweet potato), it would improve the health of poor people in developing countries that rely heavily on rice as their main staple food.

Regardless of these potential benefits, numerous consumer groups are concerned about the safety of food and animal feed derived from GM crops. They worry that – rather than having desirable attributes – GM-derived food may be more toxic or carcinogenic, result in more allergies, or be nutritionally less adequate than GM-free food. They also question whether transgenes could survive digestion, and alter the genome of the person or animal consuming it. Addressing those concerns is difficult because the feared effects may not show up for decades. However, a recent UK government report reviewed available evidence and found no adverse health effects anywhere in the world (King 2003). The report concedes that there has been no post-consumption surveillance to detect potential human health effects from GM foods, but it also points out that no country has such surveillance mechanisms for *any* types of food, hence no adequate comparison exists. In addition, in the United States, Canada, Argentina and elsewhere, hundreds of millions of people have been consuming GM food over the past seven-plus years without any substantiated ill effects. The King report therefore concludes that, on balance, "the risks to human health are very low for GM crops currently on the market" (page 23). Nonetheless, consumer concerns continue to be expressed in numerous countries.

In addition to health concerns, some consumer groups invoke several types of ethical arguments to justify the rejection of GM technologies. First, some groups advocate strict information requirements, such as mandatory labeling, based upon the idea that consumers have a fundamental right to know what is in their food and how it is produced. The strongest advocates for that right claim it should apply regardless of whether there is a risk to human health or the environment. Opponents hold that mandatory labeling would impose burdensome costs on the food supply chain. In their view voluntary labeling is sufficient in most cases, and mandatory labeling should only apply where the expected benefits in terms of reduced damage to health or the environment outweigh the expected costs.

Other groups who oppose GM technologies on ethical grounds argue that biotechnology is tampering with nature, offending the fundamental rights of living organisms, particularly when it involves transfers of genetic material across different species. Advocates of this view consider both producing and consuming GM products to be immoral because consumption condones production. Biotech proponents counter by claiming that the essence of an organism is not found in it genes, pointing out that humans, for example, share about 99 per cent of their genes with chimpanzees and around 50 per cent with plants.

Finally, consumers who wish to avoid animal products for religious or other reasons criticize the mixing of plant and animal genes. If, for example, genes from a pig were transferred to a vegetable, Jewish, Muslim and vegetarian consumers may not wish to eat that product and so would want to be aware of the source of those inserted genes. These ethical concerns have been subdued to date but may flair up in the future.

2.1 Consumer attitudes

Differences in income levels, ethical views, experiences with previous food-safety scares (and hence trust in government regulatory processes), and the extent of dissemination of information on GM products and technology (including misinformation and exaggeration) ensure consumer attitudes towards GM foods vary widely across the world. Among the high-income countries, consumers are most accepting in North America, and least accepting in Western Europe. Consumers in poorer countries are less able to afford to be discriminatory, but are nonetheless influenced by attitudes in richer countries and by anti-GMO activists in their region.

A 2001 survey in the United States, conducted by the International Food Information Council (http://ific.org), found a low degree of consumer dissatisfaction overall. Respondents cited most frequently food concerns related to packaging (27 per cent of respondents), followed by food handling (23 per cent), contamination/diseases (16 per cent), pesticides (10 per cent) and genetic engineering (2 per cent). The most recent IFIC survey (August 2003) finds strong GM acceptance, with 62 per cent believing GM food technology will benefit them in the next five years, through improved food quality, taste and variety (43 per cent), improved health and nutrition (40 per cent), reduced chemicals on plants (19 per cent), and lower food prices (10 per cent). That survey also found 77 per cent of consumers could not think of information not currently on food labels that they would like to see added; and of those that would like more information added, only 2 per cent mentioned information about genetic modification. IFIC attributes these positive attitudes partly to public trust in regulatory bodies such as the US Food and Drug Administration (76 per cent of consumers have a ‘great deal’ or a ‘fair amount’ of confidence in the US food safety authorities), and partly to consumers having acquired more information about GM food. The high level of trust in regulatory institutions in the US contrasts sharply with the situation in the EU (Gaskell et al. 1999).

In the European Union, consumer attitudes towards GM foods are more hostile and have not softened much over the past seven years, at least in terms of the perception of the usefulness and moral acceptability of GMOs. Nevertheless the proportion that perceives GM food as risky declined slightly to just below 60 per cent by 2000 (*Eurobarometer* Vol. 53, April/May 2000, www.gesis.org). The latter finding is consistent with a survey finding that in Ireland – as in the US – consumers express greater willingness to consume GM food the more familiar they are with the technology (McGarry Wolf and Domegan 2002). Pending legislation requiring stricter labelling and traceability, many European supermarket chains announced in 1999-2000 the removal of GM ingredients from their own-brand products. Food manufacturers of numerous famous brands quickly followed, saying they too would not use GM ingredients. A survey of consumer attitudes towards beef that had been fed GM maize were stronger in the EU than in the US, but not greatly so: on a scale of 1 (‘not at all concerned’) to 5 (‘very concerned’), France Germany and the UK averaged 4.7, 4.5 and 4.2 respectively while in the US the average was 3.8 (Lusk, Roosen and Fox 2003).

The UK Government's Food Standards Agency has been conducting annual surveys on GM attitudes since 2000, and its latest report concludes that UK consumers do not have entrenched views on GM food and that their concerns have decreased over the past three years. Nevertheless, since the benefits to them remain unclear, consumers remain suspicious and would like more understandable information (Food Standards Agency 2003). The proportion concerned about the food safety issues in general remains high (68 per cent, compared with 71 per cent in 2000), but it is considerably lower with respect to GM foods and foods with GM ingredients. Only 7 and 5 per cent of respondents spontaneously mentioned concerns about GM foods and foods with GM ingredients, respectively, and even when prompted the proportion rose to only 36 and 23 per cent, respectively, down from 43 and 27 per cent in 2000. This is consistent with an April 2001 National Opinion Poll (NOP) survey showing more UK consumers willing to eat GM food (an increase from 46 to 48 per cent between 2000 and 2001) and fewer believing GM food is less safe than conventional food (a fall from 30 to 20 per cent). It is also consistent with anecdotal evidence from visits to European food trade fairs where traders felt the level of GMO concern was steadily falling and they expected that trend to continue (WA Dept of Agriculture 2002).

In Japan some consumer groups have sought to generate anti-GM sentiment, but generally consumers have not expressed concerns to supermarkets. On the contrary, consumers have expressed concern that non-GM food will be more expensive than GM food and that they want access to the latter if it is going to be cheaper (WA Dept of Agriculture 2002). Hence as of 2002 no Japanese supermarket chain had claimed "GM-free" status, and all stocked GM foods.

In South Korea consumers are equally divided on the issue of whether they would buy GM food. Those who have been convinced by strong anti-GMO campaigns of NGOs there say they would be willing to pay a premium for GM-free food, but these attitudes have not been tested (WA Dept of Agriculture 2002). Taiwanese consumers may be less concerned: even though GM-free soybean products are available with price premia of 25-50 per cent, all but one-tenth of soybeans come from the US and so are not GM free. Nor have the European supermarket chain subsidiaries in Taiwan followed their main stores in Europe in declaring themselves GM free.

In Asia's poorer countries consumers are much less aware of the issue. The 17 March 2003 issue of *Food Facts Asia* (www.afic.org) reports surveys in China, Indonesia and the Philippines in 2002, by the Asian Food Information Centre, that reveal citizens there remain open-minded and wish to know more about the technology and how it might benefit them. More than one-third of respondents admitted to being not at all aware of the terms biotechnology and genetic modification, and many of the remainder associated the terms with technological improvements to food. More than half of respondents (61 per cent) believed that GM foods were already part of their diet, and almost all said they had taken no action to avoid them. And more than 80 per cent said they were likely to buy GM food if it was more nutritious, tastier or fresher (in contrast to less than one-third of Europeans in the *Eurobarometer* survey of 2000 mentioned above). Very few respondents indicated that GM information was among the items sought on food labels in their countries.

In the Middle East, awareness of GM issues by consumers is low. It has been suggested, however, that if some governments in the Middle East wished to curtail business with certain trading partners they may well follow the EU example and ban imports from GM-producing countries (WA Dept of Agriculture 2002). Awareness is also low for most South Asian consumers. Even so, Sri Lanka introduced a ban on imports of all GM food in 2001, apparently based on European concerns over the health risks.

Finally, in Australia, there continues to be about 50 per cent of consumers who see the risks of GM foods and crops outweighing the benefits, but there has been a rise in the number who are no longer uncertain and now see the benefits outweighing the risks, from 20 per cent in 2001 to 27 per cent in 2003 (Biotechnology Australia 2003). These responses appear to relate more to the production than the consumption of GM food. A more targeted survey found concern over GM foods to be minor among a list of food safety concerns (Owen, Louviere and Clark 2003). Just over half were indifferent to, or interested in paying a premium for clear benefits from, GM foods. But if there were no clear benefits then consumers would avoid GM foods even if they were somewhat cheaper.

Overall, as consumers become more aware of GM food in the marketplace their level of concern rises initially, but then subsides as they learn more about GM technology and about the absence of evidence of harmful health impacts. To date there is only limited evidence of consumers being willing to pay a premium price for GM-free food (Stone et al. 2002, pp. 29-30; Foster, Berry and Hogan 2003, pp.16-17; Parliament of South Australia 2003, pp. 49-49). Certainly consumer attitudes toward GM food are adversely affected by anti-GM propaganda, but a recent study provides evidence that credible, independent information can reverse that attitude over time (Huffman, Rousu, Shogren and Tegene 2003). Nonetheless, the lack of trust in national and EU regulatory agencies in Europe – reinforced by the food safety scares associated with BSE and foot-and-mouth problems there in recent years – may well contribute for some time to a higher level of concern in Western Europe than elsewhere (Gaskell et al. 1999).

2.2 Consumer policies: GM labelling

While no evidence exists proving that GM products pose new types of food safety risks, regulatory intervention may be justified in order to provide information to consumers who prefer to avoid GM products. The scope for intervention ranges from blunt moratoria on consumption of GM products to allowing approved GM products to be treated exactly the same as conventional food items. Only a few countries (e.g., Sri Lanka) have taken the extreme view that consumption and hence imports of GM food should be banned. At the same time, only a few countries (e.g., Argentina and the United States) have explicitly adopted the opposite view that GM food is equivalent to conventional food and therefore there does not require mandatory labelling. Many other countries have accepted the arguments that consumers have the right to know what is in their food, and/or that there is some health risk associated with GM food (notwithstanding the absence of evidence to date of any health consequences). As a result, both advanced and developing countries have adopted national labelling requirements during the past few years, partly to protect producers of conventional foods from incurring the expense of labelling their products as GM-free.[1] Effective labelling will require clear definition of which GM products can be considered substantially equivalent to their non-GM counterparts, a concept supported by the FAO/WHO and OECD for assessing the safety of foods and food ingredients.

The United Nations Codex Alimentarius Committee on Food Labelling in Rome has also attempted to develop internationally accepted set of GM standards, which the WTO could then draw on in settling trade disputes. According to the WTO’s SPS Agreement, national standards should be based on internationally agreed upon guidelines, and the substantial equivalence guidelines should be founded on scientific grounds. In a June 2003 meeting, Codex developed consensus-based risk assessment procedures for food derived from biotechnology, broadly defined. The wording of these standards was carefully crafted to leave out explicit definition of product traceability, due to disagreement within the committee about this term.[2] Codex recommended that safety studies of GM foods compare the GM food with an existing, appropriate counterpart to determine if the GM food is as safe as its counterpart.[3] But delegates were unable to reach a consensus on definitions of what

[1] Typically national regulatory systems differentiate between GM products intended for human consumption and those intended for animal feed. Within the human consumption category a complex array of products exists, including products made of GM material, products made from GM products, and products made with GM products. The EU has created a policy, to become effective from 18 April 2004, in which certain products derived from GM products have to be labelled, such as meats, even if they do not contain GM DNA or proteins and even though other products such as cheese produced using GM enzymes do not have to be so labelled. Australia and New Zealand have adopted labelling laws that define labelling requirements for GM products but exclude highly refined products such as processed soy and canola oils. When these differing types of definitions are embedded in national labelling systems they offer varying degrees of scope to discriminate against foreign products.

[2] Some countries insist that “product tracing” is the same as “traceability” while others, particularly the US, state that product tracing is limited to “one step forward, one step back” rather than a continual tracing of products through the marketing chain, implied by product traceability.

[3] The Codex has been struggling with labelling of GM products for nearly a decade. The Chair of the committee recognizing that the large size of the committee might be hindering useful development of consensus text, suggested that a smaller group be formed to deal with these issues between meetings of the Codex. In the most recent meetings of the Codex (30 June 30 to 7 July 2003) the Committee backed away from substantive discussion of what constitutes a GM product and established a working group composed of Argentina, Australia,

constitutes a GM food, including the issue of whether labelling recommendations should include foods that were derived from, but no longer contain GM organisms. Some delegations argued that including products made from GM plants, but which do not contain modified protein or DNA, made the labels essentially unenforceable because no test would be able to indicate the presence of GM content; meanwhile the EU emphasized that labelling was intended to promote consumer confidence and therefore if consumers care about this content they should also have access to this information.[4]

The task of (even voluntary) labelling is complicated by three factors. First, a product may unintentionally contain GMOs unbeknown to the producer and despite best efforts to avoid contamination. Secondly, processing can remove any traces of GMOs in some products (e.g., oil from canola or cotton seed) but not others. Finally credible labelling requires a segregation and identity preservation (SIP) system of traceability throughout the supply chain. Given varying views about the expense of implementing SIP, the likelihood and acceptability of some unintentional contamination, and the health risks with GM food, it is not surprising that countries have chosen different product definitions and content thresholds in setting their labelling standards (not to mention their food safety assessment procedures), as the following examples illustrate:

United States, Canada and Argentina: labelling is required only where there has been a significant alteration of product attributes (e.g., nutritional quality or there is an identified health risk such as allergenicity), but voluntary labelling may be used. Canada has proposed a 5 per cent threshold for unintentional GM material.

European Union: as of late 2003, labelling is expected to be required for all food and animal feed consisting of, containing, or produced from a GMO irrespective of whether there is DNA or protein of GM origin detectable in the final product. The tolerances for unintentional presence of GMOs is the least in the world: 0.9 per cent for approved GM food (of which there are very few) and 0.5 per cent for yet-to-be-approved GM food, and only then if there is evidence that appropriate steps are in place to avoid contamination. Processing aids, food additives and flavours are exempt unless they still contain GMOs, as are meat, milk or eggs produced using GM feed or medicinal products (European Commission 2003).

Japan: labelling is required if a GM food is not substantially equivalent to its conventional counterpart, or if one or more of 24 prescribed ingredients is present and contains GM protein or DNA. However, only the top three ingredients need to be labelled and only if each is greater than 5 per cent of the total weight of the food. Also, labelling is not required where DNA or protein of GM origin is not detectable, and there are tolerances for unintentional presence of GMOs (no limit set) but an IP system must be used.

Korea: labelling is required for all foods that contain GM maize, soybean or bean sprouts in the top five ingredients by weight if the level of one of those ingredients is greater than 3 per cent by weight. Labelling is not required where DNA or protein of GM origin is not detectable, and there are tolerances for unintentional presence of GMOs (currently a 3 per cent limit but it may be reduced to 1 per cent in the future).

Taiwan: labelling is required for all foods that contain GM if the GM content is above 5 per cent by weight (but not those where DNA or protein of GM origin is not detectable).

China: from March 2002 labelling is required for all foods that contain GM ingredients and also for processed foods that contains no detectable GM protein or DNA (indicating that it was sourced from

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Barbados, Bolivia, Brazil, Canada, China, Egypt, France, India, Indonesia, Japan, Kenya, Korea, Mexico, Netherlands, New Zealand, Norway, Sweden, Switzerland, South Africa, the US and the EU. This group has the mandate to develop options for the management of the discussions on the labelling of GM foods.

[4] Theory suggests a harmonized labelling standard would not be efficient when there are wide differences in consumer preferences for attribute information (Jackson 2002a; Jansen and Faria 2002).

a GM crop), and GM crops cannot be grown before first being cleared on food safety grounds (which has happened only for cotton, tomatoes and peppers as of August 2003).

India: labelling is not required but GM products cannot be released for experiments, produced, imported, sold or used without the approval of the Genetic Engineering Approval Committee.

Indonesia: labelling of GM foods (but not feeds) has been required since 1999, with a 5 per cent threshold for unintentional GM material.

Thailand: labelling is required if a food contains GMOs in any of the top three ingredients at more than 5 per cent by weight.

Brazil: labelling is required for all foods that contain GM ingredients, with the tolerance for unintentional presence of GMOs being reduced in June 2003 from 4 to 1 per cent.

Australia and New Zealand: GM foods cannot be sold unless approved (21 have been approved to date), and mandatory labelling is required for all approved GM foods including processing aids (but not animal feeds) that contain GM protein or DNA or have altered characteristics. Excluded from that definition are highly refined foods, processing aids (such as enzymes used in cheese and brewing) and additives that lost their GM protein or DNA during processing, food prepared by restaurants and takeaways for immediate consumption, GM flavourings up to 0.1 per cent by weight, and foods, ingredients or processing aids that have GMOs present unintentionally up to no more than 1 per cent by weight per ingredient. This is one of the most rigorous regimes in the world outside the EU, which means that satisfying domestic requirements makes it possible for Australian exporters to satisfy most other countries' requirements (even though different labels will be required for different markets). The food standards authority stresses though that these standards have been set solely to provide information to consumers and should not be interpreted as implying there is any food health risk associated with GM food.

2.3 Optimal vs. current consumer policies

In countries where the vast majority of people believe there is no health problem with GM food, the optimal consumer policy would be to allow uninhibited consumption of GM food, provided its domestic production or importation did not diminish the country's profits from non-GM food sales (for example through tarnishing the country's generic reputation as a supplier of safe food). That is also true in countries where consumers are unwilling or unable to pay the premium to cover the cost of the segregation and identity preservation system necessary to meet labelling requirements (since the incidence of the cost of the SIP system will be borne in part by non-GM food producers and consumers).

The proviso, that GM food production or importation does not diminish the country's profits from non-GM food sales, is important. This type of laissez faire policy would be more costly and hence less likely to be optimal, the more the country relies on exporting its food products to GM-sensitive countries, the stronger its current reputation in those countries as a supplier of safe food, and the weaker its segregation and system of co-existence. Since these systems are non-existent in many poor countries, and since many of them export food predominantly to the EU under duty free preferential arrangements, it is not surprising that they have been wary of accepting GM food aid (as offered by the US to Zambia and Zimbabwe in 2002) or approving domestic production of GM crops.

For countries willing and able to pay the premium required for a SIP system, labelling may be optimal.[5] Products containing GMOs that are perceived as inferior to their GM-free counterparts will require a price discount, so their producers would not voluntarily label them as containing GMOs, particularly given the cost of SIP. That does not necessarily mean that mandatory labelling

[5] For more on the cost and economic efficiency of labeling, see Jackson (2002a,b).

must be introduced. A non-regulatory alternative to positive labelling regulations would encourage the voluntary use of negative labels such as 'this product contains no GMOs' (Runge and Jackson 2000). With perhaps the majority of processed foods now containing some GMOs, this market alternative would require labels on a smaller and presumably declining proportion of products. And that subset, like organic food, may be able to attract a price premium sufficient to cover the cost of identity preservation and labelling. This labelling system would still require, however, the separation of GM-free products from GM-inclusive ones throughout the supply chain.

The proposed EU labelling regulations from late 2003 are draconian by comparison with the above. The large number of categories of products subject to testing in the EU is now enormous, and the threshold tolerance levels are very low. Moreover, feedstuffs also are now included in the EU's list, even though GM protein or DNA will not be present in the livestock products of feedlot operators using feed ingredients based on GM crops.

US consumer policies, by contrast, are much closer to optimal and may even be too relaxed from the viewpoint of the consumers' right to know what is in the food they eat (depending on what it would cost to implement a SIP system). A study by Mendenhall and Evenson (2002) found that over 75 per cent of the Americans they surveyed were at least somewhat concerned about the safety of GM food and over 90 per cent felt that there should be some form of labelling to distinguish GM from other food. Given that the majority of food now sold in the US contains GMOs, Mendenhall and Evenson argue that optimal intervention is for the US government to develop guidelines for voluntary certification of non-GM food so that such foods can attract a premium from GM-concerned consumers.

While Australia's consumer policies are not as extreme as the new EU ones, they are still strict by international standards and may in time be perceived as excessive given the current trend in attitudes of Australian consumers as they become more informed and less worried about the technology.

3 Producer adoption of GM technology

GM crop technology may provide additional benefits if they create fewer adverse impacts on the environment than conventional crops. For example, Bt cotton has built-in insect resistance that has dramatically lowered the need for insecticide sprays. Herbicide-tolerant GM maize, soybean, canola and cotton varieties also require less spraying than conventional varieties because they allow new weed-control and tillage strategies. Reduced chemical applications lower farmers' cash costs and reduce air, soil and water pollution and lower the health risks for spray operators – a win-win-win outcome for the economy, farmers' health, and the environment.

The potential for more positive outcomes is only just beginning to be tapped. Future varieties could be more resistant to nematodes, fungi, bacteria or viruses, allowing additional pesticide reductions. Others could improve crop production in marginal environments through being tolerant to, for example, drought, heat, cold or salt. In addition, current research points to GM crops that could provide a renewable source of energy (biomass) or medicines (biopharmaceuticals).

Nonetheless, environmental groups continue to express concerns about possible negative externalities associated with GM crop production. What if GM plants are invasive, persistent or toxic to wildlife, or lead to the emergence of pests, diseases or superweeds that are resistant to chemical sprays, or eliminate desirable native plants? These concerns are more-commonly expressed in environments where small-scale farms and villages are nestled among nature parks, as compared with countries where cropping is conducted on large-scale farms well away from towns and wilderness areas. To date no theoretical reason or empirical evidence suggests that GM crops would be any more invasive or persistent, or toxic to soil or wildlife outside the farmed environment than conventional crop varieties. Nor have substantiated reports of gene flows from GM crops to other plants arisen (King 2003).[6] As with food safety concerns, adverse effects are difficult to predict in the long term, particularly in the more-confined farming environments of densely populated countries of Europe and Northeast Asia. Perhaps for this reason, scepticism about the environmentally benign nature of GM production technologies remains in Western Europe.

3.1 Environmental and market access concerns

Most farmers, left unconstrained, would adopt GM technology if and when they perceived it to be more profitable than conventional technology. But in some countries environmental concerns, and concerns of contamination from neighbouring farmers, have created a demand for regulation of domestic GM production and of GM imports. In the UK, for example, a recent survey revealed there is greater concern there for biodiversity than for food safety issues associated with GM products. In particular, there is a fear that, once released into the environment, there could be no turning back and cross-contamination would inevitably occur between GM and GM-free food (Food Standards Agency 2003). Similar attitudes prevail elsewhere in the EU.

In Australia about 50 per cent of those surveyed by the government see the risks of producing GM crops outweighing the benefits. In 2002 there was a rise in the number who saw the benefits outweighing the risks, to 32 from 20 per cent in 2001; but following the discussions in recent months over approval for GM canola production, that rating fell to 27 per cent in 2003 (Biotechnology Australia 2003).

Developing countries also have been reluctant to approve production of GM crops apart from cotton (whose environmental and farmer health benefits are quite apparent). That reticence has been less to do with concerns for the environment than – as for Australia – with the country's reputation as an exporter of GM-free products. In China's case its current reluctance to allow farmers to embrace

[6] Presumably drawing on the same body of literature, the Nuffield Council on Bioethics also concluded in a recent discussion paper that "there is not enough evidence of actual or potential harm to justify a moratorium on either research, field trials or the controlled release of GM crops into the environment at this stage" (Thomas et al. 2003, page ix).

GM food technology is partly the result of its experience in being denied access to the EU market in 1999 for soy sauce that may have contained GM soybean that China may have imported from the US. This decision to delay adoption is reinforced by Thailand's discontinued development of GM rice, the lack of GM production in other major rice producing countries, and continued safety testing of GM rice by the Chinese Office of Agricultural Genetic Engineering Biosafety Administration. As a result, and despite the absence of pressures from consumer and environmental groups, China is holding off on approving any GM food crops despite having numerous varieties ready for commercial release or at least for field-trials (Huang, Wang and Zhang 2001; Huang and Wang 2002).

3.2 Policies affecting GM adoption by farmers

The resistance to GM food production in Western Europe triggered the imposition in October 1998 of a *de facto* moratorium on the authorization of new releases of GMOs. Before the imposition of the moratorium, releases of GMOs were reviewed on a case-by-case basis and faced approval evaluation at every step from laboratory testing through field-testing to final marketing. Now applicants initially seek approval from their national government's authority, then they require approval by the national governments of other member states. If objections are raised, the European Commission (EC) asks for the opinion of its scientific committee, otherwise the matter goes to the regulatory committee composed of representatives of the member states. If objections are raised there it goes to the Council of Ministers. And if it fails there, that GM crop variety is not approved for production in the EU, nor may it be imported. Hopeful importers of GM food and feed varieties not already approved by the EU have to go through a similar approval process (European Commission 2003).

By contrast, the permit procedure is far simpler and faster in the United States. For many other countries including Australia and China, the degree of regulation of production is closer to the EU approach than the more-relaxed ones that prevail in the US and Argentina.[7] As in the EU, these countries typically ban GM imports that are not approved by the importing country's food authority, and impose labelling requirements on GM imports that are approved. Resulting segregation and identity preservation requirements can significantly restrain adoption of GM varieties unless and until the necessary infrastructure and operating systems are in place in the transport, storage and processing sectors. Exporters in countries such as Australia that currently demand these processes for domestic sales of GM food will find that requirement less onerous in the medium term than will farmers in countries that do not have similar domestic consumer regulations.

3.3 Optimal vs. current producer policies

As with food safety concerns, since environmental concerns with GM crop production vary greatly across countries, no single optimal production intervention exists. For countries that value their biodiversity highly, they may include regulations requiring a buffer zone between GM crops and highly valued nature parks. Also, to avoid contamination of non-GM crops, buffer zones between GM and non-GM fields might be required, as in the US. Such policies will be more costly (and hence will be more discouraging of adoption) in closely settled, densely populated environments such as in Western Europe and Northeast Asia than in broad-acre settings such as North and South America and Australia.

But even in the broad-acre type of country, if domestic GM production diminished the country's profits from non-GM food sales (for example through tarnishing its generic reputation as a supplier of safe food), that amortised cost would need to be weighed against the amortised benefit from the new technology (net of any costs associated with co-existence requirements) to decide whether there is a net national gain from GM adoption by its farmers. The agony that each of the State governments in Australia have gone through in the past year or so in deciding whether to allow

[7] For details of policies in the EU and 15 other countries, see the lengthy Appendix A of Foster, Berry and Hogan (2003).

GM canola production in their State illustrates the difficulty of making these calculations in practice (see, e.g., Parliament of South Australia 2003). In addition, since the behaviour of trading partners and competitors will alter the economic effects, empirical analysis is necessary to explore different scenarios (see Section 5 below).

Optimal consumer and production regulations are integrally related. The existence and structure of GM food labelling requirements will influence farmers' adoption decisions and thus optimal production regulations. If GM adoption by some farmers harms both nearby producers of conventional, organic or biodynamic versions of that crop and the country's generic reputation for producing 'clean, green, safe food', then producers of all farm products have a stake in this outcome. On the other hand, the degree to which transport and storage systems are capable of segregating GM and non-GM products and of recording the information needed to satisfy traceability requirements will influence the effectiveness of labelling regimes. Farmers, environmentalists and logistics firms need to cooperate regionally and perhaps nationally to develop approaches to GM crops, bearing in mind that it may be difficult to return to a GM-free state once adoption has become widespread and consumers are aware of it.

4 The political economy of regulatory policy choices

Even if all citizens in a country such as Australia were convinced that GM crops posed no greater environmental risks than conventional non-GM crops, farmers individually and collectively would nonetheless have to assess the cost of GM production against demand for GM-inclusive versus GM-free products before deciding whether/when/how much to embrace this new biotechnology. This complex decision requires anticipating the development over time of consumer preferences and government policies at home and abroad towards consumption and imports of GM products. As mentioned above, in some countries their importation is banned, in others it is necessary to satisfy labelling regulations of varying standards, and in all countries the interventions are subject to non-trivial changes as information, attitudes and policies evolve. If domestic and/or foreign regulations require traceability and segregation, farmers also need to consider the additional costs associated with those requirements, including labelling costs and insurance against future claims that a product was incorrectly labelled. Since the structure of domestic regulations plays an integral role in determining both the burden of costs and the distribution of benefits from GM adoption, interest groups have the incentive to engage in the policy process in an attempt to capture a greater proportion of the benefits and to limit their cost burden.

4.1 Domestic policies

The discussion in Sections 2 and 3 above took current attitudes and preferences of citizens as given. Yet we know those concerns are based on incomplete and in some cases wrong information. Public acceptance of GM biotechnology depends heavily on the production and dissemination of verifiable information about the technology and the resulting food products. Since there is no global government providing such information, and if such agencies as the OECD are unable to fill the gap, the next-best hope is for the government of one or more large nations to provide it (Huffman and Tegene 2002). But their interests in turn are dependent on those of their constituents, so widespread dissemination of complete, unbiased information is likely to remain illusory.

As Stigler (1975, p. ix) once wrote, “Until we understand *why* our society adopts its policies, we will be poorly equipped to give useful advice on how to change those policies.” In this case it is not only constituents in the US and EU but also in third countries who have a large stake in this matter, because third countries’ own domestic policies are likely to be strongly influenced by the US and EU (not least because those countries wish to export food or feed to the EU and fear that adopting GM technology may irreversibly deny them access to that market). It is important in particular to know if the high standards set by the EU are simply a replacement of traditional protectionist measures that are under pressure to be phased out following the Uruguay Round Agreement on Agriculture (Sykes 1999), in which case the EU may be in violation of its WTO obligations in addition to imposing costs on itself and the rest of the world.

So who are the key interest groups influencing the GM policies of the US and EU directly, and indirectly via the disseminating of (possibly biased) information? The biotechnology corporations obviously have an interest in the technology being well received by the public. But those multinationals and the research communities working with them are equally prevalent in the US and EU, so this cannot be a major explanation for the differences in their policies. Consumer groups have also been negative in both regions, although more so in the EU (partly because of greater mistrust there of food safety authorities); but typically they carry very little weight in policy formation, so this too is unlikely to provide more than a small part of the explanation (even though it is commonly cited as important – see, for example, Bernauer 2003 and Louriero 2003). Environmental groups carry more political weight than consumer groups, and they typically have been strongly against GM foods even though some GM technologies (but most notably insect-resistant cotton which is *not* a food) involve less environmental damage than conventional technologies. But again those groups are strong on both sides of the Atlantic, even if marginally more so on the European side. The remaining force of relevance is the farm lobby, which while less noisy than the environmental lobby is probably far more powerful. That interest group, which is at least as powerful in the EU as in the US, is also very capable of embracing the causes of consumer and environmental groups should their views coincide with its interests.

US farmers clearly have a strong interest in a low degree of GMO regulation of production, so that they can exploit the new technology before it is disseminated beyond the US. They also have a strong interest in a low degree of GMO consumer regulation both at home and in their export markets. That is especially so in maize and soybean, given that in recent years the US shares in global production have been 40 and 43 per cent, respectively, more than one-fifth of which is exported such that its shares in global exports (including intra-EU trade) are 66 and 51 per cent, respectively (Table 3). Over the past decade feedgrains and oilseeds (mostly maize and soybean) accounted for 18 per cent of the gross value of agricultural output in the US, and the livestock sector that uses those products as key inputs accounted for another 44 per cent.

The interests of EU farmers, on the other hand, are less clear-cut. While they would benefit directly from more-productive technologies, other things equal, the first-available GM food crops (maize and soybean) are of minor direct importance to them. In the past five seasons they produced only 6 per cent of the world's maize and only 1 per cent of the soybean (Table 3). However, the EU livestock sector is almost as big as that of the US (smaller in beef and poultry, larger in pork and dairy – Table 4), and as net exporters those producers have an interest in lower costs of feedstuffs, other things equal.

There are two important offsetting influences on EU farmer interests. One is that GM technology would be less profitable in the densely settled European landscape, where non-GM crops and nature areas are much closer, and so there would need to be more buffer zoning per hectare of GM crop there than in broad-acre landscapes such as in the US. For many small farmers the potential productivity gains would be more than offset by the management costs of buffer zoning, so there would be a greater proportion of EU than US farmers wanting to continue to produce non-GM crops. That proportion would be even higher, the greater the opposition by environmental and consumer groups to the selling of GM foods in Europe (where most EU-produced crop output is sold, in contrast to the US where more than one-quarter is exported to other regions) – and even more so if that opposition succeeds (as it has) in getting tough labelling laws and low unintentional GM tolerance levels legislated, since that requires producers to put a high-cost segregation and identity preservation system in place if and when GM varieties are approved.

The other important offsetting influence on EU farmer interests is the extent to which their crop products are internationally competitive (or will be once EU expansion eastwards is complete and another WTO round of cuts to export subsidies, import tariffs and domestic supports has been implemented). Given that North America and Argentina have already adopted GM technology, EU food producers – despite not adopting GM varieties – may be more competitive in their own and in third-country markets vis a vis the GM adopters if consumers in those markets are sufficiently GM-averse, and more so the tougher are consumer policies towards GM foods. If those tough standards were to apply to feed ingredients as well (as is intended in the EU from April 2004), then the EU livestock producers also would support anti-GM policies since they too are unlikely to benefit as much from the GM technology as the more maize-and-soybean-intensive North American livestock producers.

These possibilities will change over time of course, and if consumer and environmental concerns subside in the years ahead one can imagine a time when GM food technology becomes the norm everywhere, not just in North America. But that time may still be a long way off. Brooks and Barfoot (2003), for example, expect less than 10 per cent of a few crops at most being under GM varieties in the EU by 2013. So under what circumstances over the medium term might it be conceivable that EU farmers are better off denying themselves access to GM technology, and how would current GM-adopting farmers fare in those various circumstances? This question can only be addressed using an empirical model of the world's food markets, to which we turn in the section 5.

Table 3: Key countries' world market shares of maize, soybean and canola, by volume, 1998-99 to 2002-03

(average annual per cent)

	Share (%) of world:				
	Production	**Consumption**	**Exports[b]**	**Imports[b]**	**SS index[c]**
Maize					
European Union	6	7	0	4	0.95
United States	40	34	66	0	1.25
Canada	1	1	1	4	0.82
Mexico	3	4	0	7	0.79
China	20	20	11	0	1.03
Brazil	6	6	3	1	1.05
Argentina	3	1	14	0	2.50
Australia	0	0	0	0	0.00
Japan	0	3	0	22	0.00
Korea, Rep.	0	1	0	12	0.00
Rest of world	21	23	5	50	
GM exporters[a]	***44***	***36***	***80***		
Soybean					
European Union	1	9	3	35	0.11
United States	43	31	51	0	1.42
Canada	1	1	1	1	1.45
Mexico	0	3	0	8	0.00
China	9	31	1	21	0.78
Brazil	23	16	27	2	1.41
Argentina	15	13	12	1	1.17
Australia	0	0	0	0	0.00
Japan	0	3	0	9	0.00
Korea, Rep.	0	1	0	3	0.00
Rest of world	8	10	5	20	
GM exporters[a]	***60***	***45***	***64***		
Canola					
European Union	26	26	34	34	1.14
United States	2	2	2	2	0.93
Canada	18	8	40	2	2.17
Mexico	0	2	0	9	0.00
China	28	33	0	21	0.87
Brazil	0	0	0	0	0.00
Argentina	0	0	0	0	0.00
Australia	5	1	15	0	4.33
Japan	0	6	0	24	0.00
Korea, Rep.	0	0	0	0	0.00
Rest of world	21	22	9	8	
GM exporters[a]	***20***	***10***	***42***		

[a] Argentina, Canada and the United States.
[b] Includes intra-EU trade.
[c] Self-sufficiency index is defined as domestic production divided by domestic consumption.

Source: www.affa.gov.au/gmmarkets

Table 4: Key countries' world market shares of cattle, pig and poultry meats, by volume, 1998-99 to 2002-03

(average annual per cent)

	Share (%) of world:				
	Production	**Consumption**	**Exports[b]**	**Imports[b]**	**SS index[c]**
Beef and veal					
European Union	15	15	11	9	1.00
United States	24	25	18	27	0.96
Canada	3	2	9	6	1.25
Mexico	4	5	0	8	0.81
China	11	11	1	0	0.99
Brazil	14	13	11	1	1.08
Argentina	5	5	5	0	1.11
Australia	4	1	22	0	4.08
Japan	0	3	0	18	0.00
Korea, Rep.	0	1	0	6	
Rest of world	20	19	23	25	
GM exporters[a]	***32***	***32***	***32***		
Pig meat					
European Union	21	20	36	2	1.07
United States	11	10	19	13	1.02
Canada	2	1	19	3	1.57
Mexico	1	2	2	8	1.33
China	50	50	4	2	1.00
Brazil	3	2	9	0	1.16
Argentina	0	0	0	0	0.00
Australia	0	0	2	1	0.00
Japan	1	3	0	31	0.55
Korea, Rep.	1	1	2	4	0.97
Rest of world	10	11	7	36	
GM exporters[a]	***14***	***11***	***40***		
Poultry meat					
European Union	13	13	15	8	1.05
United States	27	23	44	0	1.17
Canada	2	2	1	2	0.97
Mexico	4	5	0	6	0.88
China	18	19	8	12	0.97
Brazil	13	10	22	0	1.19
Argentina	2	2	0	0	1.03
Australia	1	1	0	0	1.03
Japan	2	4	0	17	0.60
Korea, Rep.	0	0	0	2	
Rest of world	18	21	10	53	
GM exporters[a]	***31***	***27***	***45***		

[a] Argentina, Canada and the United States.
[b] Includes intra-EU trade.
[c] Self-sufficiency index is defined as domestic production divided by domestic consumption.

Source: www.affa.gov.au/gmmarkets

4.2 International rules

Before turning to the empirical case study, consider how existing international frameworks influence the obligations of national governments specifically in relation to trade of GM seeds and food products. Given the potential use of GM policies for protectionist goals, what international obligations do countries have to justify their regulatory decisions?

It is clear from previous sections that bans on consumption or production of GM food are extreme and typically sub-optimal consumer or producer policies. Import bans of GM food are also sub-optimal. Rather, imports should be subject to the same regulations as apply to domestically produced GM food. The Cartagena Protocol on Biosafety, which has the objective of ensuring safe transboundary movement of living modified organisms resulting from modern biotechnology, potentially undermines this position. The Protocol was finalized in Montreal on 29 January 2000 and came into force on 11 September 2003 after being ratified by the governments of 50 signatories. It not only reconfirms the rights of signatory countries to set their own domestic regulations but also ostensibly allows each country to decide whether and under what conditions it will accept imports of GM products intended for release into the environment (for example, as planted seeds). This condoning of import restrictions appears also to apply to GMOs intended as food, feed or for processing. It is not only rich countries seek this protection: some developing countries also support the Protocol, fearing that their regions might be used as testing grounds for GM food production.

Diverging from existing WTO trade policy, the Protocol stipulates that lack of scientific evidence regarding potential adverse effects of GMOs on biodiversity, taking into account also the risks to human health, need not prevent a signatory from taking action to restrict the import of such organisms in order to reduce perceived risks (UNEP 2000). This reflects an acceptance of the guiding influence of the precautionary principle, that is, “better safe than sorry”. The Protocol requires that GMOs intended for intentional introduction into the environment or for contained use must be clearly identified as living modified organisms; but modified organisms intended for direct use as food or feed, or for further processing, only require a label stating that the product “may contain” such organisms. No labelling requirements for processed foods such as cooking oil or meal were established.

The Biosafety Protocol’s relationship with WTO agreements remains unclear and hence open to various interpretations. The text states that the “Protocol shall not be interpreted as implying a change in the rights and obligations of a Party under any existing international agreements”, but at the same time the Protocol claims that this statement is “not intended to subordinate [the] Protocol to other international agreements” (UNEP 2000 p.1). Certainly the Protocol’s objective of protecting and ensuring sustainable use of biological diversity whilst also taking risks to human health into account is not inconsistent with WTO agreements. The WTO acknowledges the need of member states to apply and enforce trade-restricting measures in order to protect human, animal or plant health and life as well as public morals. That right for a country to set its own environmental and food safety regulations at the national level is provided for in Article XX of the GATT. But the key goal of the WTO is to achieve efficient use of the world’s resources by reducing barriers to international trade. For that reason WTO members also have agreed to avoid unduly trade-restrictive measures to achieve environmental or food safety goals. More than that, such measures must be consistent with the key principles of the WTO: non-discrimination among member states, ‘national treatment’ of imports once having entered the domestic market, and transparent customs procedures. Whether the current WTO agreements prove to be in conflict with the rights to restrict trade in living modified organisms apparently provided for in the Biosafety Protocol, only time – and possibly legal proceedings via the WTO’s Dispute Settlement Body – will tell.

Members of the WTO also have trade obligations under other WTO agreements that restrict the extent to which trade measures can be used against GMOs. The Agreement on Sanitary and Phytosanitary Measures (SPS) and the Agreement on Technical Barriers to Trade (TBT) are specifically related to food safety and animal and plant health. These agreements allow member states to impose certain restrictions on trade if the purpose of the measure is to protect human, animal or plant life and health. The TBT agreement also covers technical measures aimed at protecting the environment and other objectives. At the same time the agreements aim at ensuring that applied measures and technical regulations are no more trade-restrictive than necessary to fulfil the stated objectives.

Both the SPS and TBT agreements encourage the use of international standards, guidelines and recommendations where they exist, such as in the realms of the Codex Alimentarius (the FAO's international food standards body). Currently there are no international standards for genetically modified products, although the Biosafety Protocol explicitly notes that signatories "shall consider the need for and modalities of developing standards with regard to the identification, handling, packaging and transport practices, in consultation with other relevant international bodies." (UNEP 2000 p. 10, Article 18.3.) International harmonization of regulatory approval procedures for genetically modified products is currently under discussion in several forums including the FAO and OECD. The establishment of international standards for the production, regulation and labeling of these products may be helpful as a way of reducing future trade disputes among developed countries – but could impose onerous compliance costs on poorer GM-exporting countries.

Under the SPS agreement a country may apply higher than international standards *only* if these can be justified by appropriate scientific risk assessments. In other words, while the SPS agreement explicitly allows member states to set their own standards for food safety and animal and plant health, it requires that measures be based on scientific risk assessments in a consistent way across commodities. The TBT agreement is more flexible because member states can decide that international standards are inappropriate for a number of other reasons, such as national security interests (GATT Article XXI). Hence it is of key importance to determine by which WTO agreement a given trade measure is covered. The SPS agreement covers food safety measures and animal and plant health standards regardless of whether or not these are technical requirements. The TBT agreement, on the other hand, covers all technical regulations, voluntary standards and compliance procedures, except when these are sanitary and phytosanitary measures as defined in the SPS agreement.

The SPS agreement's scientific requirement is important because it is more objective than the TBT agreement's criteria for determining what is a justifiable trade restriction and what is hidden protectionism. On the other hand, the SPS agreement may be inadequate for legally justifying restrictions introduced on the basis of some vocal groups' opposition to GM foods. No official disputes about trade in genetically modified products have yet been arbitrated on,[8] but experience from earlier WTO dispute settlement cases comparable to the GMO debate give an indication as to how the existing rules may be applied. The SPS agreement was used, for example, in the beef hormone dispute between the US and the EU (WTO 1998). In short, the EU import ban on meat and meat products from hormone-fed livestock was found to be in conflict with the EU's WTO obligations, the main argument being that the EU could not present documented scientific risk assessment of the alleged health risk to justify the ban.

Scientific evidence is not always sufficient for governments to make policy decisions, or it may simply be unavailable. In such cases, Article 5.7 of the SPS agreement allows WTO member states to take precautionary measures based on available pertinent information. At the same time, members are obliged to seek additional information so that a more objective evaluation of the risks related to the relevant product or process can be made within a reasonable period of time. The precautionary principle is an understandable approach to uncertainties about genetically modified products, but there is a risk that when used in connection with internationally traded products, it can be captured by import-competing groups seeking protection against any new technology-driven competition from abroad. It may thus be extremely difficult to assess whether a measure is there for precautionary reasons or simply as a form of hidden protectionism. For this reason, attention will focus acutely on how the provisions of the Biosafety Protocol – the most explicit acceptance of the use of the precautionary principle in an international trade agreement relating to food products to date – are interpreted given current WTO commitments.

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[8] Thailand did formally object to Egypt's ban on GM imports in the latter half of 2000, but the matter was settled without going to the trouble of setting up a Dispute Settlement panel at the WTO. It objected not to Egypt's right to impose a ban, but rather to the fact that Thai exports were singled out for exclusion. On 29 August 2003 the US, Canada and Argentina succeeded in getting agreement to establish a WTO panel to rule on the way the EU's current policy is implemented, but it will be a further six or more months before the panel submits its report.

The existing trade agreements deal with regulations and standards concerning not just products but also production processes and methods *if but only if they affect the characteristics or safety of the product itself*: Standards for production processes that do *not* affect the final product are not covered by the existing agreements. In relation to genetically engineered products, if the process itself were to alter the final product in such a way that there are adverse environmental or health effects associated with consumption, use or disposal of the product, restricting trade in this product need not violate existing WTO rules, ceteris paribus. However, if genetic engineering only concerns the production process and not the final characteristics of a transgenic product, domestic regulations that restrict the use of this method of production cannot be used to restrict imports of products produced by this method simply because the importing country finds it unacceptable by its own environmental, ethical or other norms.[9]

This discussion leads back to the role of scientific evidence. Some would argue that genetically modified products are different from conventional products *regardless* of whether this can be verified scientifically in the final product. One of the priorities of the European Commission in the Doha WTO round of multilateral trade negotiations is to obtain a clarification of the role of non-product-related processes and production methods within the WTO. If trade restrictions based on production methods are allowed, this could lead to the inclusion of a long list of non-tariff barriers, and not only in relation to biotechnology products.

Labelling of foods in relation to international trade is normally covered by the TBT agreement unless the label relates directly to food safety, in which case it is covered by the SPS agreement. Only labelling programs that concern production processes affecting the final product would be covered by the existing TBT agreement. Determining whether or not a genetic modification affects the final product will probably have to be done on a case-by-case basis. Where labelling programs are not encompassed by the TBT agreement, which potentially may be the case for many transgenic products, the other agreements of the WTO will be applicable without exceptions (Tietje 1997). GATT Article III concerning non-discrimination, for example, stipulates that member states may not discriminate between otherwise like goods on the basis of their country of origin. A key issue using this Article will be the interpretation of the concept of 'like goods' and whether the presence of genetically modified material is 'sufficient' to differentiate products. Article III seeks to avoid measures that are based on a false differentiation of products.

In short, the emergence of GMOs in agricultural and food production introduces several new and contentious issues to be dealt with by the WTO membership and ultimately its Dispute Settlement Body (DSB). The DSB has not yet been able to resolve the dispute over the EU's ban on imports of beef produced with growth hormones (WTO 1998), so it is difficult to see how it will be able to do any better with the far more complex issue of GM products – particularly now that there is a Biosafety Protocol on the table condoning the use of the precautionary principle and suggesting scientific evidence need not prevent importing countries from restricting GM trade. Mandatory labeling requirements of all GMO-inclusive products including processed foods such as the proposal of the European Commission will probably not violate existing WTO rules as long as they do not discriminate between foreign and domestic goods. Such requirements will add significantly to trade costs, however, particularly if multilateral agreement on such things as threshold tolerance levels proves elusive.

[9] This product/process distinction became (and has remained) prominent at the WTO as a result of the famous tuna-dolphin case in the early 1990s. The general issue continues to be hotly debated. See, for example, the recent paper by Howse and Regan (2000).

5 Quantifying the effects of GM adoption and policy responses

This empirical section illustrates how alternative crop adoption scenarios and policy responses impact economic outcomes in Australia and globally. It explores a range of GM crops including maize, soybean and canola, since these crops have enjoyed the highest rate of adoption of GM food varieties globally, and are the most significant crops in the feed-livestock complex. GM varieties for the other key cereals, rice and wheat, are almost ready for commercial release, so they also are considered. We first provide factual data on the main global players in these markets and then describe briefly a model of the global economy that is well suited to analyse the market and welfare effects of a new technology's adoption by a subset of countries. That model is used to explore several scenarios involving GM adoption by some countries and of various responses by governments or consumers to the new GM products. Results are presented showing effects on production, consumption, trade and national economic welfare. In addition micro-simulation results show how changes in real farm household incomes in different countries alter farmers incentives. The implications for the political economy of policy choices, and for the global trading system are then drawn out.

5.1 Global production, consumption and trade patterns

As we have seen, in recent years the US shares in global production have been 40 per cent for maize and 43 per cent for soybean, and its shares in global exports (including intra-EU trade) are 66 and 51 per cent, respectively. By contrast the EU produces only 6 per cent of the world's maize and only 1 per cent of the soybean (Table 3). The EU livestock sector is smaller than that of the US in beef and poultry but larger in pork and dairy (Table 4).

China, Brazil and Argentina are also big players in these two markets. China accounts for roughly one-fifth of global production and consumption (and one-tenth of global exports) of maize, and for one-tenth, one-third and one-fifth of global production, consumption and imports of soybean, respectively. Brazil and Argentina are smaller players in the maize market (6 and 3 per cent of global production, respectively, although Argentina accounts for one-eighth of global maize exports), but they are both significant in the soybean market: together they account for 37 per cent of global production, 29 per cent of global consumption, and 38 per cent of exports (Table 3).

Canada, the EU and China account for three-quarters of global canola production. Australia contributes another 5 per cent. The EU trades canola a lot among its members but is almost self-sufficient, so when intra-EU exports are excluded then Canada and Australia account for more than 80 per cent of residual world trade.

Notice from Table 3 that the three big exporters of GM maize, soybean and canola, as identified in Table 1, account for huge shares of these three product markets globally, especially exports: 80 per cent for maize, 64 per cent for soybean and 42 per cent for canola. They also account for one-third of global beef exports and more than 40 per cent of global exports of pig and poultry meat (Table 4). This contrasts with the other key cereals, wheat and rice, which are far less concentrated among the GM adopters. Wheat production and consumption is spread more evenly among four main regions: the EU, the US, China and India. China and India account for half of global rice production and consumption and, with Thailand and Vietnam, for two-thirds of global rice exports (Table 5). Hence there will be different distributional effects from the introduction of GM varieties for those products than for the feedgrain-oilseed-livestock complex, with much stronger consequences for poorer farmers and consumers.

Because of maize import restrictions and considerable domestic production of feed barley, the EU accounted for less than 4 per cent of global imports of maize. Oilseed imports have been less restricted, however (because of the EU's long-standing GATT binding of a zero tariff on

Table 5: Key countries' world market shares of rice and wheat, by volume, 1998-99 to 2002-03
(average annual per cent)

	Share (%) of world:				
	Production	**Consumption**	**Exports[b]**	**Imports[b]**	**SS index[c]**
Rice					
European Union	0	0	1	3	
United States	2	1	12	1	1.69
China	33	33	9	1	0.99
India	22	21	13	0	1.06
Indonesia	8	9	0	11	0.92
Bangladesh	6	6	0	2	0.97
Pakistan	1	1	7	0	1.69
Vietnam	5	4	15	0	1.23
Thailand	4	2	28	0	1.79
Burma	3	2	2	0	1.06
Australia	0	0	2	0	2.00
Japan	2	2	0	3	0.92
Korea, Rep.	1	1	0	1	1.05
Rest of world	14	18	11	78	
GM exporters[a]	***2***	***2***	***13***		
Wheat					
European Union	17	16	14	6	1.10
United States	10	6	26	2	1.69
Canada	4	1	14	0	2.84
China	18	19	1	1	0.94
India	12	11	2	0	1.10
Pakistan	3	3	0	1	0.95
Russia	7	6	3	0	1.04
Ukraine	3	2	4	0	1.29
Kazakhstan	2	1	4	0	1.74
Argentina	3	1	10	0	2.55
Australia	4	1	14	0	3.69
Japan	0	1	0	6	0.00
Korea, Rep.	0	0	0	4	0.00
Rest of world	17	32	8	80	
GM exporters[a]	***17***	***8***	***50***		

[a] Argentina, Canada and the United States.
[b] Includes intra-EU trade.
[c] Self-sufficiency index is defined as domestic production divided by domestic consumption.

Source: www.affa.gov.au/gmmarkets

soybean), and the EU accounts for more than one-third of global imports of both soybean and canola (Table 3).

Australia is a very small player in both the maize and soybean markets, although somewhat more significant in canola and wheat (about 4 per cent of global production and 15 per cent of exports for both). However, Australia is a non-trivial producer of livestock production and exports, which, while mostly grassfed, compete with the grain-fed production of the northern hemisphere. Australia's shares of global exports in 1998-2002 (again including intra-EU trade) were 22 per cent for beef and skim milk powder, and 17 and 19 per cent for butter and cheese, respectively (Tables 3 to 5).

The value of production of those various products is a better measure of the significant role these products play in the Australian economy. Grains and oilseeds account for about one-quarter, and meat and dairy products account for about two-fifths, of Australia's gross value of farm production (Table 6). That is, developments in maize and soybean markets abroad are going to have a direct or indirect impact on as much as two-thirds of Australian agriculture, despite the smallness of those two products in Australia's production and exports (Table 7).

The three biggest markets for Australia's food exports under current structures of agricultural protection are Japan (20 per cent), North America (13 per cent) and the EU (6 per cent). Another 20 per cent is shared almost equally among five Asian developing countries: Korea, Taiwan, China, Indonesia and Malaysia (Table 8). Hence EU policies towards GM imports are unlikely to have a major *direct* effect on Australia's food exports. But in so far as they influence the choice of GM policies in East Asia (not to mention their effects on the global trading system), they may well have an important *indirect* effect on Australia.

Data show that GM policies of the EU are substantially altering trade flows. Canadian varieties of GM canola have not been approved, so its exports to the EU ceased after 1998, to the benefit of Australian and Central European canola growers. The EU has not approved most US varieties of GM maize; hence EU maize imports from the US have almost ceased as well. In contrast, Argentina has been able to substitute for the US as a maize supplier, because it grows only EU-approved varieties. Soybean imports from the US and Argentina have been affected less seriously, but nonetheless Brazil has become the EU's preferred supplier since 1998 – despite the fact that between 10 and 20 per cent of the Brazilian soybean crop (70 per cent in the south) is estimated to consist of illegal GM varieties (USDA 2003). As a result of these sharp changes, the current shares of various exporters of these products in EU imports are now much further away from those suppliers' shares of global exports (compare the final two columns of Table 9).

Table 6: Value of Australia's food exports, 2001-02

(A$ billion)

	Value	*Share of total (%)*
Grains and oilseed products, TOTAL	**6.8**	26
Live animals and fish products	**2.6**	10
Meat products	**6.3**	23
Dairy products	**3.3**	12
Wine	**2.1**	8
Sugar	**1.5**	6
Horticultural products	**1.4**	5
Other processed foods	**2.6**	10
TOTAL	**26.6**	**100**

Source: AFFA (2003a).

Table 7: Value and export propensity of Australian production of grains, oilseeds and pulses, and shares of global production and exports, 1998-99 to 2002-03

(annual average)

	Gross value of production (current A$ billion)	**Share of production exported** (% by volume)	**Share of global production** (% by volume)	**Share of global exports** (% by volume incl intra-EU)
Wheat	4.53	69	3.7	14
Barley	1.13	55	4.4	19
Canola	0.56	78	4.7	15
Pulses	0.44	33	4.6	10
Sorghum	0.28	26	3.2	7
Rice	0.25	62	0.2	2
Cottonseed	0.18	52	2.7	37
Oats	0.17	12	4.8	7
Maize	0.08	14	0.1	0
Soybean	0.03	0	0.1	0

Source: Foster, Berry and Hogan (2003, Table 1).

Table 8: Destinations of Australia's exports of wheat, barley, canola, beef, and all food, by volume, 1997-98 to 2001-02

(average annual share, per cent)

	Wheat &flour	**Malting barley**	**Feed barley**	**Canola**	**Beef & veal**	***ALL FOOD***
European Union	0	0	0	13	1	***6***
North America	0	0	0	0	43	***13***
Japan	8	10	29	25	33	***20***
Korea, Rep.	6	4	0	0	8	***4***
Taiwan	0	3	4	0	4	***3***
China	1	59	5	36	0	***3***
Indonesia	12	0	0	0	1	***4***
Malaysia	5	0	0	1	1	***4***
India	3	0	0	0	0	***0***
Pakistan	4	0	0	10	0	***0***
Bangladesh	2	0	0	10	0	***0***
Egypt	7	0	0	0	0	***1***
Iran	11	0	3	0	0	***2***
Iraq	12	0	0	0	0	***2***
Kuwait	1	0	8	0	0	***0***
Saudi Arabia	0	0	29	0	0	***1***
United Arab Emir.	2	0	6	0	0	***0***
Confidential	0	18	11	0	0	***0***
Rest of world	26	24	5	6	9	***36***
World total	**100**	**100**	**100**	**100**	**100**	***100***
Value of exports, 2001-02 *(A$mill)*	***4,527***	***432***	***585***	***572***	***4,617***	***26,626***

Source: www.affa.gov.au/gmmarkets

Table 9: Sources of the European Union's non-EU imports of maize, soybean and canola, by volume, 1995 to 2001

(per cent)

	1995-97	**1999-2001**	*Supplier's share of world (excl. intra-EU) exports, 1999-2001*
Maize			
United States	64	2	*65*
Argentina	18	72	*13*
Brazil	0	11	*3*
Hungary	17	9	*2*
Rest of world	1	6	*17*
TOTAL	100	100	*100*
Soybean			
United States	60	42	*54*
Argentina	9	4	*9*
Brazil	24	47	*27*
Rest of world	4	5	*10*
TOTAL	100	100	*100*
Soybean meal			
United States	6	2	*19*
Argentina	36	50	*40*
Brazil	56	46	*29*
Rest of world	2	1	*12*
TOTAL	100	100	*100*
Canola (rapeseed)			
Canada	54	0	*59*
Australia	0	22	*24*
Central Europe	39	70	*12*
Rest of world	7	8	*5*
TOTAL	100	100	*100*

Source: www.affa.gov.au/gmmarkets based on EU official trade data.

5.2 The GTAP model and simulations

With the above as background, we are now in a better position to interpret model simulation results of the effects of GM adoption on different countries' economies. This sample of results was chosen from among the many possible simulations to illustrate some of the key determinants of the potential effects of GM food technology adoption and possible policy responses.

We use a well-received empirical model of the global economy (the GTAP model) to examine the effects of some countries adopting the new GMO technology without and then with government and consumer responses in other countries. Being a general equilibrium model, GTAP (Global Trade Analysis Project) describes both the vertical and horizontal linkages between all product markets both within the model's individual countries and regions as well as between countries and regions via their bilateral trade flows. The Version 5.4 database used for these applications draws on the global economic structures and trade flows of 1997, around the time of the take-off in adoption of GM crop varieties. To make the results easier to digest, the GTAP model has been aggregated to depict the global economy as having 17 regions (to highlight the main participants in the GMO debate), and 14 sectors (with the focus on the primary agricultural sectors affected by the GMO debate and their related processing industries).[10]

The scenarios analysed here assume that GM-driven productivity growth has occurred only in a subset of countries and only for a few of the GTAP sectors. Specifically, coarse grain (primarily maize in the countries considered) and oilseeds (primarily soybean and canola in the countries considered) are included in all scenarios. To illustrate potential future economic outcomes we also look briefly at adoption of GM rice and wheat in some counties.

The following scenarios are based on a simplifying assumption that the effect of adopting GM crops can be captured by a Hicks-neutral technology shift, i.e. a uniform reduction in all primary factors and intermediate inputs to obtain the same level of production. For present purposes the GM-adopting sectors are assumed to experience a one-off increase in total factor productivity, thus shifting the supply curve for the GM crop to the right.[11] Demanders of primary agricultural products such as maize and soybean meal for livestock feed will benefit from lower input prices, which in turn will affect the market competitiveness of livestock products.

The widespread adoption of GM varieties in some parts of the world will affect other regions via international trade flows. To the extent that trade is not further restricted and not currently subject to binding quantitative restrictions, world market prices for these products will tend to decline and thus benefit regions that are net importers of these products. For exporters, the lower price may or may not boost their trade in value terms, depending on price elasticities in foreign markets. Welfare in the exporting countries would decrease for non-adopters but could also decrease for some adopters if the adverse terms of trade change were to be sufficiently strong. Hence the need for empirical analysis, particularly when the countries in focus are large global players in some of the markets affected.

We have modified the GTAP model so it can capture the effects of productivity increases of GM crops, consumer aversion to consuming GM products and substitutability of GM and non-GM products as intermediate inputs into final consumable food. There are five types of productive factors in the version used here: skilled labour, basic (unskilled) labour, agricultural land, other natural resources, and other (non-human) capital. All factors except natural resources are assumed to be perfectly mobile throughout the economy.[12]

The simulations use a standard, neoclassical GTAP closure. This closure is characterized by perfect competition in all markets, full employment of all labour, factor mobility within all regions, and flexible exchange rates.

5.2.1 Production

Data on global adoption of GM technologies reveal a wide divergence in adoption across countries (see Tables 1 and 2). In these GTAP simulations we assume 45 per cent of US and

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[10] The GTAP (Global Trade Analysis Project) model is a multi-regional, static, applied general equilibrium model based on neo-classical microeconomic theory with international trade described by an Armington (1969) specification (which means that products are differentiated by country of origin). See Hertel (1997) for comprehensive model documentation and Dimaranan and McDougall (2002) for the GTAP 5.4 database used here. The model is solved with GEMPACK software (Harrison and Pearson 1996).

[11] Due to the absence of sufficiently detailed empirical data on the agronomic and hence economic impact of cultivating GM crops, the 5% productivity shock applied here represents an average shock (over all specified commodities and regions). Changing this shock (e.g. doubling it to 10%) generates near-linear changes (i.e. roughly a doubling) in the effects on prices and quantities. This lowering of the supply price of GM crops is net of the technology fee paid to the seed supplier (which is assumed to be a payment for past sunk costs of research) and of any mandatory 'may contain GMOs' labeling and identity preservation costs. The latter are ignored in the computable general equilibrium (CGE) analysis to follow, but further research might explicitly include them and, to fine-tune the welfare calculations, even keep track of which country is the home of the (typically multinational) firm receiving the technology fee.

[12] Some of the model extensions included to capture GM segregation follow a recent Productivity Commission study (Stone et al. 2002).

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Canadian coarse grain production is GM. When they adopt, all Latin American countries and Australia are assumed to adopt GM coarse grains at two-thirds the level of the US (i.e., 30 per cent of coarse grain production is GM) while all other countries are assumed to adopt GM coarse grains at one-third the level of US adoption (i.e., 15 per cent of coarse grain production is GM). For oilseeds, we assume that 75 per cent of oilseed production in the US, Canada, Argentina and Brazil is GM. Again Other Latin American countries and Australia are assumed to adopt at two-thirds the extent of the major adopters and the remaining regions adopt at one-third the extent of the major adopters. For the rice scenarios, major adopters, including the US, Canada, China, India, and all other Asian countries are assumed to produce 45 per cent of their crop using GM technologies. All other regions adopt at two-thirds this rate (i.e., 30 per cent of rice crop is GM). GM wheat adoption is assumed to occur at the same extent as coarse grain adoption for all regions. Since these countries do not have segregation and identity preservation systems in place, we ignore the costs of such schemes (5-15 per cent of farm gate price, according to Burton et al. (2002), but they would be distributed partly to consumers, and also to producers and consumers of non-GM food).

To distinguish GM from non-GM productivity, the adopting sectors are each sub-divided into GM and non-GM product, and an output-augmenting, Hicks-neutral productivity shock is implemented on the GM varieties of these commodities to capture their higher productivity. This assumes that GM technology uniformly reduces the level of primary factors and intermediate inputs needed per unit of output.[13] When a region does not adopt GM technologies, no regional factor productivity shock is included and there is no distinction between GM and non-GM production in these regions. In the constant-elasticity-of-substitution production nest, producers choose first between imported and domestic inputs according to the model's Armington (1969) elasticities, and then choose whether or not to use GM or non-GM intermediate inputs in their production of final goods.

5.2.2 Consumption

In order to capture consumer aversion to GM products, two changes are made to the traditional GTAP demand structure. First, elasticities of substitution between GM and non-GM products in regions where consumers are GM-averse are set at low levels to capture the perceived low substitutability of these products. In addition, preference shift parameters are included to capture the group of consumers in some countries that, because of food safety and/or environmental concerns, refuses to consume GM crops regardless of their price. In such cases a 25 per cent reduction in final demand for imported crops that may contain GMOs is assumed, following Nielsen and Anderson (2001) and Stone et al. (2002).[14]

5.2.3 Factor ownership

GTAP provides a comprehensive decomposition of changes in national economic welfare as measured by the equivalent variation in income. National and world measures of welfare changes hide the distributional implications within countries of GM policies, and thus fail to provide insights into the political economy of GM policy choices. While the total economic benefits from trade typically decrease when inefficient policies such as import bans are implemented, some groups within national economies will benefit. Hence further analysis of the intra-national distribution of effects is desirable.

[13] Because it makes little difference to the results being analysed here, we simply follow previous analysts in assuming that the productivity effects of genetic modification do not differ across crops or inputs (Nielsen and Anderson (2001), Anderson, Nielsen and Robinson (2002)). For studies that differentiate the degrees of factor/input saving, see Huang et al. (2002) and Van Meijl and van Tongeren (2002).

[14] Elasticities of substitution are included in the computation of the distribution of GM and non-GM consumption of coarse grains, oilseeds, rice and wheat within each region. Because these calculations are modeled as separate modules within the GTAP structure, sensitivity analysis indicates that varying elasticities of substitution for these commodities has minimal impact on the model solution. Shifts in final demand have a much greater impact on the model solutions.

We examine the effects on intra-regional distribution of income by dividing the economy into three groups of households: farmers, unskilled labourers, and owners of human and other capital. Income of each group comes from a combination of factors. Farm households earn income from farm and non-farm activities. The existing GTAP database provides information about the availability and use of land, unskilled labour, skilled labour, other natural resources and other capital in the agricultural sector, and likewise in other sectors. Non-farm activities of farm households are assumed to earn income from factors in the same proportion as activities conducted by the typical urban capital-owning household (For Australia, this proportion is one third from human capital and two thirds from other forms of non-farm capital). Hence factor shares for farm households are a weighted sum of factor shares used in agricultural production and the factor income shares of capital owners.[15] The shares of farm household income from non-farm activities are assumed to be 90 per cent in Japan and Korea, 50 per cent in China and the EU, 35 per cent in US and Canada,[16] 25 per cent in Australia, New Zealand, and Eastern Europe, and 20 per cent in all Latin American countries, India, South and South-east Asia, South African Customs Union and the Rest of the World. The remaining Sub-Saharan African countries are assumed to gain 10 per cent of their farm household income from non-farm activities. Unskilled labourers are assumed to receive all their income from unskilled non-farm labour. The expenditure shares are assumed to be the same for all households, so real household incomes are calculated simply by deflating by the consumer price index.

5.2.4 Simulations

Several sets of simulations are considered below, beginning with just coarse grains and oilseeds but then adding rice and wheat (to get a feel for the relative economic importance to different regions and the world as a whole of current versus prospective GM food crop technologies).

The first set of simulations examines the implications of adoption of GM coarse grains and oilseeds without and with an EU moratorium. In the cases involving an EU moratorium, a ban is imposed on imports of all coarse grains and oilseeds from GM-adopting countries because it is assumed no segregation between GM and non-GM products occurs. (This is modelled as an increase in the tariff on imports of all coarse grains and oilseeds from the US, Canada and Argentina (and any other adopters) to the EU to a prohibitive level.) Adoption by the US, Canada and Argentina is examined without and with Australia and New Zealand (ANZ) adopting. (New Zealand is included because while it is too small a player in these markets to affect Australia, effects on it contrast in some cases with those on Australia.) These scenarios are then compared with one where all countries of the world adopt GM varieties of these crops, to estimate the economic benefits foregone because of the reluctance in the EU and elsewhere to embrace this new technology (***Simulations 1a to 1e***).

The second set of simulations recognises that GM varieties are being developed for the world's other two major food crops, rice and wheat, and that they are almost ready for release should governments choose to approve them and consumers be willing to buy products that include them. This set examines the impact of adding GM rice and wheat adoption in the US, Canada and Argentina to their adoption of coarse grains and oilseeds, together with China and India also adopting GM varieties of all four groups of crops. Those two Asian countries are added because they are key

[15] This measure of impact on farmer income is different from the partial equilibrium measure of producer surplus used by, for example, Lindner and Jarrett (1978) who show that even with a completely inelastic demand curve a parallel shift (but not a pivotal shift) downwards in the supply curve will not reduce producer surplus. The measure of farm household income change used here can generate a loss for producers partly because it is a general equilibrium measure that also captures off-farm earnings of farm households, but also because the technology shock only applies to the GM varieties which then have to compete with the (sometimes preferred) non-GM varieties of that crop. Hence the price-depressing impact can more than offset the effect of the productivity improvement on profits of GM adopters.

[16] This is the average for commercial farmers. In the US, commercial farmers are only one-third of the total number of farmers. Another one-quarter of them are considered simply rural residents. If the remaining two-fifths, known as 'intermediates', are included in the definition, then the share of farm household income earned from non-farm sources rises to 75 per cent (USDA 2001). Sensitivity analysis of the post-simulation results is therefore reported below to show what difference the definition makes to the US results.

producers of rice and wheat globally (see Table 5) and would be unlikely to forego for very long the benefits from GM varieties of their main food staples if North America were to adopt them. There are five scenarios in this set of simulations too: adoption without and with ANZ also adopting, and without and with an EU moratorium, plus one with all countries of the world adopting GM varieties of these crops (***Simulations 2a to 2e***).

The third set of simulations recognises that the EU moratorium has prompted other countries to adopt a similar approach to GM food products. Sri Lanka, for example, has imposed a ban on imports of all food containing GMOs. More importantly for global food markets and poverty alleviation, China has not approved production of GM food crops other than tomatoes and peppers, and it imposed a ban on imports of GM food products in 2001 following a UK government ban on imports of soy sauce from China because it may have been produced using GM soybeans imported by China from the US. (That ban was somewhat relaxed in 2002 following intense lobbying pressure from US farm groups.) In the third set of simulations we examine the impact of GM adoption of coarse grains and oilseeds in just North America and Argentina in the presence of a GM import moratorium by not only the EU but also China and other key Northeast Asian countries, first without and then with ANZ adopting GM varieties of those crops. This pair of scenarios highlights the tradeoff for ANZ producers and governments between productivity growth via GM adoption and the benefits of remaining GM-free given EU and (assumed) Northeast Asian reluctance to import crops produced in GM-adopting countries (***Simulations 3a and 3b***).

Following Stone et al. (2002), these model simulations assume that total factor productivity is higher for GM than for non-GM varieties by 6 per cent for oilseeds and 7.5 per cent for coarse grains; in the later cases involving rice and wheat, a conservative 5 per cent difference is assumed for those two crops.

5.3 Model results[17]

Table 10 reports the effects on market quantities and prices for ***Simulations 1a and 1b***. In the absence of any adverse reactions abroad (Table 10(a)), the GM-adopting countries expand their output and net exports of coarse grains and oilseeds (and meat) while the opposite happens in Australia and the rest of the world. Consumption of these products expands in all regions because they are now cheaper, but especially in the GM-adopting regions since in this model the Armington assumption ensures that imported products are an imperfect substitute for domestically produced products.[18] Net exports of these products therefore fall for non-adopting regions, while they rise for the GM-adopting countries. However, when the EU moratorium is imposed on imports from GM-adopting countries (Table 10(b)), the international prices of coarse grains and oilseeds fall sufficiently to cause GM-adopting countries to reduce their output of these crops slightly. In the EU, the opposite effect occurs because the import ban drives up domestic prices. The EU also imports more from non-GM countries; Australia's output and exports therefore decrease less in Simulation 1b than in Simulation 1a.

If ANZ joins the GM-adopters, as in ***Simulations 1c and 1d***, Australian production and net exports of coarse grains increase rather than decrease, and of oilseeds (and meat) decrease less, if there are no adverse policy responses abroad. However, in the presence of the EU moratorium, Australian production and net exports of oilseeds – but not coarse grains or meat products – decrease more than if ANZ did not adopt (compare Tables 11(a) and (b) with Tables 10(a) and (b)).

What if all other countries also adopt GM varieties, as in ***Simulation 1e***? The market effects are shown in Table 12 assuming no adverse consumer or policy responses in the world. Compared with Table 10(a) and 11(a), crop production and export expansion by the first GM-adopting countries would be reduced, and decreases in crop production and net exports by the rest of the world (including Australia) are greater, because export prices of coarse grains and oilseeds fall more.

[17] This section draws on Anderson and Jackson (2004a).
[18] The price falls are less than in Nielsen and Anderson (2001) because the present study distinguishes GM from non-GM varieties and applies the productivity shocks only to the former, whereas the earlier study applied it to all production in GM-adopting countries.

The trade balance and aggregate economic welfare effects of this first set of simulations are summarized in Table 13, from which several points can be made:

- Australia's trade balance improves slightly in the absence of adverse policy reactions abroad, and worsens slightly in the presence of the EU moratorium, regardless of whether Australia adopts GM varieties;
- The global benefits of the first group's GM adoption are substantial (US$2.3 billion per year) if there are no adverse reactions elsewhere. More than one-third of the benefits are shared with the major importing regions of the EU and Northeast Asia, with Australia and New Zealand being the only regions to lose (very slightly, because of an adverse terms of trade change);
- The EU moratorium effectively – which increases farm protection there and causes the EU to be worse off by $3.1 billion per year (less whatever value EU consumers place on having avoided consuming GM products) – causes GM adopters to lose one-third of their previous welfare gain, while welfare for food-importing regions of the rest of the world improves;
- If Australia allows GM adoption then welfare there would improve instead of deteriorating, but the benefits are less than one-tenth those for North America or Argentina when expressed as a percentage of GDP; and
- If the EU allows GM adoption (and assuming that stimulates all other countries to follow suit), the EU benefits from its own productivity gains. Net importers of these products elsewhere in the world also benefit from widespread GM adoption, while net exporters of coarse grains and oilseeds would be slightly worse off. In this case the net global gains would be nearly twice that in the base case, and most of those extra gains would be enjoyed by developing countries (including Europe's transition economies).

The above results refer to GM adoption of coarse grains and oilseeds. GM varieties have been developed for the world's other two major food crops, rice and wheat, and are close to being ready for release, should governments choose to approve them. If approved in the current GM-adopting countries, it is likely these products would be adopted in China and India also. As Table 5 shows, those two large developing countries account for 55 per cent of the world's rice market and 30 per cent of the wheat market. The second set of simulations examines the impact of China and India joining the GM-adopters group to produce GM coarse grains, oilseeds, rice and wheat. Table 14 shows the combined impact on markets assuming there are no adverse policy responses elsewhere (***Simulation 2a***). When wheat and rice are included, coarse grain and oilseed production and net exports of the current GM adopters are slightly less than in Table 10, but their wheat and rice output are boosted 1-4 per cent and exports by 2-5 per cent. For China and India, adopting GM varieties of all these products boosts food crop production by less than 0.5 per cent and imports of those products decline between 1 and 5 percent. Thus demand for Australian food exports is less, as reflected in lower crop production, exports and domestic prices. That clearly benefits Australian consumers (assuming they are unconcerned about whether their food may contain GMO), but does it leave farm households and the Australian economy better or worse off?

The net national economic welfare effects of adding these two extra countries and commodities to the GM-adopting set are dramatic. The global economic welfare gain if there is no adverse policy response is $3.8 billion with just rice added or $4.3 billion if wheat is also added, instead of $2.3 billion per year (compare Tables 13 and 15). The current adopters gain little from the addition of GM rice and wheat. The latter result, which might seem surprising given the importance of wheat to current adopters (NA and ARG), occurs because their productivity gains are almost

Table 10: Production, consumption, price and trade impacts of GM coarse grains and oilseeds adoption by the US, Canada and Argentina

(percentage changes)

(a) ***Simulation 1a*** (with no policy responses)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	-0.20	-0.16	3.01	0.24	0.80	-0.16	-0.00	-0.42
Oilseeds	-3.17	-0.59	1.36	1.13	2.93	-0.70	-0.03	-1.13
Meat products	-0.14	-0.24	0.09	0.01	0.31	-0.02	-0.00	-0.02
Domestic market prices								
Coarse grains	-0.05	-0.04	-1.98	-1.61	-1.94	-0.02	-0.02	-0.08
Oilseeds	-0.06	-0.04	-4.03	-2.00	-2.90	-0.03	-0.02	-0.11
Meat products	-0.04	-0.03	-0.16	-0.30	-0.42	-0.03	-0.02	-0.03
Imports								
Coarse grains	2.40	2.24	-1.35	0.93	-2.31	0.76	7.92	0.67
Oilseeds	6.71	1.87	-7.88	0.50	-3.63	6.25	1.19	2.20
Meat products	0.38	0.73	-0.35	0.16	-1.00	0.83	0.20	0.06
Exports								
Coarse grains	-0.97	-0.93	6.62	0.89	3.67	-1.58	-1.41	-0.65
Oilseeds	-4.60	-4.06	12.16	2.78	6.37	-2.38	-1.68	-1.36
Meat products	-0.34	-0.43	0.20	-0.03	1.42	-0.29	-0.18	-0.06

(b) ***Simulation 1b*** (with the EU moratorium on GM products)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	-0.11	0.00	-0.46	-0.59	0.28	-0.16	0.01	7.30
Oilseeds	-2.55	0.21	-1.58	-8.20	-8.87	-0.46	0.15	22.31
Meat products	-0.11	0.01	0.33	0.32	0.50	-0.01	0.00	-0.38
Domestic market prices								
Coarse grains	-0.06	-0.01	-2.36	-1.96	-2.37	-0.03	0.01	1.42
Oilseeds	-0.07	-0.01	-4.42	-2.45	-3.39	-0.03	0.01	2.06
Meat products	-0.05	-0.01	-0.37	-0.57	-0.65	-0.03	0.01	0.46
Imports								
Coarse grains	2.91	2.76	-4.86	1.02	-3.44	0.79	9.60	-13.11
Oilseeds	8.04	0.89	-8.24	-0.33	-6.18	7.17	1.00	-24.28
Meat products	0.34	1.34	-2.17	-0.20	-1.57	0.91	-0.22	0.49
Exports								
Coarse grains	-0.75	1.92	-2.04	-2.05	-0.82	-1.64	4.93	10.36
Oilseeds	-3.32	8.46	7.55	-21.54	-21.86	8.56	9.58	25.68
Meat products	-0.26	0.06	2.09	0.62	2.51	0.02	-0.12	-0.72

Source: Authors' GTAP model simulation results.

Table 11: Production, consumption, price and trade impacts of GM coarse grains and oilseeds adoption by the US, Canada and Argentina plus Australia and New Zealand

(percentage changes)

(a) ***Simulation 1c*** (with no policy responses)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	0.35	-0.17	3.01	0.18	0.80	-0.19	0.00	-0.42
Oilseeds	-0.84	-0.71	1.36	1.12	2.90	-0.70	-0.03	-1.13
Meat products	-0.11	-0.24	0.09	0.02	0.31	-0.02	0.00	-0.02
Domestic market prices								
Coarse grains	-1.17	-0.85	-1.98	-1.61	-1.94	-0.02	-0.02	-0.08
Oilseeds	-1.02	-0.04	-4.03	-2.00	-2.90	-0.03	-0.02	-0.11
Meat products	-0.06	-0.03	-0.16	-0.30	-0.42	-0.03	-0.02	-0.03
Imports								
Coarse grains	-1.98	3.90	-1.33	0.92	-2.30	2.10	7.92	0.68
Oilseeds	2.71	2.39	-7.88	0.51	-3.57	6.27	1.19	2.21
Meat products	0.31	0.76	-0.35	0.16	-0.99	0.83	0.20	0.06
Exports								
Coarse grains	1.95	2.04	6.62	0.68	3.66	-1.59	-1.45	-0.67
Oilseeds	-1.14	-0.86	12.13	2.74	6.32	-2.42	-1.71	-1.36
Meat products	-0.27	-0.37	0.20	-0.02	1.42	-0.29	-0.18	-0.07

(b) ***Simulation 1d*** (with the EU moratorium on GM products)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	0.21	-0.02	-0.47	-0.65	0.28	-0.19	0.01	7.36
Oilseeds	-3.65	0.09	-1.58	-8.21	-8.88	-0.46	0.15	22.40
Meat products	-0.05	0.01	0.33	0.32	0.50	-0.01	0.00	-0.38
Domestic market prices								
Coarse grains	-1.19	-0.81	-2.36	-1.96	-2.37	-0.03	0.01	1.43
Oilseeds	-1.04	-0.01	-4.42	-2.46	-3.39	-0.03	0.01	2.07
Meat products	-0.07	-0.01	-0.38	-0.58	-0.65	-0.04	0.01	0.46
Imports								
Coarse grains	-1.56	4.45	-4.85	1.01	-3.44	2.15	9.60	-13.20
Oilseeds	3.76	1.41	-8.24	-0.31	-6.13	7.19	1.00	-24.35
Meat products	0.21	1.39	-2.17	-0.20	-1.56	0.91	-0.23	0.49
Exports								
Coarse grains	0.71	-7.67	-2.05	-2.26	-0.83	-1.64	-4.94	10.45
Oilseeds	-6.00	-25.23	-11.50	-21.58	-21.90	8.58	9.62	25.80
Meat products	-0.15	0.13	2.09	0.63	2.51	0.02	-0.12	-0.72

Source: Authors' GTAP model simulation results.

Table 12: Production, consumption, price and trade impacts of GM coarse grains and oilseeds adoption by all regions of the world

(***Simulation 1e,*** with no adverse policy responses, percentage changes)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	-0.14	-0.18	1.10	-0.54	0.27	0.05	0.09	-0.10
Oilseeds	-2.56	-0.58	0.94	0.00	0.47	0.04	0.17	0.07
Meat products	-0.16	-0.29	0.11	0.00	0.34	0.07	0.01	-0.03
Domestic market prices								
Coarse grains	-1.20	-0.87	-2.13	-1.68	-2.09	-0.74	-0.93	-0.72
Oilseeds	-1.06	-1.11	-4.17	-2.09	-3.08	-1.15	-1.19	-1.12
Meat products	-0.08	-0.06	-0.25	-0.36	-0.50	-0.20	-0.25	-0.06
Imports								
Coarse grains	0.46	1.24	-2.32	1.25	-1.87	-0.69	0.97	0.08
Oilseeds	4.07	2.00	-5.30	1.03	-1.18	0.32	-0.95	0.71
Meat products	0.42	0.85	-0.44	0.20	-1.07	0.28	-0.56	0.10
Exports								
Coarse grains	-0.76	-2.41	2.04	-1.73	0.14	-0.77	0.33	-0.27
Oilseeds	-3.96	-2.86	5.63	-0.02	0.81	-0.11	0.07	-0.07
Meat products	-0.40	-0.54	0.33	-0.07	1.48	0.31	0.58	-0.10

Source: Authors' GTAP model simulation results.

Table 13: Trade balance and economic welfare effects of GM coarse grain and oilseed adoption by various countries

(US$ million per year)

	US, CAN and ARG adopt		US, CAN, ARG + ANZ adopt		All countries adopt
	Without policy response	With EU moratorium	Without policy response	With EU moratorium	Without policy response
	Sim 1a	***Sim 1b***	***Sim 1c***	***Sim 1d***	***Sim 1e***
Change in trade balance					
Australia	8	-3	6	-5	5
New Zealand	2	-1	2	-1	2
Change in economic welfare (equiv. variation in income)					
Australia	-9	-4	7	10	2
New Zealand	-5	2	-3	3	-5
Argentina	312	247	312	247	287
Canada	72	7	72	7	65
US	939	628	939	627	897
EU-15	267	-3145	270	-3160	595
Rest of World	714	1029	730	1041	2207
WORLD	**2290**	**-1243**	**2325**	**-1226**	**4047**

Source: Authors' GTAP model simulation results.

offset by a worsening of their terms of trade as a consequence of not only their additional productivity but also of China and India's adoption. All but 15 per cent of the extra $1.5 billion per year from adding just rice accrues to China and India, with other developing countries, as a net importing group, enjoying the residual via lower-priced imports (not shown in Table 15). When wheat is also added the extra gains are spread around the world more evenly, but China and India still enjoy about 70 per cent of the extra benefit from adding wheat.

How would these adoption patterns affect Australia's food markets? Table 16 reports the impact of US, Canada, Argentina, China and India adopting GM varieties of all four sets of crops without and with the EU moratorium (columns 1 and 2), alongside the same scenarios but with ANZ also adopting those GM varieties (columns 3 and 4). Several points are worth stressing. On the one hand, if Australia chooses not to adopt GM varieties, exports fall due to the fall in international crop and livestock product prices and to Australia's reduced competitiveness; and they fall only slightly less if the EU moratorium stays in place (compare ***Simulations 2a and 2b***). If Australia instead chooses to adopt, on the other hand, its output and exports would fall less and, in the case of rice and meat, would be greater than currently if there was no EU moratorium. While that moratorium continues, however, the output effects of GM adoption are mixed: oilseeds and meat production and exports are less while rice, wheat and coarse grain output and exports are greater. The net effect on overall economic welfare in Australia is shown in Table 15 to be greater with GM adoption (S***imulations 2c and 2d***) than without (Simulations 2a and 2b), by $15 billion and $28 billion per year respectively, less any negative value Australian consumers place on not knowing if they may be consuming GM products (or less the cost of implementing a segregation and identity preservation (SIP) system). That is, Australia would gain from joining the adopters of GM varieties of these four crops even if the EU moratorium were to continue indefinitely, provided the cost of Australia's SIP system amounts to no more than 65 US cents per capita per year.

Table 14: Production, consumption, price and trade impacts of GM coarse grains, oilseeds, rice and wheat adoption by the US, Canada, Argentina, China and India
(***Simulation 2a,*** percentage changes)

	Australia	New Zealand	Argentina	Canada	United States	China	India	EU-15
Production								
Coarse grains	-0.58	-0.20	2.86	0.15	0.76	0.34	0.20	-0.44
Oilseeds	-3.41	-0.87	1.34	1.10	2.64	0.46	0.36	-1.18
Rice	-0.20	-0.18	1.02	3.89	1.70	0.25	0.46	-0.82
Wheat	-1.67	-0.24	1.79	1.50	2.42	0.24	0.19	-0.34
Meat products	-0.13	-0.29	0.08	0.05	0.31	0.21	0.25	-0.03
Domestic market prices								
Coarse grains	-0.11	-0.06	-1.96	-1.65	-1.99	-0.79	-1.14	-0.10
Oilseeds	-0.12	-0.06	-4.01	-2.06	-2.97	-1.20	-1.40	-0.13
Rice	-0.07	-0.04	-1.05	-1.69	-1.24	-1.39	-1.75	-0.07
Wheat	-0.11	-0.06	-1.20	-1.20	-1.77	-0.66	-0.69	-0.09
Meat products	-0.08	-0.04	-0.16	-0.35	-0.45	-0.29	-0.47	-0.04
Imports								
Coarse grains	2.94	2.64	-1.28	1.02	-2.34	-1.96	-0.77	0.68
Oilseeds	6.90	3.40	-7.65	0.53	-3.54	-1.29	-5.18	2.27
Rice	0.83	2.07	-3.06	-0.04	-2.68	-5.20	-4.89	0.80
Wheat	1.16	4.18	-3.63	1.43	-2.20	-1.76	-0.84	0.55
Meat products	0.32	0.85	-0.28	0.09	-0.95	-0.15	-1.63	0.09
Exports								
Coarse grains	3.01	-1.05	6.25	0.39	3.35	1.04	3.37	-0.70
Oilseeds	-4.97	-4.41	11.81	2.67	5.68	2.35	4.04	-1.45
Rice	-0.27	-1.20	4.10	5.09	3.93	5.11	6.41	-0.78
Wheat	-2.02	-2.03	3.80	1.87	4.82	1.25	1.23	-0.44
Meat products	-0.32	-0.51	0.11	0.04	1.37	0.76	1.64	-0.09

Source: Authors' GTAP model simulation results.

Table 15: Trade balance and economic welfare effects of GM coarse grain, oilseed, rice and wheat adoption by various countries

(equivalent variation in income, US$ million)

	US, CAN, ARG, China and India adopt		US, CAN, ARG, China and India plus ANZ adopt		All countries adopt
	Without policy response	With EU moratorium	Without policy response	With EU Moratorium	Without policy response
	Sim 2a	***Sim 2b***	***Sim 2c***	***Sim 2d***	***Sim 2e***
Change in trade balance					
Australia	11	-1	6	-4	6
New Zealand	3	-1	2	-2	2
Change in economic welfare (equivalent variation in income)					
Australia	-18	-10	10	5	-1
New Zealand	-6	2	-3	6	-7
Argentina	350	285	350	285	312
Canada	83	-23	82	-25	63
US	1045	754	1047	756	1041
China	841	833	851	842	899
India	669	654	671	656	669
EU-15	355	-4717	363	-4868	810
Rest of World	989	1330	1027	1376	3720
WORLD	**4308**	**-892**	4398	-968	**7506**

Source: Authors' GTAP model simulation results

What difference would it make if China, Japan and Korea were to follow the EU in imposing a moratorium on imports from GM-adopting countries? This can be seen from Table 17, which shows results from our third set of simulations in which the EU moratorium on trade in GM coarse grains and oilseeds is extended to include China, Japan and Korea. That broadening of the moratorium alters somewhat the incentives for Australia, but not New Zealand, to adopt GM varieties (first two rows of Table 17). Specifically, row 11 of Table 18 (***Simulation 3a***) shows that the positive terms of trade impact Australia experiences by not adopting GM varieties and thereby maintaining market access to these important markets ($111 million) dominates the negative allocative efficiency impact (-$15 million), resulting in a net positive welfare outcome (US$96 million). If Australia chooses to adopt and thereby loses access to both European and Northeast Asian markets, on the other hand (***Simulation 3b***), the negative terms of trade impact (-$46 million) overshadows the potential benefits from technical change ($17 million) and improved allocative efficiency ($16 million) to yield a net loss of $13 million per year (row 12 of Table 18).[19] The difference for

[19] The larger loss for China in this scenario is because Australia would be a major supplier of coarse grain imports by China if Northeast Asia were to cease buying from North America, but that trade ceases in the scenario in which ANZ adopts GM varieties.

Australia in this case between Simulations 3a and 3b (that is, between adopting and not adopting in the presence of a broadened moratorium) is thus $109 million per year – eight times greater than the impact of the EU moratorium alone (the difference between Simulations 1d and 1b). One-fifth of that $109 million difference is due to China (making its moratorium more important for Australia than the EU's), the rest to Japan and Korea. Needless to say, the world economy as a whole, and East Asia especially, would be much worse off with this broadening of the moratorium, and moreso if ANZ adopt GM crops (see final row of Table 17).

The above net national welfare changes are the sum of the effects for food producers and consumers/taxpayers, assuming no externalities on the production side and no food safety concerns on the consumption side of the market. What are the effects on just farm household incomes in Australia? To estimate them, we assume Australian farm households earn 75 per cent of their net income from farm activities (half from labour, one-eighth from land and the rest from physical capital) and the other 25 per cent from non-farm activities (one-third from wages and two-thirds as returns to physical capital). With those earnings shares and the changes in factor prices generated by the GTAP model we can estimate the changes in net earnings of farm households. To convert them to changes in real net income we assume Australian farm households have the same spending pattern as the community average and so we subtract the change in the consumer price index. The resulting estimates are shown in the final column of Table 18.

In no cases are these changes in farm household incomes more than 1 per cent. This result is not surprising because these crops contribute only a small fraction of net incomes of farm households in Australia. Also, the terms of trade changes from GM adoption abroad are only small; and in the cases of adoption at home, the assumed productivity growth is just 5 to 7.5 per cent and is applied to only 30 per cent of production of coarse grain, wheat and rice and 50 per cent of oilseeds. Even so, the results suggest Australian farmers would be slightly worse off from adopting versus not adopting GM crops, implying that Australian non-farm households would need to compensate farmers out of their gains from the fall in food prices if ANZ farmers were to be end up no worse off from embracing this technology.[20] The difference is especially marked in the case where Northeast Asia copies the EU moratorium: in that set of scenarios, Australian farm households would be 0.8 per cent better off if they do not adopt GM coarse grain and oilseed varieties but almost 1 per cent worse off if they do (rows 11 and 12 of Table 5).

5.4 Implications for the political economy of policy choices[21]

The farm household effects in other countries, summarized in Table 19, are consistent with the political economy described in Section 4.1 above. Farmers in the US and Canada are only slightly worse off as a result of their adoption of GM varieties (the productivity gains are slightly more than offset by the price declines, since that region is such a dominant part of the global market for maize and soybean). However, their welfare is worsened considerably by the EU moratorium. Farmers in the EU, on the other hand, while only slightly worse off as a result of GM adoption in the Americas, are made considerably better off if the EU moratorium on American imports is imposed. That advantage almost disappears if EU farmers are allowed to adopt these GM varieties, and more than disappears if that lifting of the EU ban prompts the rest of the world to adopt GM crops (in which case the price decline more than offsets the productivity gain for them – see the EU row of

[20] Australian consumers do this implicitly already through taxpayer matching of farmer R&D levies that jointly fund Australia's rural research and development corporations.
[21] An elaboration of this political economy analysis can be found in Anderson and Jackson (2003) and Jackson and Anderson (2004a,b).

Table 16: Australian production, domestic price and trade impacts of GM coarse grain, oilseed, rice and wheat adoption by various countries

(percentage changes)

	US, CAN, ARG, China and India adopt		US, CAN, ARG, China and India plus ANZ adopt	
	Without policy response	With EU moratorium	Without policy response	With EU moratorium
	Sim 2a	***Sim 2b***	***Sim 2c***	***Sim 2d***
Production				
Coarse grains	-0.58	-0.47	-0.02	-0.14
Oilseeds	-3.41	-2.91	-1.13	-4.03
Meat products	-0.20	0.67	1.33	-1.50
Rice	-1.67	-1.82	0.59	-1.69
Wheat	-0.13	-0.09	-0.13	0.03
Domestic market prices				
Coarse grains	-0.11	-0.11	-1.22	-1.30
Oilseeds	-0.12	-0.12	-1.07	-1.16
Meat products	-0.07	-0.08	-0.78	-0.85
Rice	-0.11	-0.11	-0.87	-0.95
Wheat	-0.08	-0.08	-0.08	-0.15
Imports				
Coarse grains	2.94	3.72	-1.32	-0.95
Oilseeds	6.90	8.70	3.23	4.36
Meat products	0.83	0.59	-2.81	-3.24
Rice	1.16	1.50	-0.93	-0.94
Wheat	0.32	0.34	0.39	0.11
Exports				
Coarse grains	-3.01	-2.90	-0.34	-1.58
Oilseeds	-4.97	-3.85	-1.60	-6.62
Meat products	-0.27	1.74	2.69	-4.26
Rice	-2.02	-2.22	0.72	-2.10
Wheat	-0.32	-0.23	-0.32	0.04

Source: Authors' GTAP model simulation results.

columns 4 and 5 of Table 19). That is, American farmers would be worse off, and EU farmers better off, if the EU bans imports of products that may contain GMOs than if their importation from the GM-adopting regions is allowed; and EU farmers would be even worse off the more the lifting of their ban encourages other countries to adopt. These differences between American and European farmers are made even greater if the set of GM crops and adopting countries is extended as in Simulations 2a-2e (Table 20). Given these differences in effects on farm incomes – which are consistent with the hypothesis that producer interest group are playing a role in determining policy in these regions – it seems likely that the tension across the North Atlantic over GMOs is unlikely to be resolved quickly.

And what about China? If China and India allow GM food crop production, real farm incomes rise on average in China. How can that result for China be reconciled with China's decision

Table 17: Economic welfare effects of GM coarse grain and oilseed adoption by the US, Canada and Argentina with EU and Northeast Asian moratoria

(equivalent variation in income, US$ million)

	US, CAN and ARG adopt	US, CAN, ARG, plus ANZ adopt
	Sim 3a	***Sim 3b***
Australia	96	-13
New Zealand	14	16
Argentina	213	214
Canada	-84	-81
US	427	431
EU-15	-3080	-3164
China	-971	-1323
Other Northeast Asia	-2552	-2645
South and Southeast Asia	117	143
Rest of World	1348	1444
WORLD	**-4471**	**-4977**

Source: Authors' GTAP model simulation results

Table 18: Decomposition of Australia's national economic welfare effects and changes in real farm household income due to GM adoption under various simulations[a]

(equivalent variation in income, US$ million)

	National economic welfare decomposition				**% change in farm h'hold income**
	Allocative efficiency impact	Terms of trade impact	Technical change impact	**Total impact**	
Sim 1a	2	-11	0	**-9**	**-0.05**
Sim 1b	3	-6	0	**-4**	**-0.02**
Sim 1c	3	-16	20	**7**	**-0.10**
Sim 1d	5	-14	19	**10**	**-0.11**
Sim 1e	5	-22	19	**2**	**-0.35**
Sim 2a	4	-22	0	**-18**	**-0.07**
Sim 2b	6	-15	0	**-10**	**-0.04**
Sim 2c	4	-38	44	**10**	**-0.12**
Sim 2d	10	-48	43	**5**	**-0.16**
Sim 2e	8	-51	43	**-1**	**-0.17**
Sim 3a	-15	111	0	**96**	**0.83**
Sim 3b	16	-46	17	**-13**	**-0.99**

[a] See the previous three tables for the descriptions of each of the simulations. The welfare decomposition follows Harrison, Horridge and Pearson (1999).

Source: Authors' GTAP model simulation results

Table 19: Percentage change in farmers' real incomes in selected countries under various GM coarse grain and oilseed, adoption and policy response scenarios

	US, CAN, ARG, adopt		US, CAN, ARG, and ANZ adopt		All countries adopt
	Without policy response	With EU moratorium	Without policy response	With EU moratorium	Without policy response
	Sim 1a	***Sim 1b***	***Sim 1c***	***Sim 1d***	***Sim 1e***
US	-0.15	-0.36	-0.18	-0.36	-0.24
Canada	-0.25	-0.51	-0.26	-0.52	-0.31
Argentina	0.04	-0.10	0.03	-0.14	-0.02
EU-15	-0.03	0.73	-0.03	0.73	-0.06
Australia	-0.05	-0.02	-0.10	-0.11	-0.35

Source: Drawing on the authors' GTAP model simulation results

Table 20: Percentage change in farmers' real incomes in selected countries under various GM coarse grain, oilseed, rice, and wheat adoption and policy response scenarios

	US, CAN, ARG, CHN, and IND adopt		US, CAN, ARG, CHN, IND, and ANZ adopt		All countries adopt
	Without policy response	With EU moratorium	Without policy response	With EU moratorium	Without policy response
	Sim 2a	***Sim 2b***	***Sim 2c***	***Sim 2d***	***Sim 2e***
US	-0.19	-0.43	-0.20	-0.50	-0.29
Canada	-0.28	-0.63	-0.28	-0.64	-0.36
Argentina	0.04	-0.13	0.04	-0.13	-0.04
EU-15	-0.03	0.85	-0.03	0.87	-0.07
China	0.09	0.07	0.10	0.07	0.12
India	0.02	-0.04	0.02	-0.04	-0.01
Australia	-0.07	-0.05	-0.12	-0.16	-0.17

Source: Drawing on the authors' GTAP model simulation results.

to not approve GM food production and to ban imports of GM products in 2001 (subsequently weakened in 2002 but only after strong protests from the US)? Import-competing coarse grain[22] and oilseed farmers there, as in the EU, might be expected to support tough GM standards, as might the many traditional livestock producers who do not use industrially prepared feedstuffs, if they feel their farm management systems would not allow them to take advantage of GM technology. The feed-intensive modern livestock sector competes with these small producers, but evidently it has not been a powerful enough lobby to prevent China from adopting a strict GM policy – even though the *average* farm household in China would gain from GM adoption if productivity gains were at least 5 per cent, according to Table 20. To avoid being inconsistent with the WTO's GATT Article III on national treatment, its GM import restrictions require China to ban the production of GM food crops too – despite the facts that China (a) has the technology and could release numerous GM crop varieties including rice almost immediately (Huang, Wang and Zhang 2001; Huang and Wang 2002), (b) exports very few food products and then mostly to East Asia and so is not likely to suffer serious problems of market access, particularly in the years ahead as industrialization causes China's agricultural comparative disadvantage to strengthen, and (c) as a poor country would gain from GM adoption of those crops about 20 times as much as North America when the gain is expressed as a share of GDP. Officially the reason is that food safety tests are still under way, but an alternative or additional possibility is that China is stalling until it has its own GM varieties ready for release so as to avoid paying foreign firms for intellectual property rights.

These findings have worrying implications for the global trading system (not to mention poor countries – see Anderson and Jackson 2004b). If it is in the interests of farmers in food-importing countries of Europe and elsewhere to forego adopting this new biotechnology in order to reduce their competitive disadvantage vis a vis more-efficient export-oriented producers in the Americas and elsewhere, then those protected producers have incentives to join with consumer and environmental groups and lobby for the retention of tough GMO standards. Such standards could provide a replacement for the traditional forms of government assistance to agriculture that are under pressure to be dismantled in agricultural-protectionist countries, following the Uruguay Round of trade negotiations (and China's WTO accession). Not only would that negate the benefits of negotiating lower farm support programs in the current Doha round of WTO negotiations, but it promises to raise the level of friction in the WTO's Dispute Settlement Body.

5.5 Caveats

In evaluating these results, several key assumptions should be kept in mind. First, in all these simulations we assume for simplicity that there are no negative environmental risks net of positive environmental benefits associated with producing GM crops, and that there is no discounting and/or loss of market access abroad for other food products because of what GM adoption does for a country's generic reputation as a producer of 'clean, green, safe food'.[23]

Second, we also assumed that there is no need for segregation and identity preservation (SIP) through the supply chain to allow consumers to choose between foods with and without GMOs, since in our scenarios countries where consumers are assumed to care ban all imports of affected crop products from GM-adopting countries. On the one hand, that assumption means we may have overstated the welfare cost of the moratoria for GM-adopting countries unless SIP costs would be prohibitively expensive. On the other hand, it also means we have overstated the gains to Australia from GM adoption domestically because, given the strict ANZ labelling legislation introduced earlier this decade, a SIP system for domestic crops would have to be introduced if GM varieties were to be grown locally.

Third, we have ignored the owners of intellectual property in GM varieties, and simply assumed the productivity advantage of GM varieties is net of the higher cost of GM seeds. In so far

[22] China has been a net exporter of maize in recent years but those exports represent only a small share of production and were helped by export subsidies that have since been phased out.

[23] If Australia were to allow GM adoption then the demand for food products in general from New Zealand may increase at Australia's expense in so far as the two countries are currently seen as close alternative suppliers of 'clean, green safe food'.

as that intellectual property is held by a firm in a country other than the GM-adopting country, then the gain from adoption is slightly overstated in the adopting country (and understated for the home countries of the relevant multinational biotech companies).

Fourth, the effects of adoption and of policy responses depend on, among other things, the elasticities of substitution in consumption between GM and GM-free (but otherwise like) products. This is unikely to be important, however: a recent study explored this issue explicitly and found that results did not vary much as those elasticities were altered (Anderson et al. 2002).

Fifth, results from the above moratoria simulations suggest that when rich countries introduce trade barriers against GM products, food-importing developing countries benefit. However, the above analysis does not take into account that moratoria will slow the investment in agricultural biotechnology, and so reduce future market and technological spillovers to developing countries from that prospective R&D. Furthermore, future generations of GM products are likely to provide health and nutritional benefits to consumers, as in GM rice enhanced with Vitamin A. The costs of delaying investments in those GM technologies will fall heavily on the world's poor consumers (Anderson and Yao 2003; Anderson, Jackson and Nielsen 2004).

Finally, and perhaps most importantly, the above comparative static modelling assumes GM technology delivers just a one-off increase in total factor productivity (TFP) for that portion of a crop's area planted to the GM varieties. But what is more likely is that, once the principle of GM crop production is accepted, there would be an increase in the *rate* of agricultural TFP growth into the future, so that the present value of future returns from GM adoption may be several times the numbers shown above.

6 WHAT SHOULD AUSTRALIA DO?

The comparative advantages of Australia in various (GM and non-GM) crops will continue to change not only because of changing consumer attitudes at home and abroad but also as Australia's trading partners alter their consumer, producer and trade policies and as new GM crop varieties appear. Currently plenty of markets for GM crops exist, as the three first GM-adopting countries – the US, Canada and Argentina – account for high shares of global exports even including intra-EU trade (80 per cent for maize, 64 per cent for soybean and 42 per cent for canola in 2002). Where price premiums for non-GM varieties exist they are small, meaning that the market for certified traditional non-GM foods may become in the long run just a niche market similar to that for organic products (Mendenhall and Evenson 2002). In the short to medium term, however, the above results show that Australia's benefits from adoption depend on the extent to which GM products are accepted by Australia's current major trading partners.

One aspect of the debate that requires further research is the impact of the cost and distributional consequences of national segregation and identity preservation (SIP) systems that will be needed to supply markets with strict GM labelling laws. Recent debates over whether to approve GM canola production in Australia illustrate that production is unlikely to be approved until a cost-effective SIP system is in place to allow co-existence of non-GM and GM varieties (Parliament of South Australia 2003). Several States of Australia, like New Zealand, continue to delay approval because they perceive insufficient economic benefit from GM crops to warrant the cost of the necessary co-existence system (which will fall more on non-GM producers, the smaller the share of GM varieties in total output) and the expected loss that would result from a downgrading of their region's status as a 'clean, green, safe food' supplier domestically and abroad. Even regions within States, such as Kangaroo Island and Eyre Peninsula in South Australia, are considering establishing themselves as GM-free areas.

These cautious approaches were understandable while only maize and soybean were ready for adoption, while consumer aversion remained high, and where SIP systems were undeveloped. However, continuing a ban on GM production is becoming less defensible as these conditions change. GM yield-increasing varieties of canola suitable for Australian conditions are now available and two herbicide-resistant ones have been approved by the Office of the Gene Technology Regulator, and new wheat varieties have also been developed by CSIRO that are drought tolerant and exhibit high tolerance to some common pests (CSIRO 2003). Prospective environmental costs are increasingly being weighed against possible environmental benefits from the switch to GM varieties instead of those possible costs being viewed in isolation. Also, consumers are showing more tolerance of GMOs where labelling laws are in place, particularly as they learn of the prospects for building in attributes desired for health, etc. reasons. And SIP systems are gradually becoming more common and cost-effective in response to consumers seeking ever-more product information in general on food labels.

Even if the gains today from GM adoption by Australian farmers may seem small, as suggested by the above results, it needs to be kept in mind that maintaining GM-free status will likely lead to a bias toward more-traditional agricultural research that will tend to be slower and hence less rewarding. Apart from farmers, that could be costly to Australian consumers, as well as to the country's biotechnology industry which is a potential export earner in its own right. Indeed the longer domestic governments restrict GM crop production, the more Australian scientists will tend to migrate to more-stimulating research environments abroad. For all these reasons, and given the time lags between R&D investment and farmer adoption of innovations, it would be prudent for Australia's rural R&D corporations to ensure a portion of their portfolio includes the development of GM technologies appropriate to local conditions so that, when markets become more accepting, those technologies can be produced and disseminated relatively promptly.

The Federal Government's current strategy as it affects the food and agricultural sector was laid out recently (AFFA 2003b). But even that official document does not provide much detail, leaving open the possibility of regulatory reform over time. In revising domestic consumer and producer regulations for dealing with GMO issues as information and views evolve, the following points might be kept in mind:

- Attitudes towards GMOs (and many other attributes of food) are continually changing as greater information becomes available to consumers, so the optimal consumer regulation will change over time;
- In particular, consumer attitudes towards GMOs will become more differentiated as second-generation GM varieties come on stream that exhibit product attributes specifically desired by consumers;
- The optimal regulation for domestic sales depends to some extent on the costliness of a segregation and identity preservation (SIP) system (since consumers will bear part of its cost), the benefits of which also depend on the consumer legislation that is still developing in Australia's export markets abroad;
- The demand by consumers for foods with (or without) specific attributes will continue to grow, so 'GMO-ness' is but one of many reasons why consumers may be willing to pay for SIP systems in the supply chain;
- Hence it may make less sense in the future for a region to forego the productivity gains in GM varieties if the main reason for that stance is to avoid the costs of a SIP system, and particularly if the region does not have the funds or organizational capacity to promote itself as a GM-free region;
- Comparative advantages of each region and of Australia as a whole in various (GM and non-GM) crops will continue to change not only because of changing consumer attitudes but also as countries alter their consumer, producer and trade policies and as new GM crop varieties appear;
- Where price premiums for non-GM varieties exist they are small, meaning that the market for certified non-GM foods may simply become a niche market similar to the market for organics products;
- Crop varieties suited to particular regions rarely appear as manna from heaven but rather as a result of a concerted and targeted R&D investment, so adopting a GM-free status will likely lead to a bias toward more-traditional research which will tend to be slower and hence less rewarding;
- Rural research and development corporations can help to counter such tendencies by ensuring a portion of their portfolio includes GM technologies so that when markets become more accepting those technologies can be disseminated relatively promptly;
- Australia's biotech R&D industry – a potential export earner in its own right –will be held back the more Australia limits production of GM crops, and as a result many scientists may choose to migrate to more-stimulating research environments abroad;
- Industry groups can prepare appropriate technology stewardship strategies, which in turn will help investors who are thinking of developing SIP systems;
- Fortunately the GMO standards set by countries in East Asia, where much of Australia's food exports are destined, are less stringent than Australia's own standards; and
- Australia should oppose excessive standards abroad if they are protectionist in intent, for they may just be substitutes for traditional protectionist measures as multilateral rounds of trade talks lead to decreased use of traditional protectionist measures.

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