The Australian Journal of Agricultural and Resource Economics, 49, 263–281

GM crop technology and trade restraints: economic implications for Australia and New Zealand*

Kym Anderson and Lee Ann Jackson[†]

How much might the potential economic benefit from enhanced farm productivity associated with crop biotechnology adoption by Australia and New Zealand (ANZ) be offset by a loss of market access abroad for crops that may contain genetically modified (GM) organisms? This paper uses the Global Trade Analysis Project (GTAP) model to estimate effects of other countries' GM policies without and with ANZ farmers adopting GM varieties of various grains and oilseeds. The gross economic benefits to ANZ from adopting GM crops under a variety of scenarios could be positive even if the strict controls on imports from GM-adopting countries by the European Union are maintained, but not if North-East Asia also applied such trade restaints. From those gross economic effects would need to be subtracted society's evaluation of any new food safety concerns and negative environmental externalities (net of any new environmental and occupational health benefits), as well as any extra costs of segregation, identity preservation and consumer search.

Key words: biotechnology, computable general equilibrium, genetically modified organisms, regulation, trade policy.

1. Introduction

Genetically modified organisms (GMO) are the focus of much attention in world food markets. GM food crop technology is claimed to have great potential for the world's farmers and ultimately consumers, following initial success with GM cotton varieties. Benefits for farmers could include greater productivity and less occupational health and environmental damage (e.g., through less use of pesticides), while benefits to consumers include lower food prices and, potentially, enhanced attributes (e.g., 'nutriceuticals', more varieties and qualities). Despite those potential benefits, GMOs

---

* We acknowledge with thanks the support provided by Susan Stone of the Productivity Commission in sharing data used for the GTAP model aggregation, and funding support from Australia's Rural Industries Research and Development Corporation (RIRDC) and the Australian Research Council. This paper draws on and updates a much longer report for RIRDC (Anderson and Jackson 2005a). Views expressed and any remaining errors are our own.

[†] Kym Anderson (email: kanderson@worldbank.org) is Professor of Economics at the School of Economics and Centre for International Economic Studies (CIES), University of Adelaide, South Australia, Australia; currently on leave at the Development Research Group of the World Bank in Washington, DC, USA. Lee Ann Jackson was a CIES Research Fellow at the University of Adelaide when the paper was drafted, but is now with the World Trade Organization, Geneva, Switzerland.

are attracting a high degree of attention among some consumer and community groups concerned about the potentially adverse impacts on food safety (e.g., 'Will they cause cancer?'), on the environment (e.g., 'Will they lead to pesticide-resistant superweeds?') and on foreign control of seeds (e.g., 'Will we end up with just a handful of crop varieties supplied by even fewer multinational seed firms?'). Producers and consumers preferring to stay with conventional varieties also worry about the cost to them of preserving the GM-free identity of those varieties.

Numerous governments are responding to those concerns, typically in conservative, command-and-control ways such as placing a moratorium on the production, use and therefore importation of products containing GMOs (as the European Union (EU) did de facto between 1998 and 2004) or, in cases where permission is granted to grow or sell certain GM crop varieties, mandating strict GMO labelling laws that necessitate expensive segregation and identity preservation (SIP) systems to be used throughout the supply chain (as the EU imposed in April 2004 as a replacement for its de facto moratorium).

Although maize, soybeans and canola have attracted the most attention in the global debate about GM crops due to their prevalence in USA, Canadian and Argentinian production, scientists have genetically modified other food crops too, including wheat and rice, that are far more important to Australia.

In this atmosphere, exporters of food products fear that customers in food-importing countries will discount or refuse to buy their products, if even a subset of the exporting country's farmers adopt GM technology. The experience in the 3 years following October 1998 when the EU imposed its de facto moratorium seemed to vindicate that concern because the USA's share of the EU's maize imports fell to virtually zero (from around two-thirds in the mid-1990s), as did Canada's share of EU canola imports (from 54% in the mid-1990s; Anderson and Jackson 2005a, table 9). Therefore, although these GM-adopting countries apparently have benefited in terms of lower production costs, they initially lost market share to GM-free suppliers, including to Australia in the case of canola.

Food-exporting countries such as Australia and New Zealand (ANZ) thus need to weigh the potential economic (and environmental) benefits from biotechnology development against any negative environmental risks associated with producing GM crops, any additional costs of SIP through the supply chain so as to avoid adventitious (accidental) presence of GM varieties in non-GM shipments and to allow consumers to choose between foods with and without GMOs, 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 ANZ's generic reputation as a 'clean, green and safe food' producer.

Pending rigorous analysis of those issues, health ministers in Australia and New Zealand have agreed to err on the side of precaution and introduce strict regulations concerning GMOs. As from mid-2001, Food Standards Australia New Zealand require that GM foods cannot be supplied to the domestic market unless approved (20 had been approved as at August 2001), and mandatory labelling is required for all approved GM foods including processing aids (but not animal feeds) that contain GM protein or DNA or that have altered characteristics. This is one of the most stringent food safety regimes in the world outside the EU, which means that satisfying domestic sales requirements makes it possible for ANZ exporters to satisfy most other countries' requirements (even though different labels will be required for different markets). On the production side there are strict controls too. By mid-2004, Australia had approved GM production only for canola (just two varieties), in addition to some GM varieties of cotton and carnation flowers. However, like New Zealand, state governments in Australia have imposed moratoria on GM food crop production in their jurisdiction.

To date there have been few general equilibrium simulation analyses of the economic benefits and costs to ANZ farmers and the economy generally of GM policies not just at home but also abroad. Partial equilibrium studies of adoption at home have been undertaken by Foster (2001) for GM canola and wheat in Australia and by Saunders and Cagatay (2003) for four products in New Zealand, and Stone *et al.* (2002) provide a general equilibrium analysis (using the GTAP model) for GM coarse grains and oilseeds adoption in Australia. The present study builds on those earlier studies in several respects: among other things, it uses the same general equilibrium GTAP model as Stone *et al.* (2002) but a more recent version of the GTAP database, and it examines a wider range of GM-adopting countries and of policy responses; it examines not just coarse grains and oilseeds but also prospective GM versions of wheat and rice (to provide a partial estimate of the opportunity cost of not approving their commercial release); and it examines within the same modelling framework the effects on both Australia and New Zealand without and then with them adopting GM crop varieties.

The next section of the paper provides details of what the GTAP model of the global economy can and cannot do in exploring the production, trade, price and national economic welfare effects of GM technology and trade measures. Results are presented in section 3 for a range of scenarios that vary by GM crop type, the set of adopting countries and various policy responses to GM technologies. Key caveats are discussed in section 4 before drawing out policy implications for Australia and New Zealand in the final section.

2. Global Trade Analysis Project model and modifications

The GTAP model of the global economy is used to provide insights into the effects of GMO technology adoption in some sets of countries without and then with trade policy responses in two other sets of countries. See Hertel (1997) for comprehensive model documentation of the GTAP model, which is a neoclassical multiregional, static, applied general equilibrium model that assumes perfect competition, constant returns to scale and full employment of all factors of production. Version 5.4 of the GTAP database (see Dimaranan and McDougall 2002) is used for these applications. It draws on global economic structures and trade flows of 1997, just before the de facto EU moratorium. The GTAP model has been aggregated to depict the global economy as having 17 regions (to highlight the main participants in the GM debate) and 14 sectors (with the focus on the primary agricultural sectors affected by the GM debate and their related processing industries).

Building on a Productivity Commission study (Stone *et al.* 2002), our modification of the GTAP model captures the effects of productivity differences between GM and non-GM crop varieties, household aversion to consuming GM products and substitutability of GM and non-GM products as intermediate inputs into final consumable food.

Our economy-wide GTAP model does not include environmental externalities, so the welfare consequences of any such externalities are not measured. This unfortunate situation is a result of the uncertainty surrounding the relationships among various economic and environmental variables. What can be said, though, is that the net environmental effects of producing GM crops could be positive or negative – just as they could be for producing non-GM crops, which are also not captured in our model. Many GM crop varieties have some attributes that are more environmentally friendly than their conventional non-GM counterparts. They are also less dangerous to farmers and the soil where they require reduced applications of pesticides. However, there is concern that some long-term and possibly irreversible negative environmental effects might occur in the future – although a recent comprehensive report to the UK Government by a high-level scientific committee could not find any significant evidence of such adverse effects, nor reasons to expect they will emerge (King 2003). Federoff and Brown (2004) give reasons why that null finding is not surprising from the viewpoint of a molecular biologist.

The welfare calculus in the GTAP model, as in all such models, is also unable to value the welfare impacts of consumers' imagined risk in eating foods that may contain GMOs. The model's incapacity to include this, as the above-mentioned production externalities, is a standard limitation of computable general equilibrium (CGE) models used for trade analysis. It affects the interpretation of the welfare results: they provide a measure of the opportunity cost of not deregulating, which society can then weigh against its subjective valuation of avoiding real or imagined externalities and risks (plus the cost of any research needed to adapt available GM technology to suit ANZ conditions and of preserving the identity of non-GM varieties, net of any recovery of those costs).

2.1 Production

The GTAP simulations reported below recognise the potential for varied national adoption of GM crops. We assume 45 per cent of USA and Canadian coarse grain production is GM (reflecting its share in 2003), while Latin American countries, Australia and New Zealand, if they adopt, are assumed to adopt GM coarse grains at two-thirds the level of the USA (i.e., 30% of their coarse grain production is GM) and all other countries are assumed to adopt GM coarse grains at one-third the level of US adoption (i.e., 15% of their coarse grain production is GM). The latter assumptions reflect the facts that maize, soybean and canola are smaller shares of coarse grain and oilseed production in the countries yet to adopt GM varieties, and that the smaller plot size of fields in all but Australia make the technology less cost-effective because more buffer zoning is required per hectare of GM crop in densely farmed regions. Similarly, we also assume that 75 per cent of oilseed production in the USA, Argentina and Brazil is GM, while Canada, other Latin American countries, Australia and New Zealand adopt at two-thirds the extent of the major adopters and the remaining regions adopt at one-third the extent of the major adopters. These and the following base-case assumptions are arrived at by drawing from a variety of sources including the European Commission (2001) and James (2004).

For rice, major prospective adopters including the USA, China, India and all other Asian countries are assumed to produce 45 per cent of their crop using GM technologies (the same share as GM coarse grain in adopting countries). All other regions, being less rice-intensive, are assumed to adopt at two-thirds this rate (i.e., 30% of their rice crop is GM). GM wheat adoption is assumed to occur to the same extents as assumed for coarse grain adoption in the various regions.

For all four products, the above GM/non-GM proportions assumed to apply to production are assumed to apply also to the other initial relationships in the model's database, such as consumption, intermediate input use, exports and imports.

Having established that initial disaggregation, the model is then used to calculate the effects of output-augmenting, Hicks-neutral farm productivity shocks on the GM crops. Marra *et al.* (2002) present empirical evidence on the positive impacts on yields and profits from adopting GM crop varieties. Following Stone *et al.* (2002), our 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 prospective cases of rice and wheat, a conservative 5 per cent difference is assumed. However, because our sensitivity analysis shows that it makes little difference to the results (see appendix to Anderson and Jackson 2005b), we follow Nielsen and Anderson (2001) and Anderson *et al.* (2002) in assuming that GM technology uniformly reduces the level of primary factors needed per unit of output. This alters the mix of GM and non-GM varieties demanded by consumers (see section 2.2).

Some earlier studies have assumed GM adoption requires the introduction of SIP systems, and have suggested their cost could amount to as much as 15 per cent of the farm-gate price of the GM product (e.g., Burton *et al.* 2002). These costs would be spread along the value chain (see details in Bullock and Desquilbet 2002) and so shared between producers and consumers, including for non-GM varieties; and the fixed cost of their introduction would be amortised. We expect in the steady state that the annual cost would be very small, bearing in mind that SIP systems are not new and are becoming more common as consumers demand ever-greater product differentiation by variety, by quality (for various food safety and environmental reasons) and by place and method of production (Lin *et al.* 2000; Wilson and Dahl 2005). Therefore, we do not include an additional segregation cost in our analysis.

2.2 Structure of intermediate and final household demand

Because consumers' knowledge and acceptance of GM foods varies around the world (James and Burton 2003), we alter the traditional GTAP demand structure. The GTAP model uses a single representative household structure to capture demand effects in each region. In the absence of household differentiation by, for example, GM aversion, the representative household consumes a bundle of products which always includes both GM and non-GM products when both are available. We modified the consumption module of the GTAP model to include a constant-elasticity-of-substitution (CES) nesting of GM and non-GM crops. The representative household chooses first between GM and non-GM products, and then between imported and domestic products. Elasticities of substitution in that first consumption choice, between GM and non-GM varieties of each product, are set reasonably high at 5 in the current GM-adopting countries and in developing countries (where there is little or no SIP), but at 3 in Australia and New Zealand where consumers are more averse to GM foods, and at just 1 in the EU. However, the model structure does not allow us to calculate the loss in welfare to GM-averse consumers who, due to lack of segregation, are denied the choice of consuming non-GM varieties, if GM varieties are allowed in the supply chain. These elasticities alter the proportions of GM and non-GM varieties contained in the composite good and consumed by the representative household but, because the model does not allow segregation, the household demand is expressed as demand simply for a composite good. After choosing the proportion of GM goods in its composite bundle of a particular product such as rice, the household then chooses its preferred proportion of domestic and imported rice. This second consumption choice is governed by the traditional Armington elasticities in the GTAP model.

In the case of intermediate goods producers, such as in the feedmix-livestock industry, they are assumed to choose first between domestic and imported feedstuffs inputs and then between GM and non-GM varieties of the crops concerned. The elasticities of substitution among domestic and imported feed grains or oilseeds are the traditional Armington elasticities. The substitution between the GM and non-GM composite tradables is then determined by the elasticities of substitution among these two varieties, and this contributes to altering the quantities of the GM and non-GM varieties produced away from the initial subdivision of the GTAP model's data into those two groups (described in section 2.1). The final output is produced by combining all other intermediate inputs with the GM/non-GM composite input, according to a Leontief production function.

2.3 Simulations

The simulations reported below are selected from many possibilities to show how different combinations of crop choice, country adoption and policy responses alter economic impacts of GM technologies. Three sets of crop adoption scenarios are considered. The core set, involving just coarse grain and oilseeds for current adopters plus ANZ, is followed by two variations on the core simulations. One is optimistic about the acceptance of GMOs, as it adds extra GM crops and adopting countries. The other is pessimistic, as it considers the consequence of a spread to North-East Asia of the EU's policy of effectively banning imports from GM-adopting countries. The EU moratorium is modelled because the EU is still by far the biggest restrictor of products that may contain GMOs even though it adopted a strict labelling requirement in place of the de facto moratorium in April 2004; and China is included in the North-East Asia moratorium scenario because it had imposed a GM-motivated import restriction on US soybean in 2001 (since relaxed after intense US lobbying).

The first or core set of simulations examines the implications of adoption of GM coarse grains and oilseeds by the USA, Canada and Argentina without and with ANZ also adopting, and without and with an EU moratorium. Although the GTAP model does not disaggregate down to maize, soybean and canola, these three account for most of the coarse grain and oilseed production in the current GM-adopting countries. These three crops are less dominant in Australia and New Zealand, therefore, further investment in adaptive biotechnology research on other coarse grains and oilseeds for ANZ conditions would be required to achieve the same productivity increase in ANZ as in the USA (the cost of which is not included in what follows), which is why we assume only two-thirds the extent of adoption for ANZ as for the first-adopting countries.

These scenarios are then compared to the scenario where all countries of the world adopt GM varieties of these crops, to get an idea of the gross global economic benefits foregone annually because of the reluctance in the EU and elsewhere to embrace this new technology – or, in other words, of the opportunity cost of precaution as practised by those non-adopting countries (Simulations 1a–1e).

GM varieties have been developed for the world's other two major food crops, rice and wheat, to the point where their commercial release would quickly follow if there was a decision by major governments to approve them and there was sufficient evidence that consumers would be willing to buy foods produced with them. The most likely place where those changes might occur is in China, where the government appeared close to reaching an approval decision in 2005 but has again deferred the matter for another year. India is also very actively examining the issue, and would likely soon follow a positive decision by China. The USA and Argentina may well then join in. We therefore ran a second set of simulations to examine the impact of adding GM rice and wheat adoption in North America 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. Paralleling the first set of simulations, there are five scenarios in this set 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–2e).

The other variant on the first set of simulations recognises that the EU policy is tempting other countries to adopt a similar approach to GM food products. A pessimistic scenario from the viewpoint of GM adopters would involve an import moratorium also in North-East Asia. In the third set of simulations we therefore examine the impact of GM adoption of just coarse grains and oilseeds in North America and Argentina in the presence of a GM import moratorium by not only the EU but also China, Japan and South Korea. Again that is run first without and then with ANZ adopting GM varieties of those crops. This pair of scenarios highlights the trade-off for ANZ producers and governments between productivity growth by means of GM adoption and the benefits of remaining GM-free given actual EU and (in this case) assumed North-East Asian reluctance to import crops produced in GM-adopting countries (Simulations 3a and 3b).

These simulations, summarised in Table 1, are clearly only a small subset of possible simulations, but they illustrate major issues relevant to ANZ.

Table 1 Simulation scenarios considered

Simulation	USA, CAN and ARG adopt GM coarse grain and oilseeds	ANZ adopt GM coarse grain and oilseeds	USA, CAN, ARG, China and India adopt GM coarse grain, oilseeds, rice and wheat	ANZ adopt GM coarse grain, oilseeds, rice and wheat	EU bans imports of affected crops from GM adopters	Japan, Korea and China ban imports of affected crops from GM adopters	All countries adopt GM coarse grain and oilseeds	All countries adopt GM coarse grain, oilseeds, rice and wheat
1a	X							
1b	X				X			
1c	X	X						
1d	X	X			X			
1e							X	
2a			X					
2b			X		X			
2c			X	X				
2d			X	X	X			
2e								X
3a	X				X	X		
3b	X	X			X	X		

ANZ, Australia and New Zealand; ARG, Argentina; CAN, Canada; EU, European Union; GM, genetically modified.

3. Results

3.1 Quantity and price effects

To examine the impacts of these various adoption patterns on ANZ agricultural sectors, Table 2 reports the production, price and trade impacts of USA, Canada and Argentina adopting GM varieties of coarse grains and oilseeds without and with the EU moratorium, alongside the same scenarios but with ANZ also adopting those GM varieties (columns 1 and 2 vs columns 3 and 4).

These quantity and price effects resulting from the productivity shock are shown for the weighted average for GM and non-GM varieties, as well as for their component parts – but keep in mind that, in the absence of segmented markets, prices for these varieties are implicit. (On the complexities of modelling the two varieties with SIP even in partial equilibrium, see Sobolevsky *et al.* 2005.)

If ANZ choose not to adopt GM varieties, and there was no EU moratorium, Australia's production and net exports of not only coarse grains and oilseeds but also of meat (and other livestock) products fall, because domestic prices of these products are lowered by the greater competition resulting from the technology shock in the USA (column 1 of Table 2). The same is true for New Zealand, although with smaller orders of magnitude (shown in parentheses in Table 2). The EU, however, has restricted imports of most coarse grain and oilseeds from North America and Argentina because of their GM content, providing greater opportunities for ANZ and other food exporters to supply European markets. When modelled as a ban, that reduces the extent of the reduction in Australian production and net exports of these products but it does not eliminate the negative effect of greater competition from GM adopters abroad. Even for New Zealand, it is barely sufficient to neutralise the production effect of GM adoption abroad because the large percentage export effect is very small in dollar terms (column 2 of Table 2).

If ANZ were to choose to join the GM adopters, Australian coarse grain production would expand instead of contracting and, if there were no EU moratorium, oilseed production would fall much less. Lower domestic prices for these products induce increases in domestic consumption but those increases would not be enough to prevent coarse grain net export earnings from rising instead of falling (compare columns 1 and 3 of Table 2). Oilseed net exports would fall less in the absence of an EU moratorium but not in its presence, should Australia adopt GM varieties not approved in the EU (see second-last row of Table 2).

3.2 National trade balance and net welfare effects

The effect on the aggregate trade balance is positive for ANZ in the absence of the EU moratorium and negative in its presence, in line with the sign of the net impact of the productivity growth and policy response on the global economy. The reduction in that trade balance from adopting GM coarse grain and oilseed varieties would be small, however, no more than $US2 million per year for Australia and less than $US0.5 million for New Zealand, without or with the EU moratorium (compare columns 1 and 3 or columns 2 and 4 of the first two rows of Table 3).

Table 2 Australian (and New Zealand)† production, price and trade impacts, under various genetically modified (GM) adoption and policy response scenarios (percentage changes, weighted average of GM and GM-free varieties)

	USA, CAN and ARG adopt		USA, CAN, ARG and ANZ adopt	
	(and no import bans) *Simulation 1a*	With EU moratorium *Simulation 1b*	(and no import bans) *Simulation 1c*	With EU moratorium *Simulation 1d*
Production volume				
Total coarse grains	*−0.2 (−0.2)*	*−0.1 (0.0)*	*0.4*	*0.2*
Non-GM coarse grains	−0.1 (−0.1)	0.0 (0.0)	−0.8	−1.0
GM coarse grains	−0.5 (−0.2)	−0.4 (−0.0)	3.1	2.9
Total oilseeds	*−3.2 (−0.6)*	*−2.3 (0.2)*	*−0.8*	*−3.7*
Non-GM oilseeds	−0.8 (−0.2)	−0.6 (0.4)	−1.1	−3.8
GM oilseeds	−5.5 (−1.0)	−4.5 (0.0)	−0.6	−3.5
Total meat products	−0.1 (−0.2)	−0.1 (0.0)	−0.1	−0.1
Domestic market prices				
Total coarse grains	*−0.1 (−0.0)*	*−0.1 (−0.0)*	*−1.2*	*−1.2*
Non-GM coarse grains	−0.1 (0.0)	0.0 (−0.0)	−0.1	−0.1
GM coarse grains	−0.1 (0.0)	−0.0 (−0.0)	−3.8	−3.8
Total oilseeds	*−0.1 (−0.0)*	*−0.1 (−0.0)*	*−1.0*	*−1.0*
Non-GM oilseeds	−0.1 (−0.0)	0.4 (−0.0)	−0.1	−0.1
GM oilseeds	−0.1 (−0.0)	0.0 (−0.0)	−2.0	−2.0
Total meat products	−0.0 (−0.0)	−0.1 (−0.0)	−0.1	−0.1
Import volume				
Total coarse grains	*7.0 (2.2)*	*8.0 (2.8)*	*−4.5*	*−3.7*
Non-GM coarse grains	0.1 (0.1)	0.5 (0.4)	−0.9	−0.7
GM coarse grains	9.2 (7.2)	10.3 (8.2)	−4.8	−3.9
Total oilseeds	*6.7 (1.9)*	*8.1 (0.9)*	*2.7*	*3.8*
Non-GM oilseeds	0.2 (−0.1)	1.07 (−1.4)	−0.4	0.24
GM oilseeds	10.3 (4.8)	11.9 (4.4)	4.5	5.8
Total meat products	0.4 (0.7)	0.3 (1.3)	0.3	0.2
Export volume				
Total coarse grains	*−0.1 (0.0)*	*−0.1 (0.0)*	*0.1*	*0.0*
Non-GM coarse grains	0.0 (0.0)	0.0 (0.0)	−0.03	−0.2
GM coarse grains	−0.5 (0.0)	−0.4 (0.0)	1.1	0.9
Total oilseeds	*−2.6 (−0.2)*	*−1.8 (0.4)*	*−0.6*	*−3.0*
Non-GM oilseeds	−0.6 (0.0)	−0.4 (0.3)	−0.6	−3.2
GM oilseeds	−4.5 (−0.3)	−3.3 (0.5)	−0.7	−3.4
Total meat products	−0.1 (−0.2)	−0.1 (0.0)	−0.1	0.0

†New Zealand percentage changes are shown in parentheses. Source: Authors' GTAP model simulation results. ANZ, Australia and New Zealand; ARG, Argentina; CAN, Canada; EU, European Union.

The net economic welfare effects on ANZ and other countries for these scenarios are summarised in the lower part of Table 3. GM coarse grain and oilseed adoption by North America and Argentina benefits those countries despite the deterioration in their terms of trade (see Table 6) as a consequence of their expanded exports, although less so (especially for Canada) in the case where the EU moratorium continues. The EU and the rest of the world also would benefit, by way of improved terms of trade, except in the case of the EU moratorium, which raises EU domestic prices of farm products and thereby attracts more resources into an already heavily protected EU

Table 3 Trade balance and economic welfare effects of genetically modified (GM) coarse grain and oilseed adoption by various countries ($US million per year)

	USA, CAN and ARG adopt		USA, CAN, ARG and ANZ adopt		All countries adopt
	(and no import bans) *Simulation 1a*	With EU moratorium *Simulation 1b*	(and no import bans) *Simulation 1c*	With EU moratorium *Simulation 1d*	(and no import bans) *Simulation 1e*
Change in trade balance					
Australia	8	−3	6	−5	5
New Zealand	2	−1	2	−1	2
Change in economic welfare (equivalent 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
USA	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. ANZ, Australia and New Zealand; ARG, Argentina; CAN, Canada; EU, European Union.

farm sector. Australia is worse off if it does not adopt but better off if it does, the difference for these commodities being (10 – (−4) =) $US14 million per year in the presence of the EU moratorium but (7 – (−9) =) $US16 million if the moratorium were to be removed. New Zealand's measured economic welfare is higher with its adoption too, by $US1–2 million per year. GM adoption by North America and Argentina (with or without ANZ adopting) would benefit the world as a whole by a substantial $US2.3 billion per year if the EU were to impose no barriers to imports of GM products. This represents more than half of the gains that would come from the whole world adopting GM varieties of these products ($US4.0 billion, see final column and row of Table 3), reflecting: (i) the fact that the adopters produce close to half the world's coarse grain and oilseed; and (ii) our assumption that the broadacre nature of production/large farms in the adopting countries ensures GM crops would represent a larger proportion of production there than in the rest of the world.

In the first set of variations on the core simulations, wheat and rice are added to the set of GM crops and China and India are included in the set of GM-adopting countries. That lowers ANZ production, prices and net exports of coarse grain and oilseeds even more than in the first set of simulations (because of greater competition from the expanded supply of wheat and rice), in addition to having negative effects on ANZ wheat and rice markets. The net economic welfare effects of adding these commodities and countries to the crop adoption set are non-trivial. Estimated global economic welfare improves, if there are no trade policy responses, by $US4.3 billion instead of $US2.3 billion per year (compare column 1 in Tables 3 and 4). The USA, Canada and Argentina gain little extra, however, because their productivity gains are almost offset by a worsening of their terms of trade (see Table 6) as a consequence of their additional productivity and of extra global supplies following adoption in China and India. When ANZ do not adopt GM varieties, Australia loses around twice as much in this extended adoption scenario regardless of the EU policy stance while New Zealand loses almost no more (since it produces almost no wheat and rice). If ANZ adopt GM varieties of coarse grains, oilseeds, rice and wheat, Australian economic welfare would improve more than in the coarse grain/oilseed adoption scenario in the absence of the EU moratorium, while New Zealand's would be no different (compare columns 3 in Tables 3 and 4).

In the presence of the EU moratorium, however, Australia's welfare would improve less than in the coarse grain/oilseed adoption scenario (but still improve) while New Zealand's would improve more (compare columns 4 in Tables 3 and 4). The reason for the difference between Australia and New Zealand in that latter comparison is because of the lowered price of wheat and rice in international markets, which alters the terms of trade negatively for Australia but slightly positively for New Zealand (see Table 6). In other words, 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 value Australians place on any adverse environmental effects of GM production (net of any positive environmental and farmer health effects such as from reduced pesticide use) and on knowing they are consuming GM-free food is no more than $US7 per capita per year, and less than 50 US cents per capita for New Zealand (assuming total annual benefits are spread equally among the population).

Table 4 Trade balance and economic welfare effects of genetically modified (GM) coarse grain, oilseed, rice and wheat adoption by various countries (equivalent variation in income, $US million)

	USA, CAN, ARG, China and India adopt		USA, CAN, ARG, China, India and ANZ adopt		All countries adopt
	(and no import bans) *Simulation 2a*	With EU moratorium *Simulation 2b*	(and no import bans) *Simulation 2c*	With EU moratorium *Simulation 2d*	(and no import bans) *Simulation 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
USA	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	3719
World	*4308*	*−892*	*4398*	*−968*	*7506*

Source: Authors' GTAP model simulation results. ANZ, Australia and New Zealand; ARG, Argentina; CAN, Canada; EU, European Union.

Table 5 Economic welfare effects of genetically modified (GM) coarse grain and oilseed adoption by the USA, Canada and Argentina with EU and North-East Asia moratoria (equivalent variation in income, $US million)

	USA, CAN and ARG adopt *Simulation 3a*	USA, CAN, ARG and ANZ adopt *Simulation 3b*
Australia	96	−13
New Zealand	14	16
Argentina	213	214
Canada	−84	−81
USA	427	431
EU-15	−3080	−3164
China	−971	−1323
Japan and Korea	−2552	−2645
Other Asia	117	143
Rest of World	1348	1444
World	*−4471*	*−4977*

Source: Authors' GTAP model simulation results. ANZ, Australia and New Zealand; ARG, Argentina; CAN, Canada.

The above results understate the impact of current EU policies on ANZ and other countries because those policies have encouraged the adoption of GM trade restrictions in other countries. What would be the impact if North-East Asian countries followed the policy example of the EU? This can be seen from Table 5, 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 the incentives for Australia, but not New Zealand, to adopt GM varieties (first two rows of Table 5). The reasons become clear in Table 6. Specifically, row 11 of Table 6 (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 ($US111 million) dominates the negative allocative efficiency impact (−$US15 million), resulting in a net positive welfare outcome ($US96 million). If Australia chooses to adopt and thereby loses access to not just European but also North-East Asian markets (Simulation 3b), the negative terms of trade impact (−$US46 million) overshadows the potential benefits from technical change ($US17 million) and improved allocative efficiency ($US16 million) to yield a net loss of $US13 million per year (row 12 of Table 6). The larger loss for China in this scenario is because Australia would be a major supplier of coarse grain imports by China if North-East Asia were to cease buying from North America, but that trade ceases in the scenario in which ANZ also adopts GM varieties.

The difference for Australia in this case between Simulations 3a and 3b (i.e., between adopting and not adopting in the presence of a broadened moratorium) is thus $US109 million per year. (Our unreported results show that one-fifth of that difference is due to China, the rest to Japan and Korea.) For New Zealand, however, its coarse grain and oilseed industries are too small for GM adoption there to make much difference (compare the final two rows of Table 6).

Table 6 Decomposition of national economic welfare effects due to genetically modified (GM) adoption under various simulations† (equivalent variation in income, $US million)

	National economic welfare decomposition			
	Allocative efficiency impact	Terms of trade impact	Technical change impact	Total impact
Australia				
Simulation 1a	2	−11	0	−9
Simulation1b	3	−6	0	−4
Simulation 1c	3	−16	20	7
Simulation 1d	5	−14	19	10
Simulation 1e	5	−22	19	2
Simulation 2a	4	−22	0	−18
Simulation 2b	6	−15	0	−10
Simulation 2c	4	−38	44	10
Simulation 2d	10	−48	43	5
Simulation 2e	8	−51	43	−1
Simulation 3a	−15	111	0	96
Simulation 3b	16	−46	17	−13
New Zealand				
Simulation 1a	0	−3	0	−5
Simulation 1b	0	1	0	2
Simulation 1c	0	−5	2	−3
Simulation 1d	0	1	2	3
Simulation 1e	0	−7	2	−5
Simulation 2a	0	−6	0	−6
Simulation 2b	0	2	0	2
Simulation 2c	0	−6	4	−3
Simulation 2d	1	1	4	6
Simulation 2e	0	−10	4	−7
Simulation 3a	2	12	0	14
Simulation 3b	1	14	2	16

†See Tables 3–5 for the descriptions of each of the simulations. The welfare decomposition follows Huff and Hertel (2000). Source: Authors' GTAP model simulation results.

In short, the estimated gross pay-off to ANZ from GM adoption is positive in the first two sets of scenarios (the second involving GM adoption by two more large countries and two more crops than is currently the case), but smaller in the presence of the EU restriction on imports. Moreover, if the EU's stance were to encourage North-East Asia also to adopt a moratorium on imports from GM-adopting countries, the pay-off to ANZ from adopting could switch to slightly negative. The net pay-off in terms of national welfare is more likely to be negative, the larger the valuation society places on any perceived adverse environmental and consumer health consequences of GM adoption net of positive environmental and occupational health benefits associated with producing GM as compared with non-GM crops.

4. Caveats

We assume 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 and safe food'. This understates the gains to New Zealand of staying GM-free because if Australia were to allow GM adoption then the demand for food products, in general, from New Zealand may increase at Australia's expense insofar as the two countries are currently seen as close alternative suppliers of 'clean, green and safe food' (and vice versa for Australia if only New Zealand were to adopt).

We assume too that there is no need for SIP through the supply chain to allow consumers to choose between foods with and without GMOs. This means we have overstated the gains to ANZ from GM adoption at home because, given the strict labelling legislation introduced by both countries earlier this decade, a SIP system for domestic crops would have to be used if GM varieties were to be grown locally. However, with SIP cost estimates varying from close to zero to as much as 15 per cent of the crop value, it is not yet possible to judge the extent of that possible overestimation (althought the study by Wilson and Dahl (2005) suggests it is small).

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

Consumer welfare depends on the imagined risk associated with consuming foods that may contain GMOs. A start to modelling this endogenous market failure associated with the introduction of a GM variety is provided by Lapan and Moschini (2004) using a partial equilibrium two-country model, but in our CGE model we have no way of evaluating what that loss of welfare would be when GM products are allowed to be sold in a market.

To date it appears there is no scientific evidence that GM food is unsafe (King 2003), and there is evidence from experimental economics to suggest consumers are less inclined to discount GM foods when given more information about the risks (Lusk *et al.* 2004). Nonetheless, the estimated welfare costs of the EU or ANZ moratoria are overstated to the extent that EU consumers value the knowledge that they have not been consuming food that may contain GMOs.

Likewise, although Wesseler (2005) recently assessed the potential environmental benefits and costs of GM varieties, we do not have enough knowledge of the potential positive and negative effects to incorporate them into our simulation model. As with food safety, though, it would in any case not be sufficient to include them only for GM varieties; they would also need to be included for non-GM varieties to ensure even-handedness.

The technology shocks in our simulations assume a uniform increase in productivity of all factors used in GM crop production. We use that assumption because it turns out to make little difference to the welfare results when it is changed to allow some factors to be saved more than others or some intermediate inputs such as pesticides to be needed less by GM crop varieties.

Finally, and perhaps most importantly, the above comparative static modelling assumes GM technology delivers a one-off increase in farm productivity for that portion of a crop's area planted to the GM varieties. But what is more likely is that, once the GM crops are accepted, there would be an increase in the rate of agricultural productivity growth into the future and adoption rates would rise, so that the present value of future returns from GM adoption may be several times those implied by the numbers shown above. Also dampened by the EU policy stance has been investment in second-generation GM crop varieties that promise enhanced consumer attributes, such as vitamin-enrichment. Recent analysis suggests the consequent welfare benefits of such varieties could well dwarf those evaluated above (Anderson *et al.* 2005).

5. Conclusions

The comparative advantages of Australia and New Zealand 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 ANZ's trading partners alter their consumer, producer and trade policies and as new (GM and non-GM) crop varieties appear. Evidently, plenty of markets for GM crops exist, as the three first GM-adopting countries – the USA, Canada and Argentina – still account for high shares of global exports (80% for maize, 64% for soybean and 42% for canola in 2002). Even so, ANZ's benefits from adoption depend on the extent to which GM products are accepted by consumers at home and by ANZ's current major trading partners, as well as on how well SIP is handled. For that reason, recent debates over whether to approve GM canola production in Australia suggest production is unlikely to be approved until a cost-effective SIP system is in place to allow coexistence of non-GM and GM varieties (Lloyd 2003; Parliament of South Australia 2003). Like New Zealand, all states of Australia (except Queensland) continue to delay approval because they perceive insufficient economic benefit from GM crops to warrant the cost of the necessary coexistence system (which will fall more on non-GM producers, the smaller the share of GM varieties in total output), of the expected loss that would result from a downgrading of their region's status as a 'clean, green and safe food' supplier domestically and abroad, and of insurance to cover the risk of adventitious presence of GM varieties in non-GM crop shipments.

These cautious approaches are understandable while only maize and soybean were ready for adoption, while consumer aversion remained high, and where SIP systems were undeveloped. However, a ban on GM production may be less economically desirable as and when these conditions change, at least for Australia. GM yield-increasing varieties of canola suitable for Australian conditions are now available and two herbicide-resistant ones were approved by the Office of the Gene Technology Regulator in 2004; and new GM wheat varieties also have been developed by CSIRO that are tolerant to drought and some common pests (CSIRO 2003). 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 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 (and in the future on bar codes). Therefore, although the above analysis does not provide strong reasons for removing current ANZ restrictions, the benefit–cost calculus associated with relaxing the moratoria on the commercial release of GM varieties will continue to change over time and so needs to be kept under review.

References

Anderson, K. and Jackson, L. (2005a). *Global Responses to GM Food Technology: Implications for Australia*. Publication No. 05/016, Rural Industries Research and Development Corporation, Canberra.

Anderson, K. and Jackson, L. (2005b). *Standards and Trade: The Case of Genetically Modified Food*. Paper presented at the Economic Policy Meeting of the Centre for Economic Policy Research, Luxembourg, 15–16 April.

Anderson, K., Jackson, L.A. and Nielsen, C.P. (2005). GM rice adoption: implications for welfare and poverty alleviation, *Journal of Economic Integration* 20 (forthcoming).

Anderson, K., Nielsen, C. and Robinson, S. (2002). Estimating the economic effects of GMOs: the importance of policy choices and preferences, in Evenson, R.E., Santaniello, V. and Zilberman, D. (eds.), *Economic and Social Issues in Agricultural Biotechnology*. CAB International, London.

Bullock, D. and Desquilbet, M. (2002). The economics of non-GMO segregation and identity preservation, *Food Policy* 27, 81–99.

Burton, M., James, S., Lindner, R. and Pluske, J. (2002). A way forward for Frankenstein foods, in Santaniello, V., Evenson, R.E. and Zilberman, D. (eds.), *Market Development for Genetically Modified Foods*. CAB International, London.

CSIRO. (2003). Rees' wheat gives more crop per drop. Media Release. Available from URL: http://www.csiro.au/index.asp?type=mediaRelease&id=Prrees&style=mediaRelease [accessed 20 June 2004].

Dimaranan, B.V. and McDougall, R.A. (eds.) (2002). *Global Trade, Assistance, and Protection: The GTAP 5 Data Base*. Center for Global Trade Analysis, Purdue University, West Lafayette.

European Commission (2001). *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: A Synthesis*. European Commission, Brussels.

Fedoroff, N.V. and Brown, N.M. (2004). *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods*. Joseph Henry Press, Washington, DC.

Foster, M. (2001). *Genetically Modified Grains: Market Implications for Australian Grain Growers*. ABARE Research Report 01.10, ABARE, Canberra, August.

Hertel, T.W. (ed.) (1997). *Global Trade Analysis: Modeling and Applications*. Cambridge University Press, New York.

Huff, K.M. and Hertel, T.W. (2000). *Decomposing Welfare Changes in the GTAP Model*. Technical Paper 5, Center for Global Trade Analysis, Purdue University, West Lafayette.

James, C. (2004). *Global Status of Commercialized Biotech/GM Crops: 2004*. International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY.

James, S. and Burton, M. (2003). Consumer preferences for GM food and other attributes of the food system, *Australian Journal of Agricultural and Resource Economics* 47, 501–518.

King, D.K. (2003). *GM Science Review: First Report*. Prepared by the GM Science Review Panel under the chairmanship of Sir David King for the UK Government, London.

Lapan, H.E. and Moschini, G.C. (2004). Innovation and trade with endogenous market failure: the case of genetically modified products, *American Journal of Agricultural Economics* 86, 634–648.

Lin, W., Chambers, W. and Harwood, J. (2000). *Biotechnology: U.S. Grain Handlers Look Ahead*, *Agricultural Outlook*. United States Department of Agriculture, Economic Research Service, Washington, DC.

Lloyd, P.J. (2003). *Review of Market Impacts of Genetically Modified Canola and Industry Preparedness: Report of the Independent reviewer to the Government of Victoria*. Department of Agriculture, Melbourne.

Lusk, J.L., House, L.O., Valli, C., Jaeger, S.R., Moore, M., Morrow, J.L. and Traill, W.B. (2004). Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food, *European Review of Agricultural Economics* 31, 179–204.

Marra, M., Pardey, P. and Alston, J. (2002). The payoffs to agricultural biotechnology: an assessment of the evidence, *AgBioForum* 5, 43–50. Available from URL: http://www.agbioforum.org/v5n2/v5n2a02-marra.pdf [accessed 22 June 2004].

Nielsen, C. and Anderson, K. (2001). Global market effects of alternative European responses to genetically modified organisms, *Weltwirtschaftliches Archiv* 137, 320–346.

Parliament of South Australia (2003). *Select Committee on Genetically Modified Organisms Final Report*. Parliament of South Australia, Adelaide.

Saunders, C. and Cagatay, S. (2003). Commercial release of first-generation genetically modified food products in New Zealand: using a partial equilibrium trade model to assess the impact on producer returns in New Zealand, *Australian Journal of Agricultural and Resource Economics* 47, 233–259.

Sobolevsky, A., Moschini, G.C. and Lapan, H.E. (2005). Genetically modified crops and product differentiation: trade and welfare effects in the soybean complex, *American Journal of Agricultural Economics* 87, 621–644.

Stone, S., Matysek, A. and Dolling, A. (2002). *Modelling Possible Impacts of GM Crops on Australian Trade*. Staff research paper, Productivity Commission, Canberra.

Wesseler, J.H.H. (ed.) (2005). *Environmental Costs and Benefits of Transgenic Crops*. Springer, New York.

Wilson, W.W. and Dahl, B.L. (2005). Costs and risks of testing and segregating genetically modified wheat, *Review of Agricultural Economics* 27, 212–228.