# GM food technology abroad and its implications for Australia and New Zealand [*]

Kym Anderson and Lee Ann Jackson[**]

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[**] Kym Anderson is Professor of Economics at the School of Economics and Executive Director of the Centre for International Economic Studies (CIES) and Lee Ann Jackson is a CIES Research Fellow, both at the University of Adelaide, Australia. Contact is: kym.anderson@adelaide.edu.au

# GM food technology abroad and its implications for Australia and New Zealand (ANZ)


## Abstract

The potential economic benefits from agricultural biotechnology adoption by ANZ need to be weighed against any likely loss of market access abroad for crops that may contain genetically modified (GM) organisms. This paper uses the global GTAP model to estimate effects of other countries' GM policies without and with ANZ farmers adopting GM varieties of various grains and oilseeds. The benefits to ANZ from adopting GM crops under a variety of scenarios are positive even in the presence of the ban on imports from GM-adopting countries by the EU (but not if East Asia also applied such a ban).

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## 1. Introduction

Genetically modified organisms (GMOs) have great potential for the world's farmers and ultimately consumers. Benefits for farmers 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'). Despite those potential benefits, GMOs are attracting a high degree of attention among some consumer and community groups 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 products containing GMOs 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 systems to be used throughout the supply chain.

Exporters of food products fear that they will find customers in food-importing countries discounting or refusing to buy their products if even a subset of their country's farmers adopt GM technology. Indeed the European Union has had a moratorium – in place since October 1998 – on the approval of GM crop varieties 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). So while these GM-adopting countries have benefited in terms of lower production costs,[1] they have lost market share to GM-free suppliers, including Australia in the case of canola.

Food-exporting countries such as Australia and New Zealand (hereafter ANZ) thus need to weigh the potential economic benefits from biotechnology development against any negative environmental risks associated with producing GM crops, any additional costs of segregation and identity preservation through the supply chain 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.[2]

Yet even before that analysis could be done, health ministers in Australia and New Zealand introduced strict regulations concerning GMOs. As from mid-2001, Food Standards Australia New Zealand requires 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 have altered characteristics.[3] This is one of the most rigorous 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. As at end-2003, Australia had approved GM production only of cotton and carnations and, like New Zealand, key State governments have moratoria on GM food crop production in their jurisdiction.

To date there has been very little empirical analysis of the benefits and costs of GMO policies abroad or at home to ANZ crop and livestock producers and the economy generally.

Partial equilibrium studies have been undertaken by Foster (2001) for 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 global GTAP model) for coarse grains and oilseeds in Australia. The present study goes beyond those earlier studies in several respects: among other things, it uses the same general equilibrium GTAP model as Stone et al. but a more recent version of the GTAP database and 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; it examines within the same modelling framework the effects on both Australia and New Zealand without and then with them adopting GM crop varieties; and it looks at effects on not only national economic welfare but also the real net income of farm households in both countries (as distinct from the partial equilibrium notions of producer welfare).

The next section of the paper provides details of the GTAP model of the global economy used to explore production, trade, price and national economic welfare effects. Results are presented in Section 3 for a range of scenarios that vary by types of GM crops, 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. The GTAP model and modifications

The well-received Global Trade Analysis Project (GTAP) model of the global economy is used to provide insights into the effects of GMO technology adoption in some countries without and then with policy responses in other countries. Version 5.4 of the GTAP database, released in late 2003, is used for these applications. It draws on global economic structures and trade flows of 1997. 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).[4] Building on a recent Productivity Commission study (Stone et al. 2002), our modification of the GTAP model captures 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.

## 2.1 Production

In the GTAP simulations reported below we assume 45 per cent of US and Canadian coarse grain production is GM 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 US (i.e. 30 per cent of 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 per cent of coarse grain production is GM). We also assume that 75 per cent of oilseed production in the US, 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. For rice, major prospective 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 are assumed to adopt at two-thirds this rate (i.e. 30 per cent of rice crop is GM). GM wheat adoption is assumed to occur to the same extent as coarse grain adoption for all regions. These base-case assumptions synthesize estimates from a variety of sources including European Commission (2001) and James (2003).

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. 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 prospective cases of rice and wheat, a 5 per cent difference is assumed. This assumes that GM technology uniformly reduces the level of primary factors needed per unit of output.[5] 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.

Some earlier studies have assumed GM adoption requires the introduction of segregation and identity preservation systems, and have suggested they could amount to as much as 15 per cent of the farm gate price of the GM product (e.g., Burton et al. 2002). But in practice such costs may be borne partly by producers of 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 segregation and identity preservation are not new and are becoming more common as consumers demand ever-greater product differentiation by variety, by quality and (for various food safety and environmental reasons) by place and method of production. For those reasons, and because in our policy response simulations we assume countries banning GM supplies exclude imports from GM-adopting countries of both the GM varieties and GM-free substitutes, we do not include segregation and identity preservation costs.

## 2.2 Consumption

Consumer knowledge and acceptance of GM foods varies around the world (Gaskell et al. 1999, MacGarry et al. 2002; James and Burton 2003). 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 varieties of each product in regions where consumers are GM-averse are set at low levels to capture the perceived low degree of substitutability. In 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).

### 2.3 Simulations

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

The first set of simulations examines the implications of adoption of GM coarse grains and oilseeds by the US, Canada and Argentina without and with ANZ also adopting, and without and with an EU moratorium. These scenarios are then compared with all countries of the world adopting GM varieties of these crops, to get an idea of 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, Argentina to their adoption of coarse grains and oilseeds, together with China and India also adopting GM varieties of all four groups of crops. As with the first 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 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 two key Northeast Asian countries (Japan and South Korea), 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***).

## 3. Model results

### 3.1 Volume and price effects

To examine the impacts of these various adoption patterns on ANZ agricultural sectors, Table 1 reports the production, price and trade impacts of US, 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 versus 3 and 4).[6] If Australia chooses not to adopt GM varieties, and all countries treat GM and GM-free varieties as like products, its production and net exports of not only coarse grains and oilseeds but also 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 Americas (column 1 of Table 1). The same is true for New Zealand, although with smaller orders of magnitude (shown in parentheses in Table 1). The EU, however, has banned 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. 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 barely is sufficient to neutralize the production effect of GM adoption abroad (column 2 of Table 1).[7]

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, oilseeds 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 1). Oilseeds net exports would fall less in the absence of an EU moratorium but not in its presence, should Australia adopt GM varieties not approved in the EU (see second-last row of Table 1).

### 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 no more than US$2 million per year for Australia and less than $0.5 million for New Zealand, without or with the EU moratorium (compare columns 1 and 3 or 2 and 4 of the first two rows of Table 2).

The net economic welfare effects on ANZ and other countries for these scenarios are summarized in the lower part of Table 2. GM coarse grain and oilseed adoption by North America and Argentina benefits those countries despite the deterioration in their terms of trade, 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, via 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 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) =) US$14 million per year in the presence of the EU moratorium but (7 – (-9) =) US$16 million if the moratorium were to be removed. New Zealand too is better off by adopting, by $1-2 million per year. GM adoption by these countries (with or without ANZ adopting) would benefit the world as a whole by a substantial US$2.3 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 ($4.0 billion – see final column and row of Table 2), reflecting (a) the fact that the adopters produce close to half the world's coarse grain and oilseed and (b) 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 second set of 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 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 dramatic. Global economic welfare improves, if there are no trade policy responses, by $4.3 billion instead of $2.3 billion per year (compare column 1 in Tables 2 and 3). The US, Canada and Argentina gain little extra, however, because their productivity gains are almost offset by a worsening of their terms of trade as a consequence of their additional productivity and of extra global supplies following China and India's adoption. When ANZ don't 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 2 and 3).

In the presence of the EU moratorium, on the other hand, 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 2 and 3). 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. 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 effects such as reduced pesticide use) is no more than US$7 per capita per year (assuming total annual benefits are spread equally among Australia's population). For New Zealand, however, that figure is less than 50 US cents per capita.

The above results understate the impact of current EU policies on ANZ and other countries because the EU moratorium has encouraged the adoption of GM trade restrictions in other countries. What would be the impact if Northeast Asian countries were to follow the policy example of the EU? This can be seen from Table 4, 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 4). Specifically, row 11 of Table 5 (***Sim 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 (***Sim 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 5).[8] The difference for Australia in this case between Sims 3a and 3b (that is, between adopting and not adopting in the presence of a broadened moratorium) is thus $109 million per year. (One-fifth of that difference is due to China, the rest to Japan and Korea.)

For New Zealand, by contrast, its coarse grain and oilseed industries are too small for GM adoption there to make much difference (compare the final two rows of Table 5).

In short, the payoff 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),[9] but if the EU does not effectively remove its moratorium, that gain to ANZ is smaller. Moreover, if the EU's stance were to encourage Northeast Asia also to adopt a moratorium on imports from GM-adopting countries, the payoff to ANZ from adopting could switch to slightly negative.

### 3.3 Real net farm household income effects

These net national welfare gains are the sum of the effects for food producers and consumers, 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 ANZ? To estimate them, we assume ANZ 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 ANZ 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 5.

In no cases are these effects 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 and even less in New Zealand. 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 ANZ farmers would be slightly worse off from adopting versus not adopting GM crops, implying that ANZ 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.[10] The difference is especially marked in the case where Northeast Asia copies the EU moratorium: in that scenario, Australian farm households would be 0.8 per cent better off if they do not adopt GM coarse grain and oilseed varieties but 1 per cent worse off if they do (rows 11 and 12 of Table 5).

## 4. Caveats

The myriad assumptions that are necessary to run the above simulation experiments make the inclusion of systematic sensitivity analysis impractical in a journal-length paper. But several key assumptions should be kept in mind. 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'.[11]

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.[12] On the other hand, it also 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 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 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 unlikely 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, our technology shocks assume a uniform increase in productivity of all factors used in GM crop production. It makes little difference to the results when that assumption is changed to allow some factors to be saved more than others; but we have underestimated the shock in so far as we have not also assumed productivity growth in the use of some intermediate inputs such as pesticides.

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.

## 5. What should Australia and New Zealand do?

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 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, ANZ's benefits from adoption depend on the extent to which GM products are accepted by ANZ'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 (including the EU and ANZ). 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.

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, a ban on GM production will be less defensible as and when 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 ANZ 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 research that will tend to be slower and hence less rewarding. Apart from farmers, that could be costly to ANZ consumers, as well as to ANZ's biotechnology industry which is a potential export earner in its own right. Indeed the longer domestic governments restrict GM crop production, the more ANZ 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 ANZ rural R&D agencies to ensure a portion of their portfolio includes the development of GM technologies appropriate to local conditions so that, when markets become more accepting, those technologies can be produced and disseminated relatively promptly.

## References

Australia Food, Forestry, and Agriculture (AFFA) 2003, *Australian Food Statistics 2003*, Canberra: Agriculture Forestry and Fisheries Australia.

Anderson, K. and Jackson, L. 2003, 'Standards, Trade and Protection: The Case of GMOs," paper presented at a World Bank seminar, Washington, DC, 2 October.

Anderson, K. and Jackson, L. 2004, *Global Responses to GM Food Technology: Implications for Australia,* Canberra: Rural Industries Research and Development Corporation (forthcoming).

Anderson, K. and Nielsen, C.P. 2001, 'GMOs, Food Safety and the Environment: What Role for Trade Policy and the WTO?' pp. 61-85 in G.H. Peters and P. Pingali (eds.), *Tomorrow's Agriculture: Incentives, Institutions, Infrastructure and Innovations*, Ashgate, Aldershot.

Anderson, K., Nielsen, C.P., and Robinson, S. 2002, 'Estimating the Economic Effects of GMOs: the Importance of Policy Choices and Preferences,' Ch. 20 in *Economic and Social Issues in Agricultural Biotechnology*, edited by R.E. Evenson, V. Santaniello and D. Zilberman, London: CAB International.

Armington, P.A. 1969, 'A Theory of Demand for Products Distinguished by Place of Production', *IMF Staff Papers* 16: 159-178.

Burton, M., James, S., Lindner, R. Pluske, J. 2002, 'A Way Forward for Frankenstein Foods', Ch. 1 in *Market Development for Genetically Modified Foods*, edited by V. Santaniello, R.E. Evenson and D. Zilberman, London: CAB International.

CSIRO 2003, Rees- More crop per drop. Media Release www.csiro.au/index/.

Dimaranan, B.V. and McDougall, R.A. 2002 (eds.), *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,* Brussels: European Commission.

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

Foster, M., Berry, P. and Hogan, J. 2003, *Market Access for GM Products: Implications for Australia*, ABARE eReport 03.13, Canberra: ABARE, July.

Gaskell, G., Bauer, M.W., Durant, J. and Allum, N.C. 1999, 'Worlds Apart? The Reception of Genetically Modified Foods in Europe and the U.S.,' *Science* 285: 384-87.

Harrison, W.J., Horridge, J.M. and Pearson, K.R. 1996, 'Decomposing Simulation Results with Respect to Exogenous Shocks', Working Paper No. IP-73, Centre of Policy Studies and the IMPACT Project, Monash University, May.

Harrison, W.J. and Pearson, K.R. 1996, 'Computing Solutions for Large General Equilibrium Models Using GEMPACK', *Computational Economics* 9: 83-172.

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

Isaac, G.E. and Kerr, W.A. 2003, 'Genetically Modified Organisms and Trade Rules: Identifying Important Challenges for the WTO', *The World Economy* 26(1): 29-42, January.

James, C. 2003, *Global Review of Commercialized Transgenic Crops: 2002* (Preview), 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(4): 501-18, December.

Lusk, J.L., Roosen, J. and Fox, J.A. 2003, 'Demand for Beef from Cattle Administered Growth Hormones or Fed Genetically Modified Corn: A Comparison of Consumers in France, Germany, the United Kingdom, and the United States', *American Journal of Agricultural Economics* 85(1): 16-29, February.

McGarry W., Domegan, M. and Domegan, C. 2002, 'A Comparison of Consumer Attitudes Towards GM Food in Ireland and the United States: A Case Study over Time', Ch. 2 in *Market Development for Genetically Modified Foods*, edited by V. Santaniello, R.E. Evenson and D. Zilberman, London: CAB International.

Mendenhall, C.A. and Evenson, R. 2002, 'Estimates of Willingness to Pay a Premium for Non-GM Foods: A Survey', Ch. 5 in *Market Development for Genetically Modified Foods*, edited by V. Santaniello, R.E. Evenson and D. Zilberman, London: CAB International.

Nielsen, C. and Anderson, K. 2001, 'Global Market Effects of Alternative European Responses to Genetically Modified Organisms,' *Weltwirtschaftliches Archiv* 137(2): 320-46, June.

Parliament of South Australia 2003, *Select Committee on Genetically Modified Organisms Final Report,* Adelaide: Parliament of South Australia, 17 July.

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(2): 233-59, June.

Sheldon. I. and Josling, T. 2002, ‘Biotechnology Regulations and the WTO’, IATRC Working Paper #02-2, University of Minnesota, January. Downloadable at www.iatrcweb.org

Stone, S., Matysek, A., and Dolling, A. 2002, *Modelling Possible Impacts of GM Crops on Australian Trade*, Staff Research Paper, Canberra: Productivity Commission.

USDA (2003), *Brazil Oilseeds and Products Annual 2003,* FAS GAIN Report BR2023, Washington, DC: US Department of Agriculture, April.

van Meijl, H. and van Tongeren, F. 2002, ‘International Diffusion of Gains from Biotechnology and the European Union’s Common Agricultural Policy,’ Paper presented at the 5th Annual Conference on Global Economic Analysis, Taipei.

Table 1: Australian (and New Zealand)[a] production, price and trade impacts, under various GM adoption and policy response scenarios

(percentage changes, weighted average of GM and GM-free varieties)

| | US, CAN, and ARG adopt | | US, CAN, ARG, and ANZ adopt | |
|---|---|---|---|---|
| | Without trade policy response | With EU moratorium | Without trade policy response | With EU moratorium |
| | ***Sim 1a*** | ***Sim 1b*** | ***Sim 1c*** | ***Sim 1d*** |
| **Production volume** | | | | |
| Coarse grains | -0.2 (-0.2) | -0.1 (0.0) | 0.4 | 0.2 |
| Oilseeds | -3.2 (-0.6) | -2.3 (0.2) | -0.8 | -3.7 |
| Meat products | -0.1 (-0.2) | -0.1 (0.0) | -0.1 | -0.1 |
| **Domestic market prices** | | | | |
| Coarse grains | -0.1 (-0.0) | -0.1 (-0.0) | -1.2 | -1.2 |
| Oilseeds | -0.1 (-0.0) | -0.1 (-0.0) | -1.0 | -1.0 |
| Meat products | -0.0 (-0.0) | -0.1 (-0.0) | -0.1 | -0.1 |
| **Import volume** | | | | |
| Coarse grains | 7.0 (2.2) | 8.0 (2.8) | -4.5 | -3.7 |
| Oilseeds | 6.7 (1.9) | 8.1 (0.9) | 2.7 | 3.8 |
| Meat products | 0.4 (0.7) | 0.3 (1.3) | 0.3 | 0.2 |
| **Export volume** | | | | |
| Coarse grains | -1.0 (-0.9) | -0.8 (18.8) | 2.0 | 0.7 |
| Oilseeds | -4.6 (-4.1) | -3.3 (23.7) | -1.1 | -6.0 |
| Meat products | -0.3 (-0.4) | -0.3 (4.3) | -0.3 | -0.2 |

[a] New Zealand percentage changes are shown in parentheses

Source: Authors' GTAP model simulation results.

Table 2: 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** (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 |
| 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

Table 3: 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 | 3719 |
| **WORLD** | **4308** | **-892** | 4398 | -968 | **7506** |

Source: Authors' GTAP model simulation results

Table 4: 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<br>***Sim 3a*** | US, CAN, ARG, plus ANZ adopt<br>***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 |
| Japan and Korea | -2552 | -2645 |
| Other Asia | 117 | 143 |
| | | |
| Rest of World | 1348 | 1444 |
| | | |
| **WORLD** | **-4471** | **-4977** |

Source: Authors' GTAP model simulation results

Table 5: Decomposition of national economic welfare effects and change 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** | |
| **Australia** | | | | | |
| ***Sim 1a*** | 2 | -11 | 0 | **-9** | **-0.05** |
| ***Sim1b*** | 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** |
| **New Zealand** | | | | | |
| ***Sim 1a*** | 0 | -3 | 0 | **-5** | **-0.05** |
| ***Sim1b*** | 0 | 1 | 0 | **2** | **0.01** |
| ***Sim 1c*** | 0 | -5 | 2 | **-3** | **-0.10** |
| ***Sim 1d*** | 0 | 1 | 2 | **3** | **-0.07** |
| ***Sim 1e*** | 0 | -7 | 2 | **-5** | **-0.35** |
| ***Sim 2a*** | 0 | -6 | 0 | **-6** | **-0.02** |
| ***Sim 2b*** | 0 | 2 | 0 | **2** | **0.01** |
| ***Sim 2c*** | 0 | -6 | 4 | **-3** | **-0.11** |
| ***Sim 2d*** | 1 | 1 | 4 | **6** | **-0.08** |
| ***Sim 2e*** | 0 | -10 | 4 | **-7** | **-0.18** |
| ***Sim 3a*** | 2 | 12 | 0 | **14** | **0.07** |
| ***Sim 3b*** | 1 | 14 | 2 | **16** | **-0.01** |

[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

[1] 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 them are grown in Argentina, Canada and the United States, where that GM share is more than 60 per cent (James 2003).

[2] Australia and New Zealand also have a stake 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. These WTO issues are not discussed in this paper but are in Anderson and Nielsen (2001). See also Shendon and Josling (2002) and Isaac and Kerr (2003).

[3] 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.

[4] 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). Welfare decomposition follows Harrison, Horridge and Pearson (1999).

[5] 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).

[6] Separate simulations of first Australia and then New Zealand adopting showed that each country is too small in global food markets to significantly affect the other's production, trade and welfare, so we only report their combined adoption in simulations 1c and 1d (and 2c, 2d and 3b, below).

[7] The positive trade effect is very small in dollar terms because it is from a tiny base.

[8] 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.

[9] These results, and those in the sub-section to follow, are not dissimilar to those from earlier partial equilibrium studies (Foster 2001, Saunders and Cagatay 2003) and a more-limited CGE study by Stone et al. (2002).

[10] Australian consumers do this implicitly already through taxpayer matching of farmer R&D levies that jointly fund Australia's rural research and development corporations.

[11] 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'.

[12] Whether in fact we have overstated the welfare cost of the moratoria for GM-adopting countries depends also on the extent (if any) to which GM adoption for some crops has reduced sales revenue from other crops because of tainting the GM-adopting country's generic 'clean, green, safe food' image.