The Implications of GMOs for Australian Trade

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Abstract

The introduction of genetically modified crops can affect international trade in a number of ways. Prior studies have focussed on the effects of higher productivity of GM crops and on differences in consumer attitudes across regions. This study builds on this earlier work by including the costs of actual or proposed regulation in different regions. It analyses two crops (grains and oilseeds), using working assumptions about productivity gains, consumer attitudes and costs of regulation. Under these assumptions, welfare increases in the major GM crop producing regions. Small GM-producing regions, such as Australia and New Zealand, experience welfare declines linked to terms of trade deterioration.

Key words: GMOs, Australia, trade, regulation

JEL codes: O3, F13, Q17, C68

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I Introduction

The rapid adoption of genetically modified (GM) crops has raised considerable debate in Australia and overseas. Much of this debate has been driven by concerns over the potential for adverse effects including reduced food safety, harm to the environment, less consumer choice, and the potential for further concentration in agricultural and food markets. In several countries, these concerns have contributed to consumer resistance to GM crops, and encouraged governments to introduce new regulatory regimes.

The potential on-farm benefits offered by GM crops, such as reduced use of conventional pesticides, more convenient and flexible crop management, and higher productivity and net returns have driven GM adoption (James 2001b). Processed GM ingredients are now used in many common food items around the world, such as bread, potato chips and cooking oils, as well as in animal feed.

Not surprisingly, questions are being asked in Australia about how the global trading of GM crops is likely to affect Australia's trade flows. Uncertainty over consumer and regulatory responses worldwide, and the size of on-farm benefits from GM crops has made answering such questions particularly challenging.

In an attempt to shed light on possible answers to these questions, this paper modifies the standard global general equilibrium model GTAP (Global Trade Analysis Project) to examine a subset of traded commodities and regions under one particular set of assumptions. This set represents one of any number of scenarios that can be made concerning the potential impact of GM technology on global trade. The paper presents early indications of possible trade movements in two major GM crops — oilseeds and grains — focusing on potential outcomes for Australia. A single period timeframe is analysed using the 1997 GTAP database.[2]

Current adoption worldwide

In 2001, GM crops were grown by approximately 5.5 million farmers in 13 countries and covered a global area of 53 million hectares (James 2001a), or around 4 per cent of the world's agricultural land (James 2001b; Anderson and Nielsen 2001). This represents more than a 30 fold increase in the 1.7 million hectares grown with GM crops in 1996 (Figure 1). Between 2000 and 2001, the area planted with GM crops increased 19 per cent — despite consumer concerns in some markets. Figure 1 shows the growth in the 4 main GM crops, with much of this growth being driven by significant uptake of GM soybeans.

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[1] This paper is part of a larger research project currently under way which will provide a more detailed discussion of the issues presented in this paper. The results will be published in a forthcoming staff research paper.

[2] GTAP is a multi-regional computable general equilibrium model. See Hertel (1997) for documentation of the model and its underlying theory and Dimaranan and McDougall (2002) for the database details.

Although the global area planted with GM crops continued to increase in 2001, there are signs of an easing in the growth of adoption of GM corn and canola. Plantings in 2000 and 2001 were lower for both these crops compared with previous years, largely reflecting declines in North America. It has been suggested that such a slowdown may reflect both problems with consumer acceptance in some markets and poorer than expected agronomic performances (Foster 2001). However, James (2001b) notes that plantings of both GM and non-GM canola fell in 2000, thus it may not be inferred that this decline was specific to GM varieties.[3] Worldwide, GM varieties represented 14 per cent of the global area grown with canola in 1999, falling to 11 per cent in 2000 and 2001. In the case of corn, the percentage of total area planted with GM varieties fell marginally between 1999 and 2001 from 8 per cent to 7 per cent.

The situation in Australia

Farming contributes significantly to the Australian economy. It accounts for around 2.6 per cent of Australia's GDP, and approximately 18 per cent of Australia's total exports (ABARE 2001). Cereal grains and products alone generated just over 3.5 per cent of Australia's total exports of goods and services in 2000-01 (ABARE 2002). Moreover, grains and oilseeds have been an expanding part of Australia's agricultural production, with the area grown increasing from 14.3 million hectares to around 21 million hectares between 1991-92 and 2000-01 (Connell, Barret and Andrews 2001).[4]

Of the four major GM crops, Australia is a major grower of cotton and canola. Together, canola and cotton represented almost 20 per cent of the gross value of Australia's total principal crop production in 2000 (ABS 2001). Australia grows smaller amounts of corn and soybeans, representing only 0.56 per cent and 0.33 per cent of Australia's total principal crops by gross value.

To date, only four licences for the commercial release of GM plants have been granted in Australia. These licences are for two varieties of cotton and two varieties of carnations.[5] In 2001, 33 per cent of Australia's cotton crop was GM (the maximum allowed under requirements specified by the National Registration Authority).[6] While no applications for commercial releases of other GM crops are currently before Australian regulators, over 100 field trails have been approved. In addition to wheat, barley and sugarcane, field trials cover a range of crops including field peas, potatoes, lupins, pineapples and apples.

Public opinion and policy responses

Numerous surveys have been conducted to try to assess community opinions about GM crops and related products, and perceptions of their potential risks and benefits. Overall, findings on the acceptance or otherwise of GM crops have varied considerably. In the EU, Australia and Japan, in

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[3] In North America the total area harvested for canola (rapeseed) fell around 9 per cent from 1999 to 2000, and again by almost 18 per cent between 2000 and 2001 (FAO 2002).

[4] Grains and oilseeds include wheat, barley, oats, triticale, maize (corn), sorghum, rice, lupins, field peas, chickpeas, peanuts, canola, sunflower seed, soybeans, linseed and safflower seed (ABARE 2002).

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

[6] These regulations have been introduced by the NRA to restrict the development of pesticide resistance in insect populations.

particular, the balance of results suggests considerable suspicion and concern surrounding GM food (EC 2000; Foster 2001; Portmann and Tucek 2001).

Survey results can often change over time, however, as consumer preferences change. As such, they may not be a good barometer of actual or future behaviour. Indeed, despite many surveys indicating consumer resistance to GM food, there is to date only patchy evidence of price premiums emerging in markets for non-GM varieties. This may suggest that the strength of consumer aversion to GM products may not be as high as some surveys indicate (although a lack of premiums may reflect extensive supplies of non-GM products reducing upwards pressure on non-GM prices). Gauging the strength of consumer concern over GM crops in such an environment can therefore be very difficult.

Community concerns have been strong enough, however, to encourage a number of governments to introduce specific regulatory arrangements for GM products. In Australia, the Office of the Gene Technology Regulator (OGTR) was introduced in June 2001 under the *Gene Technology Act 2000* and a new labelling regime for GM foods came into effect in December 2001. The OGTR oversees the development, trial and release of GMOs not covered by other agencies.[7]

Food safety is regulated (jointly with New Zealand) by the Australia New Zealand Food Authority (ANZFA). Standard A18 regulates the sale of foods and food ingredients (other than additives and processing aids), which are produced using gene technology. Regulations require a safety assessment before the release of such foods, and also stipulate labelling requirements. Current standards for labelling allow a one per cent threshold for unintended presence of GM product.

In the international arena, there have been, broadly, two principal approaches applied to the regulation of GM commodities: 1.) the use of existing food safety regulations, and 2.) the introduction of additional legislation. The US, Canada and Argentina are examples of the former approach, while the EU, Australia and New Zealand are examples of the latter.

Currently, the European Union maintains a de facto moratorium on the authorisation of new releases of GMOs and requires the mandatory labelling of GM products, allowing a 1 per cent ‘accidental’ presence of GM product. New Zealand has imposed a two year moratorium on the new release of GM products, but has allowed field trials to continue. Japan’s labelling requirements allow a five per cent limit on unintended presence while South Korea has a three per cent limit. In China, rules have been introduced to expand controls over GM crops before they can be released commercially.

The differences in policy approaches have raised considerable international debate and, in some circumstances, threatened trade disputes. Falling under several international agreements — for example, Sanitary and Phytosanitary Agreement (SPS), Technical Barriers to Trade Agreement (TBT), and the Biosafety Protocol— there is broad concern that GM technology could provide new mechanisms for protectionist measures. Regulations could potentially restrict access to markets and some developments, such as labelling of GM foods, have added to consumer pressure for the segregation and traceability of GM and non-GM crops. Changes in the supply chain to manage such segregation and labelling will inevitably add to industry costs (most likely for both GM and non-GM producers) and thus impact on relative competitive positions across markets.

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[7] For example, the development of genetic material for use in pharmaceuticals is regulated by Therapeutic Goods Administration (TGA).

Aim of this paper

The fluid nature of both consumer and regulatory developments worldwide regarding GM technology, and its use in food, raises important questions for policy makers and agricultural producers in Australia. How sensitive, for example, is Australia's agricultural trade to changing regulatory and consumer responses overseas? What overall impact can be expected from GM crops when economy-wide effects and adjustments are taken into account? Analysing these issues can provide useful insights for policy makers as they weigh up the costs and benefits of alternative policy options and engage in international negotiations. It can also assist in informing community opinion more broadly.

This paper aims to provide an initial quantitative assessment of possible short term trade implications for Australia from the global trade of GM foods under certain domestic and international regulatory and consumer responses. In doing so, the paper contributes to existing work on modelling the trade impacts of GM foods by focusing more specifically on Australian, as opposed to international, impacts and by including estimates of regulatory costs.

The paper does not, however, specifically address a number of other 'non-trade' issues relating to GM crops that are also important in terms of the economic and non-economic welfare of Australians. Issues concerning consumer choice, the ethical and environmental implications of GM food production, and intellectual property rights are examples. The analysis in this paper should therefore be seen as a useful *component* of what needs to be a broad analysis of all the costs and benefits associated with production of GM crops in Australia.

Moreover, the results presented in this paper should be interpreted with caution. The scenarios undertaken represent only one possible combination of a range of feasible scenarios that could be analysed for GM productivity gains, consumer response and regulatory costs. The paper provides a first step toward a broader and more comprehensive analysis of potential scenarios to be undertaken in a forthcoming research report.

II Evidence of the impact of agricultural GM technology

Productivity gains

The estimates of productivity gains to GM crops incorporated into the model are based on a number of studies that have reviewed the on-farm performance and effects of GM crops across several countries.[8] Studies by Nielsen, Thierfelder and Robinson (2001) and Foster (2001), for example, employed productivity estimates of 10 per cent. However, despite the usefulness of the estimates provided in these studies, some general limitations need to be noted. First, many studies have focused on only one or two factors affecting net on-farm benefits, such as impacts on yields and/or chemical use, with few studies investigating net effects or net profits from farm adoption of GM crops.

Second, many studies have covered periods of only one or two years, with the long term effects of GM crops less well known. EC (2000), for example, noted that many of the studies it reviewed only

[8] Examples include Carpenter and Gianessi (2001); Duffy and Ernst (1999); Huang et al (2001) and EC (2000).

assessed short-term profitability, thus ignoring important yearly fluctuations in yields and prices of inputs.

Third, potential farm benefits and costs that are not ‘productivity’ related, and therefore not necessarily measured in the studies examined, can also impact in a non-trivial way on farm decision making. For example, production of GM crops has been associated with reduced exposure to agricultural chemicals which may lower the private costs farmers face in producing a given amount of output. In China, survey data found that 22 per cent of farmers producing non-Bt cotton reported symptoms such as headaches or nausea after applying pesticides, compared to only 4.7 per cent for Bt cotton growers (Huang et al 2001).

Many studies do not account for the ‘convenience’ or management flexibility effects of GM crops (EC 2000, Furtan and Holzman 2001). These ‘convenience’ effects can include reduced machine movements from fewer herbicide applications, greater flexibility in the timing of herbicide applications and earlier adoption of no-till or conservation tillage. Duffy and Ernst (1999) note a farmer survey showing 12 per cent of farmers chose to adopt GM soybeans due to planting flexibility. It has also been suggested that these ‘non-productivity’ related benefits explain the considerable expansion in the use of some GM crops in the United States, for example, since the mid 1990s (ERS 2000). Environmental factors were also the main driving force behind the use of GM Ingard Bt cotton in Australia for the 1999-2000 growing season (Cotton Research and Development Cooperation 2000).

However, given that calculating the economic benefits of these flexibility or ‘convenience’ factors is difficult, many assessments to date may undervalue the benefits farmers receive from some GM crops. That said, additional management precautions often associated with GM crop use, such as controlling the spread of GM plants, restricting the development of herbicide resistant plants, and the treatment of land post-GM planting, adds uncertainty to the net effect of these labour and management flexibility factors in the long term (Furtan and Holzman 2001).

Finally, benefits and costs that do not enter farm decision making (so called ‘externalities’), are also excluded from the above estimates of on-farm gains. Examples can include potential impacts on off-farm water flows or downstream pollution arising from farmers using more or less water or chemicals in response to particular GM crop characteristics. A recent ERS Agricultural Research Service (2001) study reported that run-off water from fields planted with Bt cotton in Mississippi was virtually free of insecticide during a four year study. The House of Representatives Standing Committee on Primary Industries and Regional Services (2000) also noted that reduced insecticide use for Bt cotton in Australia has reduced the likelihood of contaminating cattle on neighbouring properties with endosulphan, which had led to their rejection by export markets in previous years.

Even though there have been a large number of studies on the performance of GM crops, the evidence to date is neither comprehensive nor compelling in many areas. However, the evidence does provide some initial indication of the likely nature and magnitude of effects of GM crops on the supply side. Overall, some of the main messages that can be gained from reviewing the evidence include:

- mixed productivity results across GM crops, with:
  - lower yields for herbicide tolerant soybeans, offset by lower herbicide costs, with profits not showing significant changes;
  - variable yield results for herbicide tolerant canola, but some evidence of net gains;

  - higher yields for insect resistant cotton along with declining pesticide use and some evidence of net economic benefit. Yields and net effects for herbicide tolerant cotton show considerable variation; and
  - higher yields for insect resistant corn, although no trend of significantly higher profits;
- considerable variability in effects across regions; and
- variability in effects depending on growing conditions.

Estimates of average expected on-farm effects from the use of GM crops are made based on the balance of evidence available (acknowledging the above mentioned limitations). While recognising that regional differences in GM crop performance can be significant, the macro and international scale of the modelling work in this paper make it impractical to incorporate spatially differentiated on-farm benefits. The GM adopting sectors are therefore assumed to experience average increases in total factor productivity of 7.5 per cent in grains and 6 per cent in oilseeds. These working assumptions on productivity gains are held fixed throughout the paper to provide a base by which to compare the additional effects of consumer resistance and regulatory costs.

Consumer demand surveys

Consumer demand and the degree to which GM crops are accepted in society will be key determinants of the success of GM products. Without favourable demand conditions, many potential GM developments may be thwarted. Societal responses to GM foods will be important in establishing governments' policies on GM crops, which in turn will affect Australia's international trade (RIRDC 2001).

Survey data published by ERS (2001b) provides a good cross-section of studies and illustrates the variance in consumer response to several GM food issues both across time and across countries. This data indicates greater acceptance of GM food technology where it is used specifically to improve foods and shows that consumer resistance is lower where a direct benefit from consumption is easily identifiable. Consumer response to GM food crops has also been correlated to community trust in the prevailing regulatory body (RIRDC 2001).

Consumer attitudes to GM foods vary greatly between countries. Survey data indicates that US consumers have the most relaxed views about the use of biotechnology in food production. By contrast, European consumers appear more cautious toward GM food, and this view has been strengthening over time (ERS 2001b).

Survey results presented at the Annual Canadian Canola Convention 2000 found that of the 80–95 per cent of Europeans who have some awareness about GM food issues, 60–80 per cent hold a negative view about the trend towards GM crops. Corresponding figures for Japan (which is a significant importer of Australian agricultural produce) show a level of awareness of 97 per cent, with over 80 per cent expressing a negative attitude toward GM crops (Portmann and Tucek 2001).

Consumer attitudes to GM foods in Australia have been changing over time. Surveys undertaken by Biotechnology Australia in 1998 and 2001 suggest there may be a softening of resistance to GM food. They report that from 1998 to 2001, Australians' attitudes changed from around 25 per cent willingness to eat GM foods to almost 50 per cent willingness (Biotechnology Australia 2001). Another survey found that those amenable to buying GM foods if it tasted better rose from 41 per cent in 2000 to 51 per cent in 2002 (Biotechnology Australia 2002).

Observed price differences between GM and GM-free foods

Reviewing behavioural and price differences between GM and non-GM crops gives a less negative representation of consumer response to agricultural biotechnology, yet even revealed preference information is ambiguous. On the one hand, ERS (2000) has reported that demand for non-GM maize and soybeans in the US is very limited, and there is only patchy evidence of price premiums for non-GM grains and oilseeds. This suggests that negative attitudes to GM food crops may not have affected purchasing decisions. However, this may be because, as stated above, there is still a considerable supply of non-GM products for most crops (except perhaps soybeans), so scarcity of non-GM crops and associated price rises have yet to materialise. Moreover, US consumers have not expressed the same level of concern regarding GM crops that has been witnessed elsewhere. On the other hand, consumers in Japan and Korea have been reported as paying price premiums for corn from countries other than the US, so as to avoid contaminated StarLink corn.

Overall, evidence suggests that consumers in such regions as the EU, and countries like Australia, Japan, South Korea and New Zealand, would show resistance to the consumption of GM goods under all circumstances. Therefore, in modelling consumer response, a 25 per cent reduction in potential demand for GM crops was assumed to apply to these regions, with replacement by non-GM varieties to maintain the overall share of grains and oilseeds in consumption.

Costs of regulating the research and application of GM crops

There are a number of costs associated with meeting regulatory requirements for approval for the release of GM crops into the environment and their subsequent use in the food supply. Many of these are met by the developers or promoters of GM crop seeds such that these costs are generally reflected in the seed prices and technology fees paid by farmers. These seed and technology costs were, in general, considered in determining the productivity gains for GM crops.

Labelling the GM status of agricultural products is currently being driven by government regulations covering GM products, and consumer demand for information. Thus, there is a need to verify the origin of food ingredients to determine their GM status. Segregation and identity preservation (IP) are ways of providing this verification. The EC (2000), for example, argues that for consumers to have confidence in labelling systems, there is a need for segregation of products throughout the processing system, and IP to distinguish products according to GM content and whether GM technology has been used in the production process. GrainCo (Planet Ark 2002) have argued that such a system is essential if Australian exporters want to retain the trust of their markets.

Segregation alone refers to keeping specific crops or products apart. It does not necessarily involve traceability along the supply chain. IP, however, refers to systems of crop and product management which allow the source or nature of crops and products to be identified along the entire supply chain. Segregation and identity preservation (SIP) therefore allows buyers to verify the grade, variety or type of product they prefer. SIPs and related labelling are not new or unique to GM crops. They are already used (at different levels of sophistication) to distinguish different grades of commodity crops and higher value varieties (such as high erucic acid rapeseed grown for technical applications and flint corn for breakfast cereals (EC 2000)).

In the case of GM crops, SIPs are designed to prevent the accidental mixing of GM and non-GM crops, depending on crop type, via:

- ‘gene flow’ from GM to non-GM crops due to pollen dispersal and cross pollination; or
- inadequate separation of GM and non-GM crops or products during harvesting, processing, transport or distribution (South Australia 2001).

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

SIPs for GM and non-GM crops will therefore introduce new costs to agricultural systems as most agricultural products are at present traded through a bulk commodity system. The size of these additional costs, however, will depend on the crop concerned, the volume of production going through SIP systems and, importantly, the threshold level of contamination accepted. It is expected that costs will increase exponentially rather than linearly for tolerance levels approaching zero per cent (EC 2000).

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

The size of SIP costs has been estimated in a number of studies (Buckwell et al 1999; Bullock et al 2000; ERS 2000). Many of these have focused on the costs of segregating non-GM from GM crops in order for U.S. suppliers to sell products to export markets such as the EU. Buckwell et al (1999), for example, gives a number of examples of SIP costs for different products under different SIP arrangements. They find, where tolerances of GM residue were between 0.1 – 1 per cent, additional costs were approximately 10 per cent of farm gate prices. They suggest that this 10 per cent cost increase is probably the most likely estimate of the additional costs of SIP, given that the direction of most labelling regulation is to allow up to 1 per cent tolerance of GM material.

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

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

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

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

For the purposes of this report, regions were broken into three categories based on regulatory standards and thresholds on labelling. As a working assumption based on the evidence presented above, a five per cent increase in costs due to regulation was imposed on countries with low thresholds (EU, Australia and New Zealand). For those countries with higher thresholds or other regulatory costs, (such as Japan and Korea) a three per cent increase in costs was imposed. No increases in regulatory costs for the remaining regions (notably the United States and Canada) were imposed.

III Method

The basic GTAP structure needed modification to carry out the proposed simulations. This also required making changes to the standard 1997 database. The first database change was to aggregate the original 57 sectors to 11 sectors and 66 regions to 9 regions. This aggregation was based on those regions important in Australian trade and those sectors affected most by GM technology (such as processed food).

Therefore, two crop sectors – grains (composed of maize, sorghum and barley) and oilseeds (composed of soybean, canola and cottonseed) – were chosen and split into GM and non-GM components. While wheat is an important Australian export, there is currently no GM wheat grown for commercial release anywhere in the world; therefore, it was not split.

The split was based on market share information for the nine regions obtained from James (2002). All initial relationships in the database are assumed to hold. Thus, shares of inputs, export shares and destinations, as well as the use for the two types of grains and oilseeds (GM and non-GM) as intermediate inputs, are assumed identical in this initial stage.

The simulations were carried out in a three step process. The first step, scenario 1, was to account for the productivity changes that come from the adoption of GM technology. In the basic GTAP model, imported and domestic intermediate inputs are obtained through CES derived demand equations. Intermediate inputs are then combined, along with value-added, in a Leontief structure, to obtain total output.

To introduce a substitution relationship between GM and non-GM commodities, a CES nesting was introduced after the import/domestic substitution. This then fed into the demand for intermediate goods. This nesting structure is illustrated in figure 2.

The productivity gains were fed into the system via a Hicks-neutral technical change effect. This shock reduces the number of inputs required to produce a given level of output in these (GM) sectors. The shock was applied uniformly to all regions producing GM crops, but varied according to the crop (oilseeds were given a 6 per cent productivity shock and grains a 7.5 per cent shock). Output from this simulation is referred to as ‘scenario 1.’

The second step, scenario 2, was to incorporate consumer responses into the simulation. A number of factors are likely to influence world demand for GM and non-GM crops into the future, including population growth, income and living standards, tastes and preferences. The modelling of private demand in this paper leaves population growth and changes in income and living standards constant while allowing for changes in tastes and preferences. This means that the key influence modelled is the relative demands for GM and non-GM crop varieties.

Consumer response is modelled using two mechanisms. First, price sensitivity, differing across regions, is introduced to the model via a CES function. Regions were classified as being highly price sensitive (eg. North America), somewhat price sensitive (eg. Australia) and price insensitive, (ie. consumers will continue to consume non-GM crops even if the relative price increases (eg. EU)). These price sensitivities are in alignment with current regional consumer sentiment regarding GM food as discussed above.

As stated above, there is little clear-cut information on consumers' attitudes toward the consumption of GM foods, other than 'concern.' However, it seems realistic to model some resistance to GM foods in such markets as the EU and Japan, where widespread concern for food safety in general has been prominent of late. In order to capture the varying degrees of consumer confidence in GM technology, a variable was introduced as a second mechanism to capture preference shifts not related to price. Under this structure, it is assumed that consumers face a structural shift in their demand for GM goods. A 25 per cent reduction in the demand for GM goods was applied to those regions which have seen the most resistance, namely EU, Japan, Australia and New Zealand. This was implemented following the methodology applied in Nielsen and Anderson (2000) and represents a working assumption on the level of consumer resistance.

In the final step, scenario 3, the cost of regulation was accounted for by implementing a series of negative technology-augmenting shocks. Regulation is thus imposed as an additional cost to producers. In order to comply with SIP and labelling regulations, firms must incur additional non-labour input costs (such as additional packaging material, for example); labour costs (such as additional handlers to ensure commodities remain separated); and possibly capital costs (equipment and technical assistance to test commodities for their GM status). Thus, there is a need for additional inputs for each level of output, or the reverse of an output-augmenting technical change.

Given the nature of the regulatory costs, it was felt that increasing all inputs proportionately would be inappropriate. As noted above, studies indicate that regulated sectors will bear a significant increase in their transport and storage costs, for example. The most likely input sectors to be affected by regulations will be manufacturing, services, and transport and storage. There will also be associated effects on value-added (thus including labour costs). The estimated increases in costs due to regulation were modelled as increases in the input requirements of affected sectors (GM and non-GM grains and oilseeds).[9]

Regulation costs were imposed on both GM and non-GM producing sectors. It is still too early to tell who will actually bear the burden of these regulation costs, and to what extent these additional costs can be passed along to the consumer. However, it seems reasonable to assume that in the early stages of GM technology, producers of affected crops will need to provide some evidence of their source, or assurances of their 'non contamination' in the case of conventional crops. This will most likely increase the costs to all market participants, regardless of who the regulation is aimed at.

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[9] Implementation details can be found in the forthcoming staff research paper.

IV Results

Scenario 1 - Productivity gains

Productivity shocks of 7.5 per cent and 6 per cent to GM grains and oilseeds respectively, are applied to allow the generation of a 'clean' market response. Australia currently produces no GM crops used in food production (although some GM inputs are approved for import). If GM production were to commence in the face of increased productivity in these sectors and no barriers due to regulation or market resistance existed, producers would be able to raise output (with the same number of inputs) and this would, in turn, reduce the price of output to intermediate users and induce increases in their input use. Thus, it is expected that both outputs of GM crops, and GM crops as inputs, would increase.

As expected, the results show that the production of GM crops would increase across the board at the expense of conventional crops (see table 1). New Zealand is the only region where a decrease in the output of a GM good (oilseeds) is observed, and this occurs from a very small base. Output of other goods appear to be relatively unaffected by the change. The pattern of production gains across sectors should typically reflect the degree of GM uptake already in place. For example, North America and China experience an expansion in the output of industries using GM inputs (such as livestock, meat and dairy and other food). Other regions, such as Australia and Japan, simply experience an increase in the production of GM goods, since their other industries currently have little or no GM inputs, and so do not benefit. However, over time, as the use of GM inputs increases in these sectors, gains (in the form of lower input costs) would be expected to be more widespread for these non-GM good producing regions.

The model indicates that exports would follow much the same pattern as output. Not only are the GM exports affected (most regions experience increased exports), but related industries such as food, livestock, processed animal and other processed food exports, are also affected in GM producing regions. Again, to the extent GM commodities are used as inputs, these related industries should benefit from a decrease in the price of their GM inputs.

Not surprisingly, the model indicates that the largest producer of GM crops, North America, would gain the most from the assumed productivity changes. North America itself accounts for half of all grains exports and almost 60 per cent of all oilseeds exports. Exports of food from this region are anticipated to increase, as are exports of livestock, processed animal products and other processed foods. As GM commodities already represent a relatively large share of the inputs in these industries in North America, the region appears to gain a comparative advantage in production of several commodities from the productivity increases in the GM sectors.

Changes in crop exports across the remaining regions largely reflect their relative standing in terms of world agricultural exports. Exports are found to increase in China and the EU, both of which are large grains exporters (about 7 and 23 per cent of total grains exports, respectively). Exports in conventionally produced grains and oilseeds show declines in every region, with the exception of a slight increase in oilseeds exports by North America. This seemingly incongruous result occurs because North American consumers would switch to the cheaper GM substitute commodity, which is readily available, thus placing downward pressure on non-GM oilseeds prices. This would occur to a larger extent in North America than in other regions because of a greater availability of the cheaper alternative GM commodity.

Imports of GM goods increase for most countries. The largest increases in grains imports are to Australia and New Zealand. However, these percentage increases appear large because they are calculated from very small bases, given that neither country imports much oilseeds or grains (less than one per cent of total imports of these commodities). Regions such as China, Japan and the EU, already significant importers of grains and oilseeds, are shown to significantly expand their imports of these commodities.

Imports of conventionally produced oilseeds and grains show declines in most regions, but substantially so in North America. Imports of food, livestock, processed animal products and other processed food products fall for this region, as consumers would shift to cheaper domestically produced food and livestock. Other regions experience a slight increase in the imports of these goods and again, this reflects the large potential flow-on effects of the productivity benefits in North America.

As stated, Australia produces no GM food products and, therefore, given the short timeframe considered, does not gain significantly from the increase in productivity enjoyed in those sectors. As expected, output changes only for GM producing industries as producers switch from conventionally produced grains and oilseeds to GM technology.

Under this scenario, there would be virtually no changes in any of the overall macroeconomic variables, including total imports and total exports for Australia. The major change would take place in the composition of trade, concentrated in the two GM producing sectors. GM grains and oilseeds imports would increase significantly (6.5 and 5.6 per cent, respectively) with much smaller increases in livestock and processed animal imports. GM grains would also experience an improvement in exports (1.2 per cent). When looking at the resulting shifts in trade for Australia, however, it must be noted that these crops represent only a small part of Australia's agricultural trade figures (accounting for about 3 per cent and 2 per cent of agricultural exports, respectively). Thus, given these small percentages, it is not surprising that Australia's relative trade position does not change much under this scenario.

These results can best be understood by observing what is happening in the global trade context. Australia's major agricultural trade competitors, such as North America, would gain directly from the GM productivity increases and make Australia's non-GM goods relatively less competitive. Moreover, North America's inputs of cheaper GM commodities into industries such as livestock and processed meat would further diminish Australia's competitiveness in its traditional export markets and also affect domestic consumption as cheaper imports entered the home market.

An overall measure of welfare changes is given by the equivalent variation, shown in table 2.[10] Overall, world welfare improves under the assumption that GM technology is associated with greater productivity. Consistent with the results outlined above, those economies already producing GM crops gain more than those not producing GM crops prior to the productivity shock. Therefore, North America would have the largest increase in welfare measures, with the EU also experiencing large gains. Japan and China would gain to a lesser extent; Japan from cheaper imports and China from an overall improvement in exports.

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

A breakdown of the sources of these total welfare changes is presented in table 2. North America's reported total welfare increase of $2.45 billion comes entirely from increased productivity (technical change), with allocative efficiencies actually declining and terms of trade deteriorating. As described above, Australia would also experience a deterioration in its terms of trade, with a negative impact on total welfare.

Scenario 2 - Adding Consumer response

To test the impact of consumer responses, a shift in consumer preferences against GM commodities is superimposed on the productivity improvement. This shift is akin to a shift in consumers' indifference curves such that households demand a lower share of GM goods in their total consumption bundle at a constant total expenditure level. This shift in consumer preferences is implemented only for Australia, New Zealand, the EU and Japan, since North American consumers are purportedly relatively indifferent between GM and non-GM and poorer consumers in the developing world are typically more sensitive to prices than to methods of production.

This shock is implemented for GM crops only, and since these goods represent small shares of the consumer's overall budget, large changes are not expected. However, in the regions experiencing a negative consumer preference shift, output of GM goods is expected to decline as markets for these goods shrink. Exports, as a result of these smaller markets, should fall compared to scenario 1 as well.

As expected, output gains under scenario 1 are reduced once consumer resistance is added to the model (see table 3). In the EU, for example, GM oilseeds production increases 4.5 per cent in the first simulation, but only 3.2 per cent when consumer resistance is introduced. Japanese GM oilseeds production increases by over 2 per cent in scenario 1, but falls 3 per cent when there is a consumer preference shift. Output remains virtually unchanged in North America and China. The decline in exports of non-GM commodities is not as great as in scenario 1 since consumers in certain regions are now assumed to view GM commodities as less substitutable. Total exports of GM grains still increase, but by a lesser amount because of consumer taste shifts in several large import markets (such as Japan). For example, increases in GM grains exports from North America fall from 4 per cent to 3.8 per cent.

The EU and China experience significant turnarounds in their GM oilseeds exports under this scenario. The EU moves from a 1.3 per cent increase to a 1.2 per cent decline. This is because, in scenario 1, the EU's largest export growth was to Australia, as well as from intra-EU trade. However, both these regions experience a negative consumer response in the second simulation, leading to a decline in the EU's oilseeds production and exports. China, whose GM oilseeds exports increased 2.3 per cent in scenario 1, moves to a 0.4 per cent decline on account of consumer resistance in two of its significant export markets – Japan and EU.

By contrast, Australia experiences an increase in its exports of GM grains compared to scenario 1. This is because consumer resistance to GM commodities in the domestic market would free more GM grain for export to those regions unaffected by preference shifts, such as North America and China. Due to lower demand for GM commodities under the new scenario, the price of Australia's GM grain falls relative to the world export price, making Australian exports attractive to these markets.

While imports of all GM commodities into regions affected by the preference shift decline as compared to scenario 1, they remain positive overall. Increases in the EU's imported GM oilseeds decline in magnitude from 4.6 per cent to 0.36 per cent (almost no increase). This is in contrast to Australia, where imports remain virtually unchanged, despite the same assumed level of consumer resistance. The reason for this is that GM productivity gains in the EU, being more widespread, would allow domestic prices to fall relative to imported prices by a greater amount than in Australia. Thus, in the EU, all of the decline in the consumption of GM oilseeds due to the consumer preference shift would be felt through a decline in imports.

GM imports for regions not subject to the change in consumer preference against GM commodities experience little or no variation compared with scenario 1. In response to the large decline in import demand for GM oilseeds into the EU, non-GM oilseeds imports rise to maintain the region's overall oilseeds demand requirements.

As foreshadowed above, when consumer resistance is added to the analysis, overall welfare effects remain virtually unchanged (table 4). The only significant change in regional welfare occurs in North America, where an abatement in the negative allocative effects experienced under the productivity shock would lead to an improvement in overall welfare in the region.

Scenario 3 - Adding Regulation

Imposing regulation costs would cause the original gains in output in GM sectors to decline as the cost of production rises (see table 5). Australia's production of GM grains and oilseeds is lower than under either of the prior scenarios because the original productivity gains assumed in scenario 1 have not only been eroded by consumer preference shifts (scenario 2), but also by higher input costs due to regulation. This is consistent across all regions incurring regulation costs.

Given that regulation should reflect societal values, it is not surprising that the largest regulatory costs would be incurred by those regions experiencing the highest degree of consumer resistance. These increased costs would result in the affected regions losing export market share to those regions that do not incur additional costs. For instance, North America and China (which are assumed not to incur regulatory costs) experience gains in all GM and non-GM export commodity markets, while Australia, New Zealand, Japan, and the EU experience setbacks. In particular, EU oilseeds exports show a decline which would constitute a significant share of total agricultural exports from the region. However, GM grains exports still increase, but at half the level observed in scenario 1.

Results for exports of agricultural produce other than crops, such as livestock, processed meat and dairy and other foods, do not change significantly. If anything, exports would decline slightly in the EU and Australia as part of the regulatory costs imposed on GM and non-GM crops passed through to industries by way of higher input prices.

Australia's exports of grains and oilseeds show significant declines as they become relatively less competitive internationally. This is true of both GM and non-GM varieties in this simulation. However, the impact of these declines would be far more significant for the non-GM sectors, since Australia's base production of GM commodities is very small. Exports of 'other foods' from Australia also decline slightly as they become less internationally competitive.

Imports typically rise for regulated regions, as imported GM and non-GM grains and oilseeds from those regions not affected by regulation would become relatively cheaper compared to domestic products. In contrast, imports of these commodities into unaffected regions such as North America and China would decline slightly as the regions switched to their cheaper domestically produced crops.

Australia's imports of all GM and non-GM crops show increases, mainly from North America, as cheaper imports are demanded in favour of the more expensive domestic product. Imports of other foods also rise slightly, again because they are favoured on price.

Overall welfare is found to be lowest in this scenario (table 6) . The EU experiences the largest decline as a result of regulation. However, Australia has the lowest welfare measure with a total decline of $US 18 million after productivity gains, consumer resistance and regulation are all taken into account. This loss continues to come from terms of trade effects. Prior to the regulation costs being included, New Zealand was faring the worst of the regions examined, however, once the costs of regulations are added, Australia experiences the largest welfare fall. This is because these regulation requirements apply to a larger proportion of output in Australia than in New Zealand.

Decomposition of welfare effects shows that the EU's welfare declines would chiefly be the result of adverse technical change conditions. Thus the negative total factor productivity shocks imposed to simulate the effects of regulation overwhelm the productivity gains from the introduction of GM technology in this region. By contrast, North America's welfare is shown to rise as the deterioration in its terms of trade is less than in the previous scenarios. This is because domestic prices fall more than import prices, leading to a decline in imports. In addition, this leads to gains in export market share in the EU and Australia.

While both the EU and Australia face similar consumer resistance and regulation costs in this scenario, there is a distinct difference in their total welfare changes. This difference stems from initial shares in GM production. The EU, because it produces GM products (albeit not to the scale of North America, for example), would gain from the productivity increases in this sector, leading to a terms of trade improvement. When regulation costs are added, these productivity gains are shown to decline, but the terms of trade effect remains positive. Australia, on the other hand, having little GM production, would experience only small gains from the productivity shock and a relatively large deterioration in its terms of trade. When regulation costs are imposed, productivity gains would be reversed and the terms of trade effect would reduce overall welfare.

V Conclusion

This paper examines the effects of adoption of agricultural GM technology for grains and oilseeds on Australian and international trade and welfare. It approaches the analysis in three steps. First, it explores what happens when crops produced using GM technology, namely grains and oilseeds, experience an increase in productivity consistent with estimations of on–farm benefits reported in recent studies. Results from this simulation show that those regions where production of GM commodities is more firmly entrenched, such as North America, gain most. This is because these regions gain in productivity, which translates into lower input costs and expanded output in GM sectors, as well as sectors using GM commodities as inputs (such as livestock and processed foods). For those regions with little current GM adoption, the main result is an expansion of the GM sectors at the expense of conventional sectors.

Australia, which produces little GM grains and oilseeds, experiences a decline in total welfare stemming from a deterioration in its terms of trade. This occurs due to the diminished competitiveness of its grains and oilseeds sectors — industries in other countries move away from using less productive non-GM inputs and into more productive GM crops. Imports of affected industries, such as livestock and processed foods, increase.

The second step is to introduce consumer resistance to GM crops into the model. Most studies have shown that consumers throughout the world are experiencing varying degrees of resistance to the new technology. The two extreme positions are exemplified by North America, where concern over GM crops exists but is low, and the EU, where up to 85 per cent of surveyed consumers report concern over the technology.

Given the small share these crops represent in consumer expenditure, little happens to total welfare measures in this scenario. Trade patterns, however, are affected. For example, the EU's GM oilseeds imports fall sharply, as does GM oilseeds production in Japan. For Australia, there is little change other than a slight decline in the gains in output achieved by GM sectors under the first simulation. The reduction in output experienced by conventional crops is also tempered by consumer preference for these goods.

The third step is to introduce regulation costs. The costs are based on estimations reported in the literature. The degree to which legislation actually adds to costs, or merely reinforces an existing trend toward identity preservation, is debatable. This study thus applies moderate estimations of regulatory costs to those regions with existing or pending legislation.

Results from this simulation show a further erosion of productivity benefits to GM crops made under scenario 1. Global welfare gains are smaller, since productivity gains are tempered by regulatory costs in regions experiencing consumer resistance.

Australia's welfare declines in comparison to the previous two simulations. This is due to a further erosion in the terms of trade. While regions such as the EU experience smaller gains from trade when regulations are imposed, the total welfare effect remains positive. Australia, on the other hand, does not gain enough domestically from the GM sector productivity increases to offset its increased costs of regulation and resulting loss in international competitiveness.

When examining these results, several factors should be kept in mind. The first is that these are single period simulations. Thus longer term effects (such as the adoption of GM technology into other downstream industries) are not captured. Second, welfare measures fail to capture utility associated with non-economic aspects of GM technology, namely environmental impacts and perceived health risks and gains.

Third, movement into GM technology in Australia is lessened when regulatory costs are imposed on the model. While the reported welfare losses are small and overall changes in exports and imports negligible, the lack of an incentive to move into this technology may have longer term implications for Australia's trade position. As demonstrated, the benefits to Australia from productivity increases in GM crops are small, as compared to North America, for example, because of the limited uptake of the technology. Moreover, the results are affected by the fact that grains and oilseeds have small shares of Australia's trade. These effects may not be so small in magnitude if GM technology is applied to wheat, one of Australia's main exports.

Finally, given that this paper presents the results of just one consumer and regulatory response scenario out of a range of feasible scenarios, no policy recommendations may be drawn at this stage.

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Table 1 **Effects on selected regions of productivity gains in GM and GM-related sectors**
Percentage changes

	Australia	*North American*	*New Zealand*	*EU*	*China*	*Japan*
Production						
Non-GM Grains	-0.79	-2.15	-0.16	-0.88	-0.76	-1.31
GM Grains	5.35	4.43	4.63	6.29	6.57	7.17
Non-GM Oilseed	-1.81	-1.62	-0.33	-0.93	-0.99	-1.37
GM Oilseed	1.86	0.38	-0.80	4.47	4.73	2.23
Food	-0.10	0.27	-0.13	-0.002	0.01	-0.03
Livestock	-0.22	0.31	-0.38	-0.03	0.06	-0.06
Meat and dairy	-0.15	0.19	-0.22	-0.005	0.04	-0.04
Other foods	-0.03	0.22	-0.08	-0.03	0.02	-0.002
Exports						
Non-GM Grains	-1.07	-0.14	-1.74	-1.18	-1.25	-2.26
GM Grains	1.16	3.95	2.03	4.43	2.97	-2.32
Non-GM Oilseed	-2.56	0.20	-3.20	-1.73	-1.36	-2.88
GM Oilseed	-0.26	3.56	-1.43	1.34	2.30	-1.20
Food	-0.19	0.85	-0.14	-0.04	-0.37	-0.43
Livestock	-0.67	1.89	-1.22	-0.34	-0.36	-0.58
Meat and dairy	-0.43	0.97	-0.31	-0.08	0.05	-0.35
Other foods	-0.20	0.73	-0.26	-0.17	-0.19	-0.30
Imports						
Non-GM Grains	-0.37	-2.83	0.42	-0.88	-0.37	-0.58
GM Grains	7.09	2.80	6.18	5.62	2.16	5.42
Non-GM Oilseed	0.04	-4.20	0.50	-0.33	-0.43	-0.54
GM Oilseed	5.56	1.64	5.16	4.57	4.70	5.02
Food	0.10	-0.19	-0.005	0.004	0.25	0.19
Livestock	0.38	-0.38	1.05	0.05	0.24	0.19
Meat and dairy	0.13	-0.31	0.11	0.01	0.11	0.22
Other foods	0.10	-0.16	0.06	0.04	0.12	0.20

Table 2 **Welfare effects of productivity gains in GM and GM-related sectors**

Region	*Equivalent variation (EV)*	*Decomposition of welfare results, contributions of ($ US million):* [a]		
	$ US million	**Allocative effects**	**Technical change**	**Terms of trade**
Australia	-7	3	13	-22
North America	2455	-37	2700	-249
New Zealand	-11	-1	0	-10
China	222	29	167	25
Japan	182	40	3.5	160
EU	546	275	219	71

Table 3 **Effects on selected regions of productivity gains and consumer resistance in GM and GM-related sectors**

Percentage change

	Australia	*North American*	*New Zealand*	*EU*	*China*	*Japan*
Production						
Non-GM Grains	-0.58	-2.15	-0.16	-0.86	-0.76	-1.29
GM Grains	3.37	4.43	3.73	6.04	6.54	6.96
Non-GM Oilseed	-1.69	-1.50	-0.32	-0.77	-0.97	-0.52
GM Oilseed	1.16	2.23	-1.38	3.22	4.67	-3.09
Food	-0.11	0.27	-0.13	-0.003	0.01	-0.03
Livestock	-0.22	0.31	-0.38	-0.03	0.06	-0.06
Meat and dairy	-0.15	0.20	-0.22	-0.01	0.04	-0.04
Other foods	-0.03	0.22	-0.08	-0.03	0.02	-0.002
Exports						
Non-GM Grains	-1.14	-0.12	-1.72	-1.09	-1.20	-2.27
GM Grains	1.76	3.83	2.12	3.56	2.55	-2.25
Non-GM Oilseed	-2.34	0.43	-2.99	-1.32	-0.99	-3.23
GM Oilseed	-1.36	2.58	-1.89	-1.18	-0.36	1.85
Food	-0.19	0.86	-0.14	-0.04	-0.37	-0.43
Livestock	-0.67	1.89	-1.22	-0.34	-0.36	-0.58
Meat and dairy	-0.43	0.97	-0.31	-0.08	0.05	-0.35
Other foods	-0.20	0.74	-0.26	-0.17	-0.19	-0.30
Imports						
Non-GM Grains	-0.30	-2.83	0.39	-0.76	-0.39	-0.57
GM Grains	6.50	2.80	4.35	4.49	2.35	5.27
Non-GM Oilseed	0.03	-4.24	0.48	0.14	-0.46	-0.44
GM Oilseed	5.58	1.67	3.18	0.36	4.76	4.05
Food	0.10	-0.19	-0.005	0.004	0.25	0.19
Livestock	0.38	-0.38	1.05	0.05	0.24	0.19
Meat and dairy	0.13	-0.31	0.11	0.01	0.11	0.22
Other foods	0.10	-0.16	0.06	0.04	0.12	0.20

Table 4 **Welfare effects of productivity gains and consumer resistance in GM and GM-related sectors**

Region	*Equivalent variation (EV)*	*Decomposition of welfare results, contributions of ($ US million):* [a]		
	$ US million	**Allocative effects**	**Technical change**	**Terms of trade**
Australia	-7	3	13	-22
North America	2468	-24	2700	-248
New Zealand	-11	-1	0	-10
China	222	29	168	25
Japan	182	39	4	160
EU	544	273	219	71

[a] Does not include miscellaneous factors affecting EV.

Table 5 **Effects on selected regions of productivity gains, consumer resistance and regulations costs in GM and GM-related sectors**

Percentage change

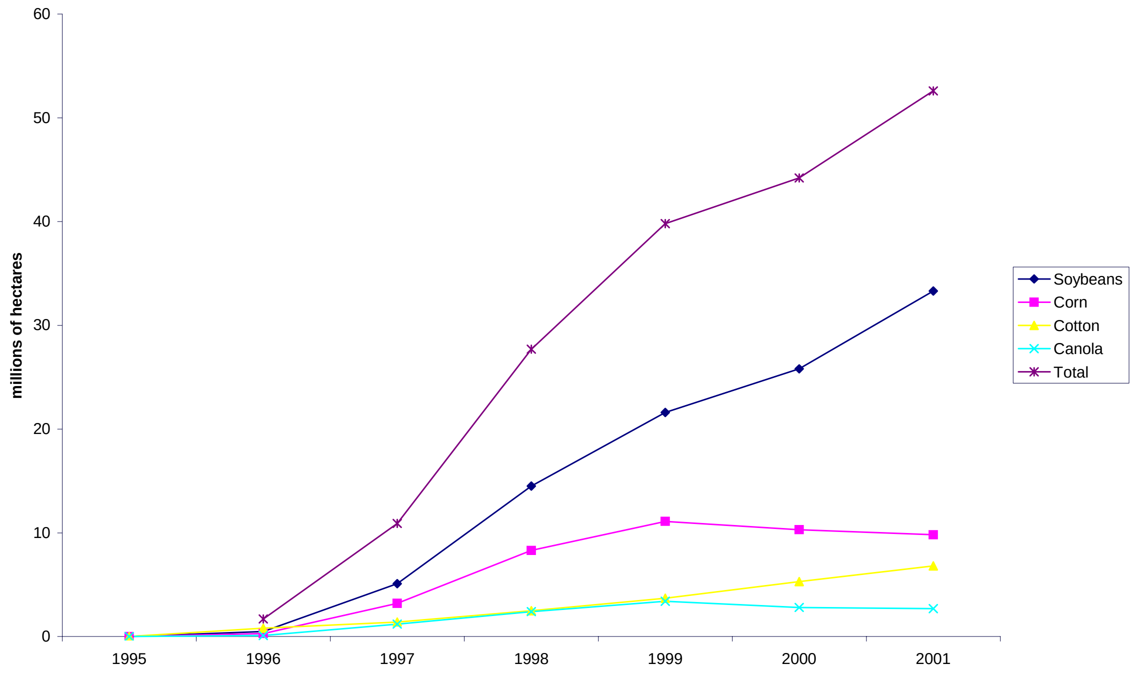
	Australia	*North American*	*New Zealand*	*EU*	*China*	*Japan*
Production						
Non-GM Grains	-0.86	-2.08	-0.19	-1.24	-0.71	-2.05
GM Grains	3.09	4.45	2.84	5.68	6.59	6.19
Non-GM Oilseed	-2.59	-1.22	-0.50	-1.66	-0.93	-1.43
GM Oilseed	0.11	2.32	-3.13	2.22	4.70	-4.16
Food	-0.12	0.27	-0.13	-0.01	0.01	-0.03
Livestock	-0.21	0.31	-0.36	-0.06	0.06	-0.06
Meat and dairy	-0.14	0.20	-0.22	-0.02	0.04	-0.03
Other foods	-0.07	0.22	-0.08	-0.06	0.02	-0.002
Exports						
Non-GM Grains	-2.63	0.28	-3.83	-2.52	-0.96	-3.43
GM Grains	0.26	4.07	0.20	2.20	2.77	-3.61
Non-GM Oilseed	-3.83	0.92	-4.91	-4.05	-0.34	-4.72
GM Oilseed	-2.91	2.88	-3.81	-4.17	0.17	0.31
Food	-0.18	0.84	-0.15	-0.03	-0.37	-0.42
Livestock	-0.62	1.94	-1.12	-0.49	-0.25	-0.49
Meat and dairy	-0.42	0.98	-0.30	-0.11	0.06	-0.32
Other foods	-0.33	0.77	-0.25	-0.23	-0.15	-0.27
Imports						
Non-GM Grains	1.50	-2.89	1.23	-0.69	-0.93	-0.48
GM Grains	8.31	2.75	5.12	4.55	1.82	5.37
Non-GM Oilseed	0.63	-4.31	1.28	0.83	-0.54	-0.44
GM Oilseed	6.23	1.63	3.89	1.07	4.73	4.08
Food	0.08	-0.18	-0.001	-0.01	0.25	0.18
Livestock	0.38	-0.39	1.04	0.09	0.19	0.18
Meat and dairy	0.11	-0.32	0.12	0.001	0.10	0.21
Other foods	0.14	-0.18	0.03	0.04	0.11	0.19

Table 6 **Welfare effects of productivity gains, consumer resistance and regulation costs in GM and GM-related sectors**

Region	*Equivalent variation (EV)*	*Decomposition of welfare results, contributions of ($ US million):* [a]		
	$ US million	**Allocative effects**	**Technical change**	**Terms of trade**
Australia	-18	1	-1	-18
North America	2488	-25	2700	-226
New Zealand	-11	-1	-1	-9
China	215	25	168	23
Japan	172	38	1	153
EU	209	269	-94	50

[a] Does not include miscellaneous factors affecting EV.

Figure 1 **Growth in global area of key GM crops: 1995-2001**



Data sources: James (1998); (2001b); (2002)

Figure 2 **Production nesting**