



GM crops in emerging economies

impacts on australian agriculture

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foreword

Argentina, Brazil, India and China are important exporters and importers of agricultural commodities. These emerging economies have increased their adoption of GM crops, improving their crop productivity and competitiveness.

The pace of uptake of GM crops in these economies has exceeded that of most developed nations and adoption is likely to continue to progress rapidly. Given this, the evaluation of the likely implications for key industries in Australia's export oriented agriculture sector has become imperative.

In this report, the potential economic impacts on Australia of an increased uptake of GM varieties of oilseeds and wheat in the above named emerging economies are assessed. The modelling results reported in this study consider the benefits of adopting GM oilseeds and wheat in Australia under alternative assumptions of access stances of the European Union on importing GM crops.

The illustrative analysis undertaken in this report shows that Australia will potentially have to forgo significant economic gains by delaying the introduction of GM oilseeds and wheat in an environment where these emerging economies are increasing their GM uptake. If these crops are increasingly adopted by emerging economies but not Australia, Australia's export competitiveness will be adversely affected.



Phillip Glyde
Executive Director
March 2008

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summary

global status of GM crops

- Genetically modified (GM) crops have been rapidly adopted across the world, covering more than 114 million hectares of agricultural land in 23 countries by 2007. The most notable expansion has been in the emerging economies of Argentina, Brazil, India and China.
- The most widely adopted GM crops by area in 2007 were those with traits for herbicide tolerance (HT crops) (63 per cent) and resistance to pests (mostly Bt crops) (18 per cent), as well as newly developed varieties that have a combination of herbicide tolerance and pest resistance traits (stacked trait crops) (19 per cent). The inclusion of these traits in crops can benefit farmers by reducing input requirements, increasing crop yields, or both.
- Soybean, maize, cotton and canola are the most widely adopted GM crops, accounting for more than 99 per cent of the GM crop plantings globally. These crops are widely traded internationally, with more than 50 importing countries. Around 98 per cent of soybean, 80 per cent of maize, 73 per cent of canola and 57 per cent of cotton traded globally is sourced from countries growing GM crops.
- Increased crop production as a result of GM crop uptake has enabled emerging economies to gain a larger share of global crop markets.

diffusion of GM crops in emerging economies

- The continued uptake of GM crops in Argentina, Brazil, India and China has allowed these economies to achieve significant increases in crop productivity, improving their competitiveness on international markets. These four countries, in aggregate, account for around 39 per cent of the world's GM crop plantings and this share is likely to increase as they continue to introduce GM crops at a faster pace than other countries.
- The agriculture sectors in these emerging economies are well situated to adopt new biotechnologies. Farmers in these economies have gained experience in adapting to new technological developments and in taking up opportunities for productivity improvement.
- Looking forward, challenges that emerging economies may face in increasing their adoption of GM crops include:
 - improving the regulatory frameworks governing adoption of GM crops
 - strengthening intellectual property rights to enable a greater level of foreign investment in research and development
 - improving transport and storage infrastructure for agricultural commodities.

GM crops in australia

- Cotton is the only crop currently produced in Australia with GM traits. More than 90 per cent of cotton produced in Australia is from GM varieties, with the majority exported to markets including Japan, China and Indonesia.
- Two varieties of GM canola were approved for commercial production in 2003 by the Office of the Gene Technology Regulator (OGTR). However, GM canola has not yet been planted on a commercial scale because of state government moratoriums in all canola producing states. A number of field trials for other crops are being undertaken.
- Commercial canola cultivation is likely to commence in some parts of Australia in the short term. Following a recent review, Victoria announced the expiry on 29 February 2008 of the moratorium on the commercial production of GM canola. In New South Wales, the government has amended the GM food crop legislation and approved the cultivation of GM food crops under licence. Under this scheme the commercial growing of GM canola in NSW was approved in March 2008.
- Canola and cotton are currently the only markets in which Australia competes where GM crops have a significant market share. However, Australia has a major role in other world grain markets in which there is potential for a significant uptake of GM crops. For example, Australia is currently undertaking field GM crop trials in rice and wheat.

economic impacts of GM crop uptake in Australia

- More than half of Australia's production of grains and oilseeds is exported and Australia shares common world markets with emerging economies. Delaying GM crop uptake in Australia while emerging economies continue to increase uptake will have adverse impacts on Australian exports.
- In this report, the potential benefits from Australia adopting GM oilseed and wheat crops are examined using ABARE's global trade and environment model (GTEM).
- This analysis is based on an illustrative scenario in which GM oilseeds and wheat will be ready for uptake in Australia and in the emerging economies of Argentina, Brazil, India and China in 2009. Alternative policies taken by the European Union on importing GM crops are considered. The scenario analysis is undertaken for a ten year period to 2018.

main conclusions of the ABARE analysis

- If Australia adopts GM oilseeds and wheat, alongside increases in adoption of these crops by emerging economies, there will be a gain to Australia's export competitiveness and world market shares. Under the assumption that imports of GM crops are not restricted in foreign

markets, the estimated aggregate gain to the Australian economy (measured by an increase in gross national product) would be around \$912 million (in 2007 Australian dollars) by 2018 relative to what would otherwise be the case.

- Australian farm export income is expected to increase if Australia adopts GM oilseeds and wheat alongside the emerging economies. Under the assumption that imports of GM crops are not restricted in foreign markets, estimated earnings from Australian oilseeds and wheat exports would increase by \$918 million (in 2007 Australian dollars) by 2018, compared to what would otherwise be the case.
- As a result of improved export competitiveness of the oilseeds and wheat industries, resources are expected to move into these industries from the rest of the agriculture sector, leading to an estimated small decline in exports in other agricultural industries. For the agriculture sector as a whole, estimated export earnings would increase by \$747 million (in 2007 Australian dollars) by 2018, compared with what would otherwise be, if Australia adopted GM varieties of oilseeds and wheat alongside emerging economies.
- Under an alternative assumption that the European Union bans imports of GM crops from GM adopting countries, the estimated gain to the Australian economy of adopting GM oilseeds and wheat would reduce to \$732 million (in 2007 Australian dollars) by 2018, compared with what would otherwise be the case.
- Under the assumption that the European Union bans imports of GM crops, the estimated increase in Australia's agricultural exports would be around \$558 million (in 2007 Australian dollars) in 2018, compared with what would otherwise be the case. Export earnings of the oilseeds and wheat industries are estimated to rise by \$682 million (in 2007 Australian dollars) by 2018, from what would otherwise be the case.

1 introduction

The changing nature of global agricultural markets, as a result of GM crop adoption and the success of GM crops in emerging economies, is likely to have implications for Australia's agricultural exports. Australia has high adoption rates for GM cotton, but no other GM broadacre crops are commercially produced.

Argentina, Brazil, India and China are rapidly adopting GM crops, and at a faster rate than in most developed economies. These emerging economies have become the largest GM crop producers, alongside the United States and Canada. The increase in GM crop adoption has increased on-farm productivity, farm incomes and reduced input use. Hence, these economies have increased their agricultural production and exports.

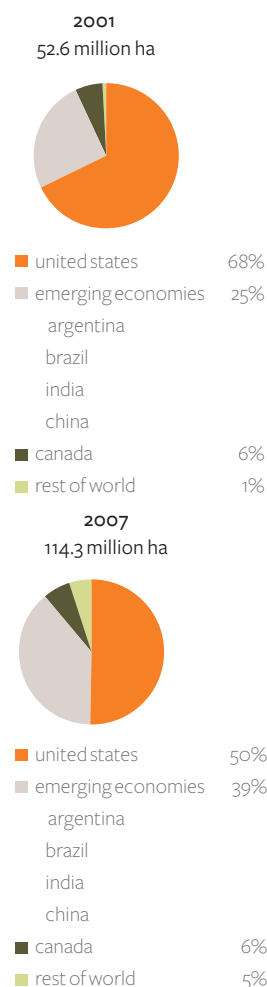
Countries adopting GM crops now account for more than half of global exports of soybeans, corn, canola and cotton — the most dominant GM crops globally. Argentina and Brazil account for more than 60 per cent of global exports of soybeans and soybean products. China and India have also achieved dramatic productivity improvements through GM technologies. For example, India has moved from a net importer to a net exporter of cotton following the introduction of GM cotton varieties.

Delaying the further uptake of GM crop adoption could result in Australia experiencing a loss of market competitiveness, forgone productivity gains and reduced export income. These impacts are partly determined by the extent and rate of GM crop adoption in emerging economies. Country specific factors, such as biotechnology policies and the varied performance of GM crops between countries, are also likely to influence these impacts.

The aim in this report is to investigate the status of GM crop adoption in major emerging economies — Argentina, Brazil, India and China — and to quantify the potential implications for Australia of rapid adoption and development of GM crops in these economies.

2 global status of GM crops

a GM crop uptake of major GM crop producers



The area under GM crop production has risen dramatically since the first GM crop was commercialised in 1996, reaching 114 million hectares in 2007. This is more than double the area grown to GM crops in 2001.

There are now more than 12 million farmers across 23 countries growing GM crops (James 2007). The principal adopters are the United States, followed by Argentina, Brazil, Canada, India and China. These six countries account for 95 per cent of total GM crop plantings. Notably, the emerging economies – Argentina, Brazil, India and China – have increased their share of GM crop area over the past five years — from 25 per cent in 2001 to 39 per cent in 2007 (figure a, James 2001, 2007).

In general, the potential productivity gains from planting GM crops are greater for farmers in emerging economies because of the higher incidence of pests in crops, and the significant potential for yield improvements (Abdalla, Berry, Connell, Tran and Buetre 2003; Qaim 2005). Accordingly, emerging economies are adopting GM technologies faster than developed economies. For example, the area under GM crops increased by 20 per cent in emerging economies in 2007 compared with 6 per cent in developed countries.

The main traits for commercialised GM crops are improved agronomic features comprising herbicide tolerance (HT crops) or resistance to pests (Bt crops). More recently, varieties have been developed containing stacked traits for both pest and herbicide tolerance — loosely termed stacked trait varieties. The most widely adopted trait for GM crops by area in 2007 was herbicide tolerance (63 per cent), followed by stacked traits (19 per cent) and then pest resistance traits (18 per cent) (James 2007).

The most widely planted GM crop worldwide in 2007 was soybean (51 per cent of total GM crop area) followed by maize (31 per cent), cotton (13 per cent) and canola (5 per cent) (table 1). GM soybean and canola varieties have traits for herbicide tolerance, while maize and cotton varieties have been developed for both pest and herbicide resistance. Collectively these four crops account for more than 99 per cent of the global GM crop area.

Of the total area grown to soybeans, cotton, canola and maize in 2007 (301 million hectares), 38 per cent was planted with GM varieties. This compares with 16 per cent for these four crops in 2000. GM adoption has been highest for soybeans, reaching 64 per cent of total soybean plantings in 2007 (figure

b; James 2007). Corresponding adoption rates were 43 per cent for cotton, 20 per cent for canola and 24 per cent for maize.

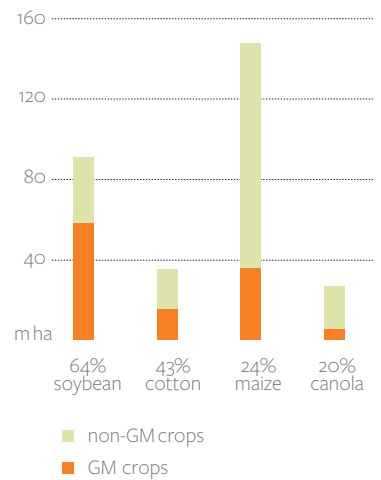
global policies and their influence on GM developments

In various countries, some people are concerned about the potential health and environmental impacts of GM crop adoption, particularly in the longer term (Anderson and Jackson 2005). Accordingly, in many countries, regulations are implemented to protect domestic industries and consumers. These regulations cover the approval of GM crops, marketing, imports, labelling and documentation requirements. Details of these regulations are presented in appendix A.

At the country level, regulations governing production and trade of GM crops are developed in accordance with global policies on genetically modified products. These regulations include, in particular, the Cartagena Protocol on Biosafety, and the World Trade Organisation (WTO) Agreement on the Applications of Sanitary and Phytosanitary Measures (SPS agreement).

However, the relationship between these two agreements is ambiguous and can hamper trade in GM based products. For example, country specific regulations restricting the production and import of GM products, particularly those of the European Union, are having a negative impact on international trade in GM products (Zarrilli 2005). These impacts have the potential to intensify given the disparities between international agreements applying to trade in agricultural biotechnology (box 1).

b global adoption for principal GM crops, 2007



1 major GM crops, 2007

	total area million ha	share of global GM crop area %
herbicide tolerant soybeans	58.6	51
Bt maize	9.3	8
Bt/herbicide tolerant maize	18.8	17
Bt cotton	10.8	9
herbicide tolerant maize	7.0	6
herbicide tolerant canola	5.5	5
Bt/herbicide tolerant cotton	3.2	3
herbicide tolerant cotton	1.1	1
total	114.3	100

Source: James (2007).

International standards for GM production, regulation and labelling may assist in reducing future trade disputes (Anderson and Jackson 2005). There is currently no international standard for GM products; however, the Cartagena Protocol requires parties to consider the implementation of standards for identification, handling and transport practices (Secretariat of the Convention on Biological Diversity 2000). In moving toward this goal, the OECD has actively assisted in harmonising international regulatory requirements, standards and policies related to biotechnology since 1985 (Phillips 2003).

box 1 The Cartagena Protocol on Biosafety and WTO agreements

The Cartagena Protocol on Biosafety is part of the 1992 Convention on Biological Diversity. It was finalised in Montreal in 2000 and came into effect in September 2003. Its primary aim is to ensure the safe movement of living modified organisms, derived from biotechnology, between countries. The protocol reinforces the right of governments to issue domestic regulations and conditions for allowing GM product imports. It specifies a country's right to refuse GM imports to avoid or minimise environmental and/or human health risks, through the use of the precautionary principle in setting domestic regulations. Under the Protocol, GM organisms intended for direct use for food, feed or processing, require a label stating that the product 'may contain' GM organisms. However, no labelling is required for processed foods such as cooking oil or meal (Nielsen and Anderson 2000).

World Trade Organisation rules relating to trade in agricultural biotechnology includes the Agreement on the Applications of Sanitary and Phytosanitary Measures (SPS agreement). The SPS agreement aims to eliminate nontariff barriers to trade based on the pretext of plant and animal health or food safety protection (WTO 2005). Under this agreement, any trade restrictions must be based on sound scientific assessments and be no more trade restrictive than necessary to achieve the desired protection level.

Clearly, the Cartagena Protocol and the SPS agreement have implications for international trade in GM products. However, there is an unclear relationship between the two agreements, potentially undermining their effectiveness.

The SPS agreement is consistent with the Cartagena Protocol's objective of ensuring sustainable use of biological diversity and the consideration of human health risks.

Conversely, the key aim of the WTO is to facilitate trade by reducing barriers and overrestrictive measures used to achieve environmental or food safety objectives. Although the Cartagena Protocol specifically stipulates that it does not imply a change in a country's rights and obligations under any existing international agreements, it also specifies that it is not intended to be subordinate to any other international agreements (UNEP 2000). The potential relationship between the two agreements therefore appears ambiguous.

diffusion of GM crops in emerging economies

Argentina, Brazil, India and China are important producers of agricultural commodities. Together, these economies produce a significant portion of global output of soybeans, maize, canola, rice, wheat and cotton (see appendix B).

GM crops have demonstrated significant benefits to farmers (box 2). The increase in global farm income from GM crop uptake has been estimated at US\$27 billion in nominal terms, for the decade to 2005, with approximately 47 per cent of income gains accruing to farmers in developing countries (Brookes and Barfoot 2006). Increases in farm income arising from adoption of GM crops in emerging economies has been driven by crop yield increases and reductions in production costs (box 2).

The increase in farm income that GM crops offer is to some extent offset by increased seed costs in some cases. For example, in Brazil, seed costs for GM soybean varieties were approximately US\$20 per hectare higher than for non-GM varieties in the early part of the decade (da Silveira and Borges, 2007). In China, seed costs for Bt cotton varieties were 100–250 per cent higher than non-GM cotton seeds in the period 1999–2001, although this price difference has declined over time in high adopting areas (Huang, Hu, Van Meijl and Van Tongeren 2003).

Growth in GM crop adoption in emerging economies has been stimulated by policy and regulatory settings. The current policy arrangements for GM crops in emerging economies are presented in appendix C.

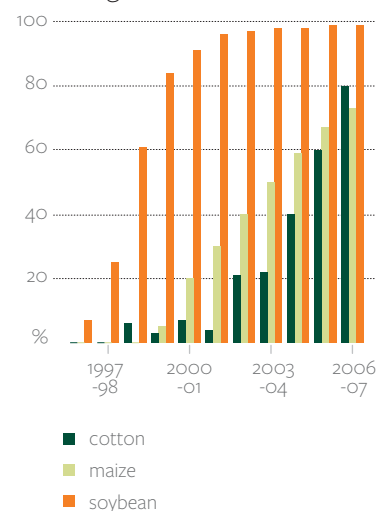
argentina

GM soybeans resistant to glyphosate herbicide were the first GM crop to be released in Argentina in 1996, followed by GM maize and cotton varieties with herbicide and insect resistance in 1998 (table 2).

Argentina has the second largest GM crop area in the world after the United States, covering 19.1 million hectares. On average, the total GM crop area in Argentina has increased by 70 per cent a year since 1996. The widespread use of GM varieties has enabled a rapid expansion of planted area, leading to growth in production and exports.

Uptake of GM soybeans has been most rapid, with GM soybean crops accounting for around 99 per cent of soybean production in 2006–07 (figure c; ArgenBio 2007). There has also been rapid adoption of GM maize and GM cotton since these varieties were introduced in 1998. By 2006 the area of GM maize varieties was 73 per cent (3.1 million hectares) of total maize plantings, while GM cotton area reached 80 per cent (360 000

C adoption rates for GM crops in Argentina



box 2 benefits of GM crop adoption

increased yields

The adoption of GM crops has in general increased crop yields in many economies but owing to a range of factors — including the type of crop being considered, location of crop and farm management factors — the magnitude of yield improvement over non-GM crop varieties in a specific location has been varied. In particular:

- for soybeans, there is little evidence that GM crops lead to a yield advantage over non-GM varieties (da Silveira and Borges 2007)
- Bt and glyphosate tolerant maize is estimated to improve yields by at least 10 per cent, owing to a reduction in yield losses associated with insect infestations (Iannone 2002, quoted in Trigo and Cap 2006)
- cotton yield gains have been significant, ranging from around 10 per cent in China (Frisvold, Reeves and Tronstad 2006; Huang, Hu, Pray, Qiao and Rozelle 2003; Huang, Hu, Rozelle and Pray 2007; Huang, Hu, Rozelle, Qiao and Pray 2002; Pray, Huang and Rozelle 2002) to 30 per cent in Argentina (Elena 2001, quoted in Trigo and Cap 2006) and between 30 and 40 per cent in India (Qaim 2003) in terms of prevented yield loss from insect outbreaks.

increased flexibility

The adoption of GM crops also offers farmers increased flexibility in farm management practices. In Argentina, for example, the rapid adoption of GM cropping technology has resulted in a considerable increase in no-till planting, as well as uptake of double cropping systems in which soybeans are planted immediately after the wheat crop has been harvested, shortening crop rotation times (Chudnovsky 2007), leading to considerable savings in labour costs in the short term and machinery costs in the medium to longer term.

In China, where insect pests have been a major constraint to cotton production, Bt cotton varieties have reduced pesticide use, leading to reduced pesticide expenditures as compared with non-GM cotton growers. In addition, farmers are able to spend less time spraying pesticide, increasing the time available for other farm activities (Huang, Hu, Pray and Rozelle 2002).

health and environmental benefits

There may be health and environmental benefits from lower levels of pesticide and herbicide applications as a result of GM crop adoption. For example, glyphosate, the herbicide used in most GM soybean and maize production, is less toxic to human health than some other herbicides. Also, in some emerging economies, pesticide is generally applied by hand without masks or protective clothing. Pesticide poisoning has been a significant problem affecting up to 29 per cent of non-GM cotton farmers in China (Huang et al. 2007). Reduced pesticide application also lowers the detrimental impact of pesticide use on groundwater, which is often used for domestic, irrigation and drinking purposes.

2 commercialised GM crop varieties in argentina

crop	introduced trait	variety	year released
soybean	herbicide tolerance	40-3-2	1996
maize	herbicide tolerance and insect resistance	176	1998
maize	herbicide tolerance	T25	1998
cotton	insect resistance	MON531	1998
maize	insect resistance	MON810	1998
cotton	herbicide tolerance	MON1445	2001
maize	herbicide tolerance and insect resistance	Bt11	2001
maize	herbicide tolerance	NK603	2004
maize	herbicide tolerance and insect resistance	TC1507	2005
maize	herbicide tolerance	GA21	2005

Source: CONABIA (SAGPyA).

hectares). Other GM crops produced, although not yet on a commercial scale, include sunflower, tomato, canola and sugar.

brazil

Commercialised GM crops in Brazil include soybean, cotton, and maize, covering an area of around 15 million hectares in 2007 (table 3). During the late 1990s, herbicide tolerant soybeans were rapidly adopted by farmers in several regions of Brazil, with seeds illegally imported from Argentina. By 2004 when GM soybeans were officially approved for commercial production, approximately a third of the planted area was already cultivated with GM varieties. In 2005, Brazil became the third largest producer of GM crops globally and, in 2006, accounted for 25 per cent of world soybean production.

Brazil is the world's third largest producer of maize, with around 13 million hectares planted in 2006.

Brazil is also a large producer of cotton. A variety of Bt cotton was commercialised in 2005, and in 2006 farmers planted 120 000 hectares, approximately 10 per cent of the total crop area. Brazil's cotton producers have severe pest problems and face significant insecticide costs. Bt cotton is

3 commercialised GM crop varieties in brazil

crop	introduced trait	developer	year released
soybean	herbicide tolerance	monsanto	2003 ^a
cotton	insect resistance	monsanto	2005
maize	herbicide tolerance	bayer	2007

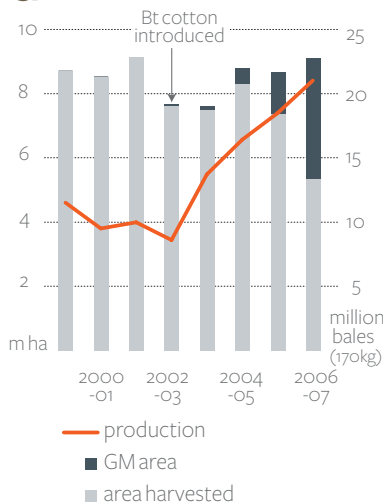
^aYear of official commercial release.

Sources: James (2006); GMO Compass (2007a).

therefore expected to provide significant benefits to cotton farmers. Brazil currently cultivates more than 1 million hectares of cotton.

Brazil has also invested significant resources in the research and development of GM varieties of rice, sugar cane, potato, papaya and eucalyptus.

d cotton production in India



india

India initially commercialised three varieties of Bt cotton in 2002. By 2006, there were 62 hybrids of Bt cotton approved for commercial production. Cotton is an important cash crop, contributing around 30 per cent of the gross value of India's agricultural production (Bennett et al. 2004). The area under Bt cotton increased from 50 000 hectares in 2002 to 3.8 million hectares in 2006 (figure d; Indian Department of Agriculture and Cooperation 2007). In 2006-07, India surpassed the United States as the second largest cotton producer after China.

Other GM crops under trial for release in India include eggplant (brinjal), rice, cauliflower, tomato, okra, potato and mustard. These crops have traits such as insect and disease resistance, increased shelf life and higher levels of essential amino acids.

china

China has been highly effective in utilising biotechnology in the agricultural sector and has field trialled a range of GM crops (table 4). Two Bt cotton varieties were approved in 1997 and were rapidly adopted. There are now more than 53 varieties of GM cotton grown commercially. China has the

4 commercialised GM crop varieties in china

crop	introduced trait	developer	year released
cotton	insect resistance	monsanto	1997
cotton	insect resistance	chinese academy of agricultural sciences	1997
cotton	insect resistance	chinese academy of agricultural sciences	1999 – present (numerous varieties)
tomato	delayed ripening	huazhong agricultural university	1997
tomato	delayed ripening	institute of microbiology, cas	2000
tomato	virus resistant	beijing university	1999 – present (numerous varieties)
sweet pepper	virus resistant	beijing university	1999 – present (numerous varieties)

Source: James (2006).

third largest area of GM cotton after the United States and India, with 3.8 million hectares planted. China also has the largest number of farmers (7.1 million) growing Bt cotton.

Around 69 per cent of total cotton plantings by area in China are pest resistant varieties (Bt cotton) or both Bt and herbicide tolerant varieties (stacked trait crops). Bt cotton has not been adopted to the extent it has been in United States (83 per cent) or Australia (92 per cent), largely because insect infestations are lower in China, reducing the benefit of planting Bt varieties (Petry and Xinping 2007). In 2005, the area under Bt cotton fell slightly as farmers replaced land intensive with labour intensive crops (Anderson, Valenzuela and Jackson 2006) (figure e, James 2006).

Since the late 1980s, China has been developing GM rice varieties. One variety (Xaz1) with a resistance to bacterial blight is close to commercialisation. It is currently being assessed for biosafety requirements (Huang et al. 2007). GM rice varieties able to resist rice stem borers, and leaf rollers and a hybrid variety able to resist many pests have also been developed.

Other GM varieties that have been approved for commercialisation include tomato, sweet pepper, and petunia; however, plantings of these crops remain small. Other crops currently under field trials include wheat, maize, soybeans, potato and canola. A virus resistant papaya was also approved for commercialisation in late 2006 (James 2006).

market acceptance of GM crops

GM crops have been widely accepted by many importing countries. As of 2006, 51 countries had approved imports of GM crops for food and/or feed. Many of these are major food importing countries, such as Japan, the Republic of Korea and Chinese Taipei, that do not plant GM crops (James 2006).

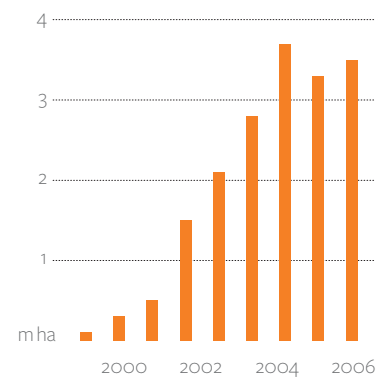
The majority of soybeans, maize, cotton and canola exports are from GM adopting countries. It is estimated that in 2006, globally, up to 98 per cent of soybean trade, 80 per cent of maize trade, 73 per cent of canola trade and 57 per cent of cotton trade were sourced from countries that produce GM crops (figure f, Brookes and Barfoot 2006).

Global trade in grains and oilseeds is dominated by GM cropping countries such as the United States, Canada, Brazil and Argentina (figure g; USDA 2007b).

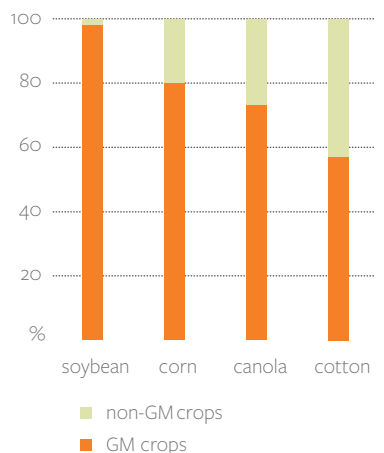
soybeans and maize

Soybeans and maize are both important crops in emerging economies. Brazil and Argentina together account for around 44 per cent of global

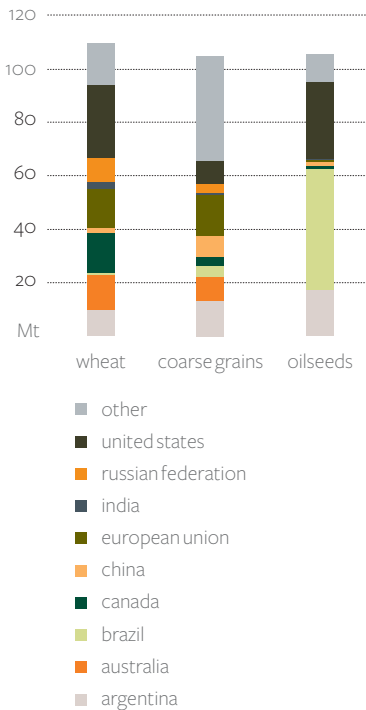
e area under Bt cotton in China



f global trade for major GM crops, 2006



09 main grain and oilseed exporters average, 5 years to 2006-2007



soybean production and 48 per cent of global soybean exports. Both soybeans and maize are used as feed inputs to livestock production in the northern hemisphere.

Argentina and Brazil export the majority of their soybean production. Around 22 per cent of the increase in global soybean production as well as an 11 per cent reduction in world price between 1996 and 2005 was, to some extent, attributable to increased GM crop production and exports by Argentina (Trigo and Cap 2006).

Non-adopters of GM technology have forgone the potential on-farm benefits and incomes. For example, countries producing only non-GM soybeans are estimated to have lost farm income of around US\$291 million in 2001 (Qaim and Traxler 2005).

Exports by Argentina and Brazil of GM based soybean and maize products have faced market access restrictions into the European Union. Following the lifting of the European Union's moratorium on GM crop imports in 2004, market restrictions have been replaced by the implementation of strict labelling requirements.

However, other major export markets for soybean based products (India, Iran and South Africa) do not have labelling requirements for highly processed GM products. Similarly, soybean meal is primarily destined for the European Union, Egypt, Malaysia and Thailand. Of these, the European Union is the only market where labelling for GM products is required, and this only applies to meal destined for food rather than feed.

The adoption of both GM soybeans and maize has contributed to an increase in production and consequently exports of these products in Argentina and Brazil (figure h; FAO Statistics Division 2007).

cotton

The main emerging economies to adopt GM cotton varieties have been India and China. Further diffusion of Bt cotton in these countries is likely given the benefits and the higher revenue relative to non-Bt varieties. For example, India was previously a net importer of cotton; however, since Bt cotton was introduced, it has become a net exporter. As a result of Bt cotton's introduction, India's share of world cotton exports has increased from 0.2 per cent in 2001-02, to 7.0 per cent in 2005-06.

China is the world's largest producer and consumer of cotton, accounting for around a quarter of the world's cotton production and more than a quarter of global consumption and imports. China is also a significant net importer of cotton. The majority of imports are sourced from the United States, India and Australia.

challenges for further adoption of GM crops in emerging economies

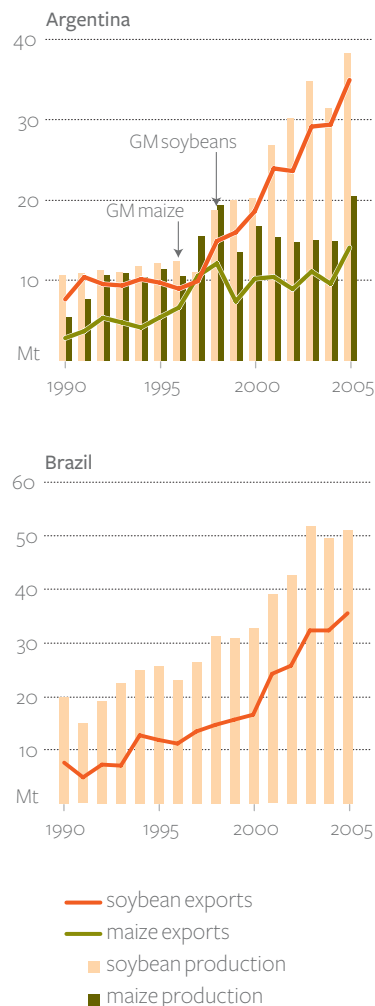
The uptake of GM crops in emerging economies has been facilitated by the experience of developed countries that have adopted GM crops. For example, in Argentina, glyphosate tolerant soybeans (and subsequently other GM crops) were able to be directly transferred from the United States into Argentinian cropping systems. This removed the need for domestic investments in research and development. However, the extent to which this practice occurs in future will be influenced by the status of intellectual property rights in the emerging economies.

Intellectual property rights in emerging economies are still underdeveloped. Illegal seed trade and the legal diffusion of some GM seeds at low cost in emerging economies remain a significant problem for developers of GM seeds. For example, illegal seeds are responsible for around 35 per cent of GM crop plantings in Argentina. Additionally, the use of GM seeds legally, through loopholes in property right arrangements, has given emerging economies cost advantages over farmers in developed regions. For example, GM soybean seed was around 30 per cent more in Argentina in early part of the decade than conventional varieties, compared with 43 per cent more in the United States.

Improvements in intellectual property rights in emerging economies are likely to aid in attracting foreign investment in research and development of GM crop traits in emerging economies. For example, China has achieved a good balance in its regulatory approach to GM crops, which has assisted its development. The government has supported biotechnology development through funding and research programs, and has also responded to demand for increased biosafety protection. Also, India has developed a strong policy regime for the development and commercialisation of GM varieties. The strengthened intellectual property rights regime and focus on foreign investment is likely to assist India in the development of GM varieties for large scale commercial crops.

Production factors in emerging economies suggest that they are in a suitable position to adopt future biotechnology developments. Farmers are often experienced in adapting to new technological developments. However, inefficient farming practices and pest problems pose significant challenges yet to be overcome in these economies. For example, although India has the largest area under cotton plantings, output is less than that in the United States and China. Also, the Indian Government continues to provide considerable assistance to the agriculture sector through input subsidies, government procurement of output and price supports, limiting incentives for the agriculture sector to attain higher levels of efficiency.

h production and exports of major GM crops



China's agricultural policy is focused toward achieving self sufficiency but in recent years also on improving market access and opportunities for farmers to adapt to market conditions. Farmers are unable to own land, but are now able to take a lease for up to thirty years. In 2004, farmers were also granted permission to lease out their land, with a view to increased efficiency through expanding farm area. While farmers are now more flexible in altering production in response to demand, government policy is still focused toward promoting production of cereals and food grains (ABARE 2006).

Other policies have also been introduced in China to boost agricultural productivity and rural incomes, notably tax cuts, subsidies and investments (USDA 2007a). In 2004, China spent \$18 billion on rural infrastructure and agreed to reduce production taxes, previously set at 8.4 per cent.

In addition, emerging economies may face infrastructure constraints. For example, India's transport costs are 20–30 per cent higher than in many other developing countries, and significant infrastructure investment is required to enable India to reach its potential in terms of agricultural production and trade. In recent years, poor maintenance of infrastructure has been a key factor slowing growth in India's agricultural production (Ministry of Finance 2007). Similarly, in Brazil, improvements in transport and storage facilities are likely to be needed to cope with the increase in production and exports.

3 GM crop adoption in australia

Australia is a major producer and exporter of cereal crops – wheat, barley and sorghum, and oilseeds, in particular cottonseed and canola. For example, Australia's share of global exports of canola and wheat exceeded 10 per cent, and of barley and cottonseed exceeded 20 per cent in the five years ended 2005-06 (table 5). Australia is also a major producer and exporter of cotton fibre but produces only small quantities of soybeans and maize.

Introduced in 1996, GM cotton is currently the only GM crop produced in Australia. Herbicide tolerant, insect resistant and stacked varieties have all been widely planted, and GM cotton accounted for around 92 per cent of total cotton production in 2006. More than 90 per cent of cotton production in Australia is exported, with key markets including Indonesia, China, Thailand and Japan.

Australia is a major producer and exporter of canola with more than 65 per cent of production exported in 2006 (figure 1). Japan is the largest export market for Australian canola, with other destinations including the United Arab Emirates, Pakistan, Bangladesh, China and the European Union.

The Gene Technology Ministerial Council — established under the Commonwealth Gene Technology Act (2000) — has adopted a policy to recognise any state or territory legislation issued to preserve the identity of non-GM or GM products for marketing or trade purposes.

Two varieties of GM canola were approved for commercial production in 2003 by the Office of the Gene Technology Regulator (OGTR). However, the main canola producing states enacted moratoriums on production owing to market access concerns. Consequently GM canola has not yet been planted on a commercial scale in Australia.

States and territories, except Queensland and the Northern Territory, enacted GM crop moratorium legislation preventing the commercial production of GM crops. In Western Australia and Tasmania, the legislation applied to all GM crops, while in other states it applies only to GM food crops.

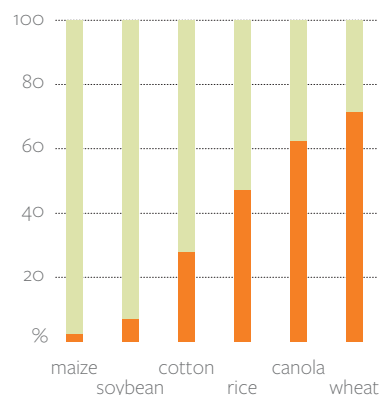
Most states and territories have now reviewed their moratoriums. The Australian Capital Territory reviews their moratorium legislation of GM crops annually. Following a recent independent review, Victoria announced

5 australian cereals and oilseeds production and trade

average 2002-03 to 2006-07

	production		australia's share of global exports
	volume kt	value \$m	
cereals			
wheat	18 792	4 315	13
barley	7 129	1 362	29
sorghum	1 756	321	4
maize	346	85	<1
oilseeds			
canola	1 210	483	14
cottonseed	637	1 026	40
soybeans	47	16	<1

i exports as a share of crop production, Australia average 2002-06



the decision to allow the moratorium order on the commercial production of GM canola crops to expire on 29 February 2008. The New South Wales Government accepted all recommendation of their review and amended the GM food crop legislation. As a result a scheme for approving the cultivation of GM food plants under licence has been introduced. Under this scheme an expert committee was established to advise the NSW Agriculture Minister, on applications for the commercial production of GM crops. Under this scheme, NSW approved the commercial production of GM canola in early 2008. South Australia announced its decision to maintain a moratorium on the growing of GM crops in early 2008. Tasmania's review is continuing and not expected to be completed until 2009. Western Australia is scheduled to review their moratorium order on GM canola, and is expected to submit a report to the Minister by late 2009. State and federal policy arrangements on GM crop uptake are discussed further in appendix D.

GM crops that are currently under field trials in Australia include rice, wheat, Indian mustard, sugar cane, white clover and grapes (table 6). In June 2007, a variety of drought tolerant wheat was also approved for trial. In addition, cotton varieties are under continual development targeting new traits including improved fibre quality, disease and viral resistance, drought tolerance and water use efficiency, and cottonseed oil modification to produce healthier oils. These varieties could lead to significant benefits to consumers as well as producers.

6 GM field crop trials currently underway in australia

crop	traits
canola	herbicide tolerance, hybrid breeding system
wheat	modified starch characteristics, drought tolerance
cotton	insect resistance, herbicide tolerance, high oleic acid content, water-use efficiency, waterlogging tolerance, fungal resistance
rice	herbicide tolerance
rose	altered flower colour
indian mustard	herbicide tolerance, hybrid breeding system
sugarcane	altered sugar production, test modification process, water-use efficiency, nitrogen-use efficiency
white clover	virus resistance
grapevine	colour expression, sugar composition, flower and fruit development, reporter gene expression
pineapple	reduction of blackheart, delayed flowering, reporter gene expression
papaya	delayed fruit ripening, reporter gene expression
torenia	altered flower colour

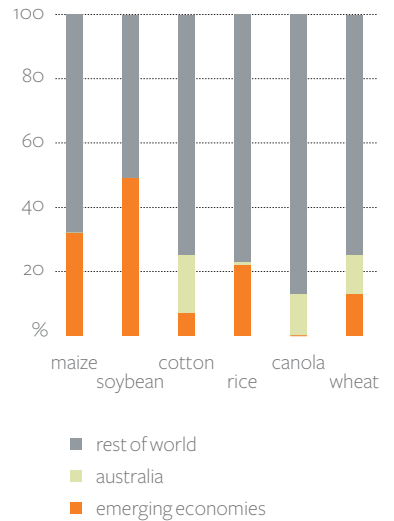
Source: OGTR (2007).

grains and oilseeds trade by Australia and emerging economies

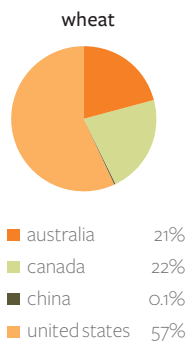
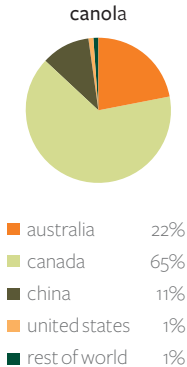
The four emerging economies of Argentina, Brazil, China and India account for a major portion of global grains and oilseed production and play a significant role in global trade for these commodities. They account for 49 per cent of global soybean trade, 32 per cent of maize trade, 22 per cent of rice trade and 13 per cent of wheat trade (figure j, table 7). Australia competes with these countries to gain market access.

Australia and the emerging economies also share common markets for some crop exports. For example, Japan sources canola and wheat from Australia and China (figure k; United Nations Statistics Division 2007).

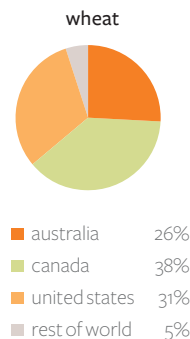
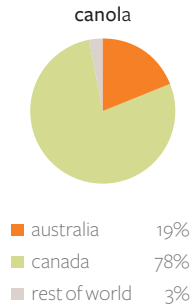
j grains and oilseeds share of world export markets average 2002–06



k sources of Japan's canola and wheat imports average 2002–06



l sources of China's canola and wheat imports average 2002–06



Emerging economies, particularly China, also import crop products for food and stock feed use. For example, China accounts for 8 per cent of global canola imports, 39 per cent of global soybean imports and 2 per cent of wheat imports. In this regard, Australia supplies around 19 per cent of China's canola imports and 26 per cent of China's wheat imports (figure 1; United Nations Statistics Division 2007).

If GM varieties of wheat are commercialised, China, India and Argentina are likely to benefit most from adoption. These three economies account for around 30 per cent of world wheat production and 13 per cent of global wheat exports (table 7). Conversely, Australia accounts for around 12 per cent of global wheat exports and 3 per cent of global wheat production. Global market changes could therefore have significant implications for the Australian wheat industry.

Argentina, Brazil, India and China are significant producers and exporters of grains and oilseeds, many of which are GM based crops. As Australia's agriculture sector shares some common export markets with emerging economies, and competes in the global market for these commodities, delaying the adoption of GM crops while emerging economies continue to increase uptake, can be expected to have important economic implications for Australia. These impacts are quantified in the following chapter using several illustrative scenarios.

7 share of world production and export for selected countries and crops

average 2002–06

	soybean		canola		maize		cotton		rice		wheat	
	production %	exports %	production %	exports %	production %	exports %	production %	exports %	production %	exports %	production %	exports %
australia	0.03	0.01	3	13	0.05	0.01	2	18	0.1	1	3	12
argentina	18	13	0	0	3	15	1	1	0	1	2	9
brazil	26	35	0	0	6	6	5	5	2	1	1	0
india	3	0	14	0	2	1	18	0	21	15	12	2
china	8	1	28	0	19	10	26	1	31	5	16	2
emerging economies total	55	48	42	0	30	32	50	7	54	22	31	13
united states	38	44	2	4	40	60	16	43	2	12	9	25
canada	1	2	17	73	1	3	0	0	0	0	4	14
eu-27	1	0	33	5	9	1	2	5	0	1	22	13
rest of world	5	5	3	5	20	4	30	27	44	64	31	23

4 economic impacts on australia of diffusion of GM crops in emerging economies

The economic effects on Australia of increased uptake of GM crops in Argentina, Brazil, India and China are explored in this chapter. The crops considered for adoption in the analysis are oilseeds (predominantly canola for Australia) and wheat. Canola and wheat are significant export commodities in Australia's agriculture sector.

While GM canola has not yet been actively adopted by emerging economies and Australia, this may change over time. In early 2008 Victoria lifted its moratoria on growing GM canola and NSW made amendments to the Gene Technology (GM Crop Moratorium) Act 2003 to allow the growing of GM crops under licence and with Ministerial approval. GM canola has since received approval for commercial production in both states in early 2008.

GM wheat is not grown anywhere in the world. However, research is being undertaken into developing GM wheat varieties for commercial release. For example, Syngenta, a Swiss based company, is carrying out field trials in North America of a GM wheat variety resistant to the fungal disease, Fusarium, a disease that can stunt plant growth and reduce yields of wheat crops by around 1-3 per cent (Gianessi 2005). Fusarium infected crops also pose a serious risk to consumers as toxins produced by the fungi can affect human health (GMO Compass 2007b). GM wheat field trials are also underway in Mexico and China (Berwald et al. 2006).

Similar to soybeans, wheat is a basic building block to a range of food ingredients, and is used widely in food applications. The commercial release of a HT wheat in northern America suffered a set back when Monsanto, a leading agricultural biotechnology company, shelved its research in 2004 owing to market access concerns (Decision News Media 2004). Syngenta continues to assess market acceptance of the genetically modified wheat. In preparation for release of GM wheat, US Wheat Associates — which markets US wheat to foreign buyers — has voted to approve a plan to promote biotech wheat through educational seminars, country specific promotional programs, safety and quality demonstrations and guiding development of segregation systems (Decision News Media 2005). In media reports it is stated that the earliest possible date for the release of Syngenta's GM wheat is early next decade (Heller 2006).

Given the uncertainty surrounding the commercial release of GM wheat, and adoption of GM canola in the emerging economies, the illustrative anal-

ysis presented in this chapter should be considered as only an indication of how Australia's wheat and oilseeds competitive position in export markets would be affected by an assumed uptake of these crops by emerging economies.

Two illustrative cases are analysed for the increased adoption of GM grain crops in Australia — namely access everywhere including the European Union (unrestricted) and restricted access to the European Union market (restricted). A reference case is developed for each case, with the only difference between the two being the stance taken by the European Union on GM crop imports. Each reference case assumes that GM oilseeds and wheat are gradually adopted in Argentina, Brazil, India and China over the period 2009–18, reaching full adoption in 2018. Under each reference case a scenario is developed to analyse the likely gains to the Australian agriculture sector from adoption of GM canola and wheat, alongside emerging economies (table 8).

ABARE's global trade and environment model (GTEM) — a general equilibrium model of the global economy — is used in the analysis. Full documentation of the model is available on ABARE's website (abare.gov.au). GTEM has the capacity to simulate interactions between sectors within countries as well as the linkages between countries through trade and investment flows.

Economic impacts of adoption of GM crops on the Australian economy are measured in terms of percentage changes from the reference case in gross national product (GNP) in 2018. This is also the case for changes in Australian agricultural commodity exports.

8 illustrative cases for adoption of GM oilseeds and wheat in australia

	adoption in china, india, brazil and argentina of GM oilseeds and wheat	europaen union import stance on GM oilseeds and wheat	australian stance on GM oilseeds and wheat
unrestricted reference case scenario	all adopt	unrestricted	australia does not adopt
unrestricted australia in	all adopt	unrestricted	australia adopts
eu restricted reference case scenario	all adopt	restricted	australia does not adopt
eu restricted australia in	all adopt	restricted	australia adopts

assumptions

Yield improvements resulting from GM crop adoption were assumed for each crop in the countries analysed based on a review of literature (box 3) and are reported in table 9. These assumptions are based on field trials in specific regions and under specific climatic and agronomic conditions. It is assumed that the actual productivity gains that these GM crops achieve in individual emerging economies and Australia are likely to approximate those simulated here, depending on the specific climatic and agronomic conditions.

9 percentage yield improvements applied to crop sectors over the period 2009–18 in GTEM simulations

	australia	argentina	brazil	china	india
	%	%	%	%	%
canola a	10	na	na	10	10
soybean a	3	3	3	3	3
wheat	9	9	9	9	9

a Canola and soybeans are aggregated into the oilseed sector in GTEM. The impacts of the yield improvements are adjusted to a single yield improvement in the simulations to reflect the relative contribution of canola and soybeans in the aggregate GTEM oilseeds sector. na Not applicable.

In each illustrative scenario, the estimated economic impacts on Australia are expressed as a change in gross national product relative to the reference case in 2007 Australian dollars. These impacts should be regarded as indicative only. The results also need to be viewed within the context of any possible additional costs incurred — for example, potentially higher seed costs and costs of identity preservation in agricultural systems producing both GM and non-GM crops. These likely increases in costs are not considered in the scenarios because of a lack of information.

economic impact of GM crop uptake

An uptake of GM oilseed and wheat crops in Argentina, Brazil, India and China is likely to lead to productivity gains that will affect Australia through international trade flows. This will be reflected in a reduction in per unit production costs and increased crop production and exports for GM adopting countries. Accordingly, higher supplies would put downward pressure on world prices for these products.

The implications of higher supplies and lower prices in the world market vary for different sectors and regions. Net importers and consumers of these crops would benefit from the lower prices. The emerging economies also benefit — not only from lower production costs but from potentially higher export incomes or, in the case of India and China, from being able to gradually replace imports with progressive increases in domestic production.

box 3 yield benefits from adoption of GM oilseeds and wheat*oilseeds**soybeans*

Yield impacts from GM soybeans have been limited. With the exception of Romania (low standards of weed control and 30 per cent yield gains from GM soybean adoption), the impact of GM soybeans on yield has largely been small or neutral (Brookes 2005; Brookes and Barfoot 2006). For the purposes of the simulations, a 3 per cent yield gain in each economy is assumed.

canola

Canada is the world leader in HT canola production. A research study found that over the seasons 1997–2001, farmers experienced an average yield increase of 10 per cent (Serecon Management Consulting Inc and Koch Paul Associates 2001). This was supported by Mayer and Furtan (1999) who also found a yield increase of about 10 per cent. Carew and Smith (2006) reported a slightly smaller yield increase (6 per cent).

Several explanations for the variability in yields have been suggested in the literature. Fulton and Keyowski (1999) attributed yield differences to farm size variability, geographic location, product specialisation, and farmer management skills. Carew and Smith (2006) offered further explanation for yield differences based on the weed intensity in any location.

In Australia, Norton (2003) estimated that HT canola has the potential to improve average yield from 1.27 tonnes per hectare to 1.38 tonnes per hectare, an increase of 8 per cent. The results of Monsanto field trials, conducted side by side with HT canola and alternative non-GM canola varieties and weed management systems, are presented in Foster (2003). With the exception of Clearfield canola, Monsanto's Roundup Ready canola provided substantial yield gains compared with non-GM varieties (8–24 per cent).

Bayer Crop Science produced a GM canola known as 'InVigor' where field trials indicated yield gains of 9–38 per cent (ACIL Tasman 2007).

For the purpose of the simulations, a 10 per cent yield gain in Australia, India and China is assumed. Argentina and Brazil do not produce canola.

wheat

There is a paucity of data on the potential yield gain in GM wheat. GM wheat field trials conducted in northern America show a yield advantage of 9 per cent for GM wheat resistant to herbicide and 1–3 per cent yield advantage for disease resistant wheat (Berwald, Carter and Gruere 2006). For the purposes of the simulations a 9 per cent yield gain in each emerging economy and Australia is assumed.

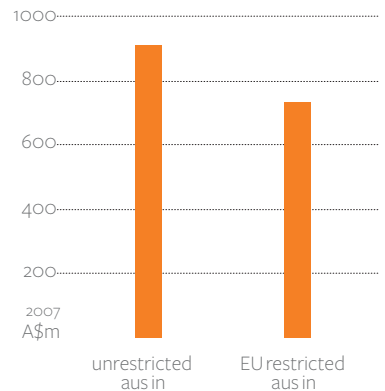
Australia would potentially face a loss of market share and both production and exports could fall if Australia does not take up GM crops alongside the emerging economies. However, Australia might be able to take advantage of markets for non-GM crops, reducing, to some extent, the negative impact. For example, if the European Union restricted GM imports, Australia could potentially increase its market share in the European Union.

Alternatively if Australia adopted GM crops, Australian crop production could expand as farmers would benefit from lower per unit production costs. Total exports are likely to increase as Australia's crop exports gain competitiveness in international markets.

economic gains if australia adopted GM crops

If Australia adopted GM technology, alongside China, India, Brazil and Argentina, Australia's economy would benefit compared with each of the two assumed reference cases (figure m). Under unrestricted access for GM crops everywhere, Australia's gross national product (GNP) is estimated to be \$912 million (in 2007 Australian dollars) higher in 2018 — the year assumed for full adoption — relative to the reference case where Australia does not adopt. This gain in GNP would reduce to \$732 million, compared with the reference case, in the case where access to the EU market for GM crop imports was restricted for Australia, China, India, Brazil and Argentina.

m changes in Australia's GNP, 2018 relative to the reference case



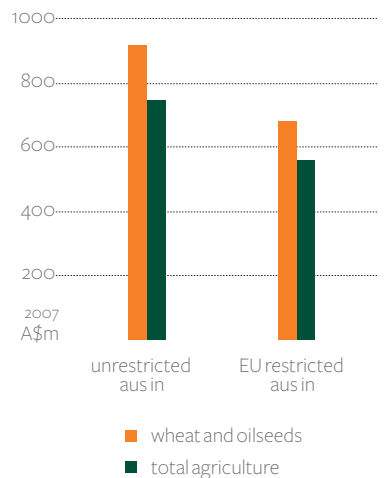
effects on australia's wheat and oilseed exports

If Australia fully adopted GM oilseed and wheat crops by 2018, the value of exports for these crops would increase relative to the reference case. If there were no restriction in foreign markets on GM crop imports, the export income for these crops increases by an estimated \$918 million by 2018, relative to the reference case. If the European Union restricted imports of GM crops, the export income for these crops increases by an estimated \$682 million by 2018, compared with the reference case (figure n).

With the improved export competitiveness of the oilseeds and wheat industries, resources would be likely to move into these industries from the rest of the agriculture sector, leading to a small decline in exports in other agricultural industries. For the agriculture sector as a whole, export earnings would increase by an estimated \$747 million by 2018, compared with the reference case, if Australia adopted the GM varieties of oilseeds and wheat alongside the emerging economies and there were no restrictions on the imports of GM crops in foreign markets.

Under the assumption that the European Union bans imports of GM crops, the increase in agricultural exports as a whole would be around \$558 million in 2018, compared with the reference case.

n change in agricultural in exports (free on board), 2018 relative to the reference case



5 conclusions

The growing of GM crops has provided benefits to farmers in Argentina, Brazil, India and China through yield improvements and/or reduced production costs. The proportion of cotton, soybean, maize and canola planted to GM varieties in these countries is already significant and continues to increase each year. These countries are expected to approve additional GM crops in the future.

Australia competes with emerging economies on global markets, particularly for oilseeds, wheat and cotton. Additionally, Australia is a major supplier of grain and oilseeds to China, and more recently India. Increases in agricultural productivity in emerging economies as a result of their adoption of GM crops can be expected to have potential adverse implications for Australia's export competitiveness in these crops.

In a market environment where emerging economies continue to increase their uptake of GM crops, the illustrative modelling results presented in this report indicate that Australia would benefit from the introduction of GM crops. The modelling undertaken considers only the impacts on Australia of additional GM crop uptake for a limited number of countries and crops – oilseeds and wheat. However, the uptake of additional GM varieties in other major cropping countries is likely to intensify the implications for Australia of GM crop uptake.

appendix **A** GM regulation and labelling rules for selected countries

There is significant variability in regulation and labelling requirements for GM crops across regions.

The United States has a GM crop policy diametrically different from that of the European Union and Japan. The United States, as well as Canada and Argentina, have taken an approach to agricultural biotechnology based on the 'equivalence principle', regulating products rather than the processes from which they are derived and favouring no labelling or voluntary labelling of products containing GM materials.

On the other hand, the European Union and Japan have followed the 'precautionary principle' on new agricultural biotechnology. These countries consider the process from which a GM product has been derived, rather than comparing the product with its non-GM counterpart. Additionally, they have imposed strict controls on the import and marketing of GM products.

Other countries, including Australia and New Zealand, fall in between these policy stances, implementing individual approval systems and labelling requirements. The variability in regulation and labelling requirements are indicated in table 10.

10 regulation and labelling requirements, by region

countries	food safety approval regulations	labelling regulations	specificity
european union – 25	process based mandatory	stringent, mandatory, includes derived products	traceability requirements, 0.9% threshold for GM materials
brazil, china, russia, switzerland, norway	process based mandatory	stringent, mandatory, includes derived products	no traceability, low threshold for GM materials
australia, japan, korea, saudi arabia, thailand	process based mandatory	'pragmatic' mandatory	many labelling exceptions
united states, canada, argentina, south africa, taiwan	substantial equivalence mandatory (US: voluntary consultation)	voluntary for substantially equivalent food	5% threshold level for labelling
indonesia, malaysia, mexico, philippines, vietnam	mandatory (in place or pending)	mandatory, introduced but not implemented	'pragmatic' labelling
india, kenya	mandatory (in place or pending)	intention to require labelling	slow regulatory process
bangladesh, most african countries	considering mandatory	no clear position	wait and see approach
a few african countries (zimbabwe, zambia)	no	no	GM free

Source: Gruère (2006).

appendix **B** agriculture sectors in emerging economies

argentina

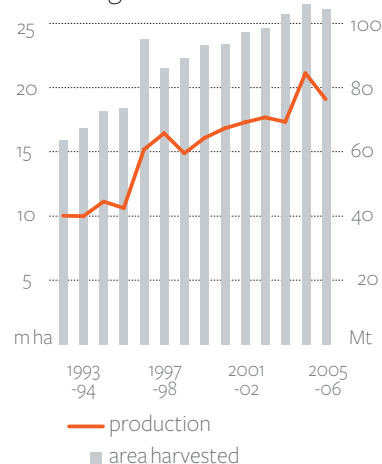
Microeconomic reform and technological innovations in Argentina's farm sector have led to a substantial increase in agricultural production over the past fifteen years. From the early 1990s, markets were deregulated, import tariffs on inputs and capital goods were reduced and taxes and voluntary restraints on agricultural exports were eliminated. These reforms allowed rapid technological upgrades in the farm sector, including use of improved machinery and equipment, fertilisers and chemicals, and GM crop technologies (Trigo and Cap 2006). As a result, production of grains and oilseeds increased from 40 million tonnes in 1992-93 to around 80 million tonnes in 2005-06 (figure 0; SAGPyA (2007).

The main crops grown in Argentina are soybeans, maize, wheat, sunflower and sorghum (table 11). Globally, Argentina is a major producer of these crops, ranking third in soybeans and sunflower seed, fifth in maize and sixth in sorghum production.

Agriculture makes up around 70 per cent of Argentina's export income. The majority of Argentina's crop production is exported to overseas feed markets. Argentina is the largest exporter of soybean meal and oil, and the third largest exporter of soybeans, after the United States and Brazil. Argentina is also an important exporter of sunflower seed oil, sorghum, maize and wheat (table 12).

In 2005, soybeans and soybean products comprised 48 per cent of agricultural export income and 22 per cent of total export income. Argentina's soybeans are mainly exported to China, the European Union and Thailand.

0 grain and oilseed production in Argentina



11 main crops produced in argentina, 2006

	area harvested '000 ha	yield t/ha	production quantity '000 tonnes
soybeans	15 097	2.7	40 467
wheat	5 500	2.5	14 000
maize	2 447	5.9	14 446
sunflower seed	2 195	1.7	3 798
sorghum	498	4.7	2 328
sugar cane	285	66.0	18 799

Source: FAO Statistics Division (2007).

12 argentina's agricultural exports, 2005

	world rank	quantity exported '000 tonnes	export value us\$m
soybean meal	1	20 797	3 797
soybean oil	1	4 827	2 237
sunflower seed oil	1	1 199	718
sorghum	2	323	26
soybean	3	9 915	2 284
maize	3	14 602	1 363
wheat	5	10 425	1 280

Source: FAO Statistics Division (2006).

The main export destinations for soybean oil are India and China and soybean meal is mostly exported to the European Union, Egypt, Malaysia and Thailand.

brazil

Agriculture is a significant sector in Brazil's national economy, accounting for around 10 per cent of gross domestic product and 40 per cent of total exports.

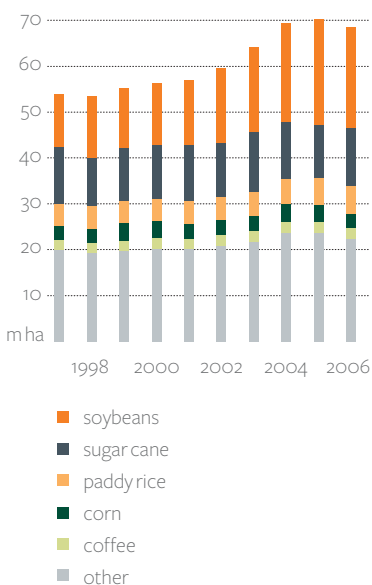
Deregulation of the farm sector over the past three decades has led to dramatic productivity growth and efficiency gains in Brazil's agricultural sector, leading to significant increases in production of key agricultural commodities such as soybeans, meat and fruit (Jales, Jank, Yao and Carter 2006). Deregulation of the farm sector has been achieved predominantly through the removal of state enterprises, marketing boards, price supports and government purchases of wheat and milk. Export taxes, export restriction and import licences have also been removed. Current assistance focuses on diversification of production and trade expansion and includes preferential credit, some tax exemptions and public research financing.

Between 1990 and 2004, the total area planted rose by 14 per cent to 60.4 million hectares in Brazil (Jales et al. 2006). In recent years, soybeans have been the main driver of this increase (figure p, FAO Statistics Division, 2007).

The main crops grown in Brazil are soybeans, maize, sugar cane, rice, coffee and wheat (table 13). Globally, Brazil is the second largest producer of soybeans and the third largest of maize.

In Brazil, agricultural production has increased faster than consumption, leading to agricultural exports rising from US\$8.9 billion in 1990 to \$30.9 billion in 2005 (Council and Hanrahan 2006). By 2005, Brazil had the largest agricultural trade surplus in the world, totalling US\$27.5 billion, and was

p total crop area harvested in Brazil



13 main crops produced in brazil, 2006

	area harvested '000 ha	yield t/ha	production quantity '000 tonnes
soybeans	22 007	2.4	52 356
maize	12 603	3.4	42 632
sugar cane	6 153	74.0	455 291
rice	2 975	3.9	11 505
coffee	2 325	1.1	2 593
wheat	1 558	1.3	2 482

Source: FAO Statistics Division (2007).

the third largest agricultural exporter (following the United States and the European Union). Brazil is the world's largest exporter of sugar, coffee and tobacco, second in soybeans and soybean products and fourth in maize (table 14). Brazil's major export markets include the European Union, China, the United States, the Russian Federation and Japan.

14 brazil's agricultural exports, 2005

	world rank	quantity exported '000 tonnes	export value us\$m
soybeans	2	22 435	5 345
soybean meal	2	14 422	2 865
coffee	1	1 352	2 517
sugar (raw)	1	11 601	2 388
tobacco	1	616	1 660
sugar (refined)	2	6 568	1 537
soybean oil	2	2 697	1 267
cotton lint	5	391	450
maize	4	1 070	121

Source: FAO Statistics Division (2007).

india

Agriculture plays a major role in the Indian economy. It accounts for around 25 per cent of gross domestic product, and 13 per cent of total exports (IBEF 2007). More than 60 per cent of India's population is employed in the agriculture sector. The sector is dominated by small farming families. Of the approximately 89 million farming households in India, 60 per cent own less than one hectare of land (James 2006).

Major crops produced in India include sugar, rice, wheat and maize (table 15). Globally, India is the largest producer of milk, fruit, cashew nuts, ginger, coconuts and tea, the second largest producer of wheat, sugar, vegetables and fish, and the third largest producer of rice and cotton.

15 main crops produced in india, 2006

	area harvested '000 ha	yield t/ha	production quantity '000 tonnes
rice paddy	43 700	3.1	136 510
wheat	26 480	2.6	69 350
millet	9 500	1.1	10 100
seed cotton	9 139	1.2	10 692
cotton lint	8 900	0.4	3 564
sorghum	8 670	0.8	7 128
soybeans	7 710	1.1	8 270
maize	7 590	1.9	14 710
sugar cane	4 200	67	281 170

Source: FAO Statistics Division (2007).

Major exports from India include tea and coffee, rice, oilseed meals, cashew nuts, spices, fruit and vegetables (table 16). Significant quantities of wheat have also been exported in recent years in an attempt to reduce government stocks. Almost 35 per cent of agricultural exports from India are destined for developed markets. Key export partners include the United States, Bangladesh, the United Kingdom, Indonesia, Germany and Malaysia.

India is a leading importer of pulses and oilseeds. Despite being the largest producer of pulses, its production is not sufficient to meet domestic consumption. Edible oils account for almost two-thirds of agricultural commodity imports and pulses account for an additional 20 per cent (IBEF 2006). Other imports include cashew nuts (for processing), tree nuts, fruit, raw cotton, wool and silk. Indian production depends greatly on climatic conditions, and as such, during production shortfalls, wheat, rice and sugar may also be imported.

16 india's agricultural exports, 2005

	world rank	quantity exported '000 tonnes	export value us\$m
rice	9	3 824	1 364.8
soybean meal	5	4 784	968.7
cotton lint	9	598	639.7
tea	4	159	372.6
coffee green	12	157	254.6
tobacco	12	143	231.7
wheat	10	746	126.5

Source: FAO Statistics Division (2007).

china

China's economy has undergone rapid development since the early 1990s. Gross domestic product has increased by an average of 9 per cent a year, reflecting high investment levels, new technologies and a transfer of resources to more productive industries (ABARE 2006). While there has been a large movement of the population from rural to urban areas, the agriculture sector has maintained a dominant role in China's economy.

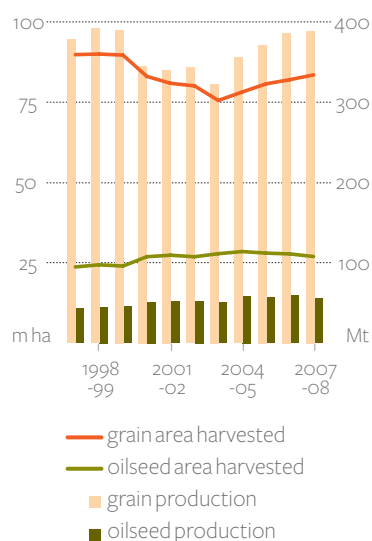
China is the world's largest producer of rice, wheat, cotton, peanuts and canola. It ranks second in maize and fourth in soybean production. In recent years, there has been a shift in resources away from intensive cereal production as farmers adapt to domestic consumer demand for a greater variety of foods and opt for higher value, labour intensive products, such as meat, vegetables, fruit, eggs and milk. Cereals' share in agricultural production fell from 63 per cent in 1991 to 33 per cent in 2005. There has also been a shift from wheat and rice into maize production for the livestock industry.

Over the past decade, the total area of agricultural plantings has remained stable for oilseeds but fallen for grains (figure q). Following a fall in grain yields and planted area in 2003-04, the government introduced 'grain production targets', as well as tax relief payments and guaranteed payments to grain farmers. These measures led to an increase in grain production from 2004-05 (FAS USDA 2005).

Rice, maize and wheat are the main crops planted by area in China, accounting for around 70 per cent of total area harvested (table 17).

Imports have been used mainly to make up for production shortfalls, primarily in wool and wheat. Prior to 2004, there was only a minimal need for wheat imports, despite a significant reduction in production, as China

q grain and oilseed production in China



17 main crops produced in china, 2006

	area harvested '000 ha	yield t/ha	production quantity '000 tonnes
rice paddy	29 380	6.3	184 070
maize	27 143	5.4	145 625
wheat	23 450	4.5	104 470
soybeans	9 100	1.7	15 500
canola	6 740	1.9	12 649
cotton lint	5 416	1.2	6 730
cottonseed	5 416	2.5	13 460
potatoes	5 416	3.7	20 190
sugar cane	1 220	83	100 684

Source: FAO statistics division (2007).

was able to rely on stocks reserved in the 1990s (ABARE 2006). In 2004-05, however, China became a large importer of wheat. China has also become a major importer of soybeans, soybean oil and palm oil, reflecting increased demand for vegetable oil and feed for the expanding livestock sector. In 2005, China's agricultural imports were valued at \$36.7 billion and sourced primarily from the United States, Brazil, Argentina, the Russian Federation, Australia, Malaysia and Thailand.

appendix **C** policy arrangements for GM crops in emerging economies

Biotechnology policies in Argentina, Brazil, India and China are likely to have implications for the future uptake of GM crops. In particular, improved intellectual property rights protection will be important in attracting further public and private investment in the agricultural biotechnology sector. Also, biosafety and environmental assessment measures will need to be continued, reflecting the demand of consumers and export markets. In this appendix, the regulatory arrangements for agricultural biotechnology in Argentina, Brazil, India and China are outlined.

argentina

Institutions were founded in the early 1990s specifically to regulate biosafety and biotechnology development, establishing a strong base for the introduction of GM crops. For example, Argentina established a Biotech Commission and biosafety guidelines for the release of GM plants and micro-organisms. Other agriculture sector advisory and regulatory bodies responsible for regulating GM crop adoption in Argentina are outlined in box 4.

box 4 agricultural advisory and regulatory bodies in argentina

seed regulation

The National Institute of Seeds (INASE) was established in 1991 to regulate seed trade and ensure quality seed availability.

food safety

The National Food and Agriculture Safety and Quality Service (SENASA) regulates food quality and safety, including food derived from GM products. SENASA evaluates potential risks for animal and human health from the consumption of GM food and feed. The body is also responsible for managing and enforcing regulations for new varieties.

environmental assessment

The National Advisory Commission on Agricultural Biotechnology (CONABIA) established in 1991 assesses applications for field testing and advises the Department of Agriculture, Livestock, Fishing and Food (SAGPyA) of risks to the environment from the release of GM products and derivatives.

marketing and trade

The marketing of GM products and their acceptance on world export markets is investigated by the National Directorate of Agrifood Markets (DNMA).

commercialisation

SAGPyA is responsible for granting authorisation for the commercialisation of GM crops, based on the reports made by CONABIA, SENASA and DNMA.

research and development

Limited resources are allocated to research and development in the agriculture sector in Argentina. In particular, public sector investment is low — less than 1 per cent of GDP — and between 1991 and 2004, 80 per cent of field trials undertaken for GM crops were from the private sector.

intellectual property rights

IP rights are limited in Argentina and continue to constrain GM crop diffusion. In particular, illegal seed trade makes it difficult to incorporate new biotechnology breakthroughs. In addition, Argentine law stipulates that farmers can store seed for personal use, rather than purchasing seed annually. Illegal seed sales account for approximately 35 per cent of plantings in Argentina with another 30 per cent coming from legally saved seed (Qaim, Subramanian, Naik and Zilberman 2006).

Illegal trade, along with the lack of intellectual property rights protection has put downward pressure on seed prices. In 2003, the Department of Agriculture, Livestock, Fisheries and Food (SAGPyA) and the National Institute of Seeds (INASE) both recommended policies to collect royalty payments. While no agreement has yet been reached on seed payments, the adoption of such policies is likely to strengthen IP rights for GM seed suppliers to Argentina.

brazil

Under the Biosafety Bill — introduced in 1995 — Brazil addresses all stages of GM crop approval, including research, experimentation, marketing, storage and dissemination (da Silveira and Borges 2007). The National Biosafety Technical Committee (CTNBio) within the Ministry of Science and Technology oversees the implementation of biotechnology regulations.

The operation of biotechnology policy has faced obstacles in Brazil. Widespread illegal plantings of GM soybeans in 2003 prompted CTNBio to introduce provisional measures to permit the use of GM soybeans in 2003 and 2004. In 2004 the National Council on Biosecurity — a board representing eleven ministries — was introduced to provide a second opinion on the approval of GM crops. The agriculture sector advisory and regulatory bodies relevant to the use of GM traits in crops in Brazil are further outlined in box 5.

research and development

Agricultural biotechnology in Brazil has been largely associated with the adoption of foreign technologies, suited to local tropical conditions (da

Silviera and Borges 2007). This adaptation process has been assisted by the National Centre for Research on Genetic Resources and Biotechnology (CENARGEN) which has the role of coordinating technology transfer from other countries.

Public institutions contributing to GM crop development are limited and generally lack resources, infrastructure and investment. However, they have made some progress in the development of local crops such as sugar cane, beans and manioc, whereas global companies have focused on the introduction of global cash crops.

The Brazilian Corporation for Farming and Livestock Research (EMBRAPA), established in 1973, is the public body responsible for coordinating R&D for GM crops. The National Farming and Livestock Research System (SNPA) encourages cooperation between the private sector and other research institutions and universities. These bodies have focused their efforts on improving coordination between public and private institutions to develop commercial products.

box 5 agricultural advisory and regulatory bodies in brazil

food safety

Food safety assessments for GM products are undertaken by the Ministry of Science and Technology, based on domestic regulations for GM food and feed set by the Ministry of Health.

environmental assessment

Initial trial of a GM produce requires a Biosafety Quality Certificate, issued from the Ministry of Agriculture, Cattle-raising and Provisioning (MAPA). The National Biosafety Technical Committee (CTNBio) within the Ministry of Science and Technology then authorises use in the environment based on environmental and safety assessments. Following this, a Temporary Field Experimentation Authorisation is required from MAPA, as well as an Operation Licence for research and an Environmental Licence.

CTNBio's biosafety and environmental laws are based on the precautionary principle and a full environmental impact assessment is conducted by CTNBio for each application.

marketing and trade

The acceptance of Brazil's GM crops on world export markets is investigated by CTNBio as well as the National Council on Biosecurity before final approval.

commercialisation

Following a successful field trial period, commercial approval is granted by CTNBio. The National Council on Biosecurity has 90 days to ratify this decision to finalise commercial release.

intellectual property rights

The introduction of intellectual property rights laws in the late 1990s, including the national Law of Patents (1996) and the Law of Cultivars Protection (1997), has improved coordination between public and private research; and enabled the collection of royalties and fees by technology owners for plant biotechnologies. These laws allow patents for the insertion of a gene into a plant variety, and as a result, seeds can only be reproduced with authorisation from the patent holder. These laws also enable joint technology transfer agreements between local and foreign research entities. For example, these joint agreements have been important for the introduction of Roundup Ready soybeans in Brazil.

india

Indian GM policy is focused toward the development of GM crops to suit national growing conditions and socioeconomic requirements. For example, low priority is given to crops that are labour saving, such as those with herbicide tolerant traits, whereas varieties targeting pests and biotic stresses are major objectives (Ramaswami and Pray 2007).

GM crops in India must pass several approvals before commercialisation is authorised. Bt cotton was not approved for 5 years after the initial biosafety testing was completed. Further information is included in box 6.

research and development

The Indian Government has invested significant funding in public research systems, including the Centre for Plant Molecular Biology, the National Plant Genome Research Centre and the International Centre for Genetic Engineering and Biotechnology.

The Indian Council for Agricultural Research supports R&D in crop biotechnology and has developed programs in rice and wheat varieties in particular. Publicly developed GM crop varieties are marketed by the National Seed Corporation and the State Farm Corporation of India. Products developed by the public sector include chickpea, rice, tobacco, cotton, potato, tomato, eggplant and mustard (Ghosh and Ramaniah 2000), but many of these products are yet to be commercialised. A concern with public R&D programs is that resources are spread thinly across many individual projects and not focused toward specific goals (Balasubramanian 2007).

Private sector research in India has adapted foreign GM products to suit Indian conditions (Indira, Bhagavan and Virgin 2005). Investment has focused on cotton, rice and vegetables – all with the Bt gene for insect resistance. Significant funding from the private sector has enabled large

box 6 agricultural advisory and regulatory bodies in india

seed regulation

In 2002, India introduced the Seed Policy, with specific reference to GM seeds. Under the policy, seeds can only be imported through the National Bureau of Plant Genetic Resources (NBPGR). After trial, seeds may be approved for commercial release. The seed must then be registered under the provisions of the Seeds Act. Monitoring of seed varieties is required every 3–5 years by the Ministry of Agriculture.

food safety

India introduced the Food Safety and Standards Act in 2006. The act established the Food Safety and Standards Authority to develop standards for food (including GM crops) and to regulate and monitor food manufacture, processing, distribution and imports.

environmental assessment

Before trial of a GM crop, authorisation must be granted by a local Institutional Biosafety Committee (IBC) whose role is to review toxicity, allergenicity and environmental biosafety issues. Every public or private biotechnology institution must establish its own internal IBC approved by the Department of Biotechnology. An external specialist will be nominated by the department to sit on each committee. There are more than 230 IBCs in India, 70 of which are involved in agricultural biotechnology (Ramaswami 2005).

Following approval by an IBC, the Review Committee on Genetic Manipulation (RCGM) under the Department of Biotechnology is responsible for biosafety clearance and the authorisation of controlled field trials. The review committee also monitors trial sites to ensure compliance with environmental and biosafety guidelines. Generally, a Monitoring and Environment Committee is assigned by Review Committee on Genetic Manipulation to review crop trials.

marketing and trade

The Genetic Engineering Approval Committee under the Ministry of Environment and Forests is made up of scientists and bureaucrats representing various ministries. The committee approves GM crops for import and export.

commercialisation

Before commercialisation, the Genetic Engineering Approval Committee needs to approve a large scale field trial. Since 2001, the approval committee has required that all field trials last a minimum of two years and be supervised by the Indian Council of Agricultural Research. Following a successful trial, the Genetic Engineering Approval Committee may then approve commercial release.

scale, multilocation field trials to be undertaken. As a result, privately developed GM products — in particular cotton varieties — have entered the market more rapidly than publicly developed products.

intellectual property rights

Intellectual property rights in India have increased significantly in recent years. As a result, the private sector has increased its role in agricultural biotechnology research, focusing on commercial crops.

India's intellectual property rights laws come under the Protection of Plant Varieties and Farmers' Rights Bill 2001. It includes protection for farmers, plant breeders and plant varieties as well as genetic material (Lalitha 2004). These laws have created incentives for international investors and several international biotechnology firms have sought entrance to the Indian market.

china

China has incorporated agricultural biotechnology as a major national development goal. The National Biotechnology Program was initiated in the early 1980s with the objectives of improving food security, increasing farm income, and improving China's competitive position in international agricultural markets. Since then, the public sector has made significant investments in biotechnology research capacity.

Biotechnology regulations have been regularly updated to meet consumer and export market concerns. In particular, biosafety laws have become stricter and monitoring guidelines for GM crops have been implemented. More extensive testing for GM crops is also required in the form of a pre-production trial, a small scale field trial and a medium scale environmental release trial. Labelling is now required also for all products containing GM food components (box 7).

research and development

The Chinese Government has contributed significant funding to R&D programs for GM crops. Biotechnology has been a major focus of the National High-Tech Research and Development Plan initiated in 1986, as well as the National Basic Sciences Initiative (1997) and the Special Foundation of Transgenic Plants Research and Commercialisation (1999). Since the mid 1980s the National Science Foundation of China has also allocated a significant budget to agricultural biotechnology research.

Almost all of China's biotechnology funding has been sourced from the public sector. Funding increased from US\$25 million in 1990 to US\$120

million in 2003 (Huang et al. 2007). Funding for agricultural biotechnology has enabled China to establish significant research infrastructure and most provinces now have a large scale technological research program. In 2001, there were nearly 150 laboratories working on agricultural biotechnology in more than fifty research institutes and universities (Huang et al. 2007).

More than fifty plant GM varieties have been developed, mainly for cotton, rice, maize, wheat, canola and soybeans.

box 7 agricultural advisory and regulatory bodies in China

seed regulation

Seed regulation in China is directed by the Joint Ministerial Meeting, which consists of representatives from several ministries and commissions.

food safety

Food safety management for GM products is the responsibility of the Ministry of Health. An appraisal committee within the ministry assesses the food safety properties of GM products and grants a food safety certificate for new products. GM developers need a food safety certificate before applying for field trial approval.

environmental assessment

The State Environmental Protection Authority reports on the potential impacts of a GM crop on biodiversity, and implements international biosafety protocols.

All applications for field trials, environmental release trials, pre-production trials and commercialisation are evaluated by the National Agricultural GMO Biosafety Committee within the Ministry of Agriculture. The committee is composed of 56 scientific experts who meet biannually to assess the applications and make recommendations to the Leading Group on Agricultural GMO Biosafety Management (also within the Ministry of Agriculture) for final decision.

Several provinces also have biosafety management offices to monitor research, field trials and commercialisation in their local area as well as oversee the implementation of biosafety regulations.

marketing and trade

The Joint Ministerial Meeting is also responsible for determining import, export and labelling policies for GM products in China.

commercialisation

The Leading Group on Agricultural GMO Biosafety Management is the body that grants approval for commercialisation of GM crops. The group may also consult with the Joint Ministerial Meeting and national leaders before finalising approval.

intellectual property rights

China has improved its intellectual property rights regime over the past two decades, reflecting domestic and international seed firm requirements. The Plant Variety Protection Act was passed in 1997 and the first applications for patents were accepted in 1999. All major crops, except cotton, are eligible for patent protection and applications more than tripled between 1999 and 2003 (Huang et al. 2007).

One key aspect of China's intellectual property rights system is that commercial varieties can be used as parents in the development of new varieties. These new varieties can then be legally sold without fees or royalties being awarded to the original developer. In response, domestic and international firms have used patents and trademarks in attempt to prevent the use of their varieties. For example, Monsanto in China has patented the process used to create their Bt cotton varieties, as well as certain genes (Huang, Hu, Rozelle and Pray 2005). It is unclear whether these measures have been effective, with evidence indicating that protection is still inadequate under current regulation and enforcements of intellectual property rights.

appendix **D** policy arrangements for GM crops in australia

federal regulatory arrangements

Agricultural biotechnology is regulated in Australia by two main government agencies: the Office of the Gene Technology Regulator (OGTR) and Food Standards Australia New Zealand (FSANZ). The OGTR was established in 2001 within the Australian Government Department of Health and Aging under the Gene Technology Act (2000). The role of the OGTR is to regulate the use of genetically modified organisms, while FSANZ is responsible for the regulation of GM food products (box 8).

The Gene Technology Regulator grants authorisation for research, manufacture, production, field trials and commercial release of GM organisms. The OGTR also assesses the import of GM organisms for food or feed. Australia has strong standards on potential risks to human health and safety and the environment from biotechnology and these factors are thoroughly assessed by the OGTR before approval will be granted for a GM organism. The OGTR is also advised by other gene technology committees on potential issues such as ethical concerns and the broader interests of the Australian community.

FSANZ assesses the safety of all consumable foods, including imports, before they are permitted for consumption in Australia. This includes all aspects of the food supply chain, including primary production, manufactured food and food retail outlets. Cottonseed oil derived from GM cotton is the only approved GM food product produced in Australia. However, FSANZ has approved for import several GM food products not currently approved for production in Australia. These products include varieties of maize, potato, soybean, sugar beet and canola.

FSANZ has also developed standards for the labelling of GM food products, which have been in place since 2001. All food products with GM ingredients are subject to mandatory labelling if introduced DNA or proteins are present in the final product. Non-GM food products with an unintended presence of GM material in a quantity of no more than 10 grams per kilogram per ingredient do not require a GM label (FSANZ 2007).

box 8 regulations affecting GM crop adoption in australia**trial and commercial release**

All field trials and commercial releases of genetically modified organisms (GMOs) must be approved by the Gene Technology Regulator whose powers are prescribed by the *Gene Technology Act 2000* (Commonwealth). The object of this act is to protect the health and safety of people and to protect the environment, by identifying the risks posed by, or as a result of, gene technology and by managing those risks through regulating certain dealings with GMOs.

marketing approval

All genetically modified foods must undergo a rigorous science based pre-market safety assessment by Food Standards Australia and New Zealand. This safety assessment is aimed at ensuring that GM foods sold in Australia are at least as safe as non-GM varieties of the same crop.

imports

Import of live and viable genetically modified organisms must be approved by the Gene Technology Regulator.

labelling

Under standard 1.5.2 of the Australia New Zealand Food Standards Code, labelling is mandatory for a food that is, or contains an ingredient, a processing aid, or a food produced using gene technology that contains novel DNA and/or novel proteins or has altered characteristics, but does not include:

- highly refined food, other than with altered characteristics, where the effect of the refining process is to remove novel DNA and/or novel protein
- a processing aid or food additive, except where novel DNA and/or novel protein from the processing aid or food additive remain present in the food to which it has been added
- flavours present in the food in a concentration not more than 1 gram per kilogram or
- a food, ingredient or processing aid in which genetically modified food is unintentionally present in a quantity of no more than 10 grams per kilogram per ingredient.

Source: Foster and French (2007).

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