Independent Review of the South Australian GM Food Crop Moratorium

Prepared by
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Report to the SA Minister for Primary Industries and Regional Development

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Hon. Tim Whetstone MP
Minister for Primary Industries and Regional Development
1 King William Street, Level 10
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Dear Minister,

I am pleased to submit to you the requested *Independent Review of the South Australian GM Food Crop Moratorium*.

I would like to thank all those who have taken part in the Review so far by providing submissions or other pertinent information. I am very grateful also for the excellent Secretariat support provided by your department's staff in PIRSA offices at 25 Grenfell Street and on the Waite campus.

Sincerely,

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Terms of reference

South Australia currently has a moratorium on the commercial cultivation of GM food crops which is scheduled to continue until 2025. This Independent Review is to investigate the benefits and costs of the moratorium to the state of South Australia and to the state's agricultural and food production industries, and to consider whether it is in the interests of maximising the state's economy and of maximising returns for the state's agricultural and food production industries for the moratorium to continue, and if so, under what conditions.

The Review will:

1. Assess available evidence on the market benefits of South Australia's moratorium on the commercial cultivation of GM crops.

2. Assess the degree of awareness of South Australia's moratorium by key trading partners and food production businesses operating in South Australia and other Australian states.

3. Where there is evidence of market benefits resulting from the moratorium, examine whether it is possible to retain such benefits for industry through the use of systems of segregation in the supply chain, having regard to segregation protocols adopted in other jurisdictions.

4. Consider evidence from South Australian businesses and industry, market and trade data, the experience in other Australian and international jurisdictions and other relevant evidence to inform the analysis.

5. Explore whether there are potential innovations likely to be available for commercial adoption by South Australia's agricultural industries prior to 2025 that would justify a reconsideration of the moratorium on grounds of economic benefit to the state.

6. Quantify where possible the economic costs and benefits of maintaining, modifying or removing the moratorium, not limited to but including on-farm impacts, food manufacturing, supply chain costs and impacts on research and development investment in South Australia.

Under a policy principle established within the *Gene Technology Act 2000*, the current SA moratorium exists for trade and market access purposes.

Outside the scope of this review are matters that are the responsibility of regulatory agencies in other jurisdictions, such as matters relating to the human health, safety and environmental impacts of GM crops.

Acknowledgments

The reviewer is very grateful for all those organizations and people who made submissions following the call for them on 14 September 2018. Thanks also go to those contacted for data, research papers and other information needed to assess potential consequences of alternative policies. A special thanks to members of the Minister's GM Crop Advisory Committee, Professor Ross Kingwell (University of Western Australia and AEGIC), Dr Tony Gregson (farmer in western Victoria), Dr Stuart Smyth (University of Saskatchewan), Scott Biden (University of Guelph), numerous PIRSA and DTTI staff, and University of Adelaide food crop researchers at the Waite Campus.

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List of abbreviations and acronyms

APVMA	Australian Pesticides and Veterinary Medicines Authority
AQIS	Australian Quarantine and Inspection Service
CRISPR/Cas9	Clustered regularly interspaced short palindromic repeats and CRISPR-associated protein 9 (a family of DNA sequences found within the genomes of prokaryotic organisms such as bacteria and archaea and derived from DNA fragments from viruses that have previously infected the prokaryote and are used to detect and destroy DNA from similar viruses during subsequent infections)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWR	(Commonwealth) Department of Agriculture and Water Resources
DNA	Deoxyribonucleic acid
DTTI	(South Australian) Department of Trade, Tourism and Investment
EU	European Union
FSANZ	Food Standards Australia New Zealand
GDP	Gross domestic product
GM	Genetically modified
GMO	Genetically modified organism
GM food	Food produced from or using GMOs
GM-free	Contains no GM material (novel DNA or novel protein), and has no altered characteristics, hence stricter requirements than for non-GM food
GRDC	(Commonwealth) Grains Research & Development Corporation
IGTA	Intergovernmental Gene Technology Agreement
KIPG	Kangaroo Island Pure Grain
LLP	Low Level Presence (of grain contamination by another product)
NICNAS	National Industrial Chemicals Notification and Assessment Scheme

Non-GM food	Food with no more than a small fraction per ingredient (1% in Australia) of GM material unintentionally present, hence a less strict requirement than for GM-free food. Non-GM food need not be labelled as 'genetically modified'.
OGTR	Office of the Gene Technology Regulator
PIRSA	(Department of) Primary Industries and Regions South Australia
RARMP	Risk assessment and risk management plan (issued by the OGTR)
R&D	Research and development
RR	Roundup Ready ®
TAF	Technology access fee
TGA	(Commonwealth) Therapeutic Goods Administration
TT	Triazine tolerant (canola varieties)

Executive summary

There has been a moratorium on GM crop production in and transportation of GM crop products through South Australia since 2003. The key objective of the moratorium, following the approval in 2003 by Commonwealth authorities of commercial production of GM canola in Australia, has been to provide time to assess the risks that GM food crops might impose, in terms of access to markets and trade, for the state's conventional and organic growers and consumers/users of non-GM crop varieties.

In the fifteen years that have elapsed since the moratorium was first imposed, the policy has been re-considered and renewed three times (in 2008, 2014 and 2017) by the state's previous Labor Government. As currently legislated, the moratorium is to apply through to 2025. Meanwhile, all other mainland states have allowed their farmers to grow GM crops, most recently Western Australia in 2009; and in 23 other countries the area sown to GM crop varieties has grown from zero in 1995 to 13% of the world's total cropland.

A nationally consistent legislative scheme for gene technology was introduced with the Commonwealth's *Gene Technology Act 2000* and corresponding State and Territory legislation, including South Australia's *Gene Technology Act 2001*. The federal Act was enacted to protect the health and safety of people and the environment. It regulates all dealings with genetically modified organisms (GMOs) in Australia, including research, manufacture, import, production, propagation, transport and disposal of GMOs. That Act is administered by the Office of the Gene Technology Regulator (OGTR) within the Australian Department of Health, which decides whether to approve field trials and then the commercial release of a GMO. Before issuing each such national licence, the Regulator prepares a risk assessment and risk management plan that identifies any potential risks, based on credible evidence, and the means of managing those risks. As well, GM food products are regulated by Food Standards Australia New Zealand. FSANZ sets standards for the safety, content and labelling of all foods sold in Australia, both domestically produced and imported. Each GM food or ingredient is subjected to a mandatory pre-market safety assessment to ensure it is safe for human consumption; and any GM final-product food with novel DNA or protein present must be labelled as such, according to FSANZ specifications. Labelling is also required for GM foods that have an altered characteristic when compared to a counterpart non-GM food.

However, the Commonwealth regulatory agencies do not take into account trade or marketing considerations, which are at the discretion of each State or Territory government. It is those (and only those) considerations that are the subject of this Review (as promised by the Liberal Opposition in the lead-up to South Australia's March 2018 election, which the Opposition won).

The current status of GM approval by Australian states and territories is as follows:

- **No restrictions** on GM crop production of varieties approved by OGTR: Northern Territory, Queensland, Victoria and Western Australia;
- **Partial restrictions** on GM crop production: New South Wales (currently allows GM varieties of only cotton and canola);

- **Moratorium** on GM crop production: South Australia, Tasmania and the Australian Capital Territory (although exemptions are granted for trials in SA and the ACT).

This suggests three options available to South Australia today: to maintain its moratorium through to 2025 as currently legislated, to partially de-restrict GM food crop production in the state, or to remove all restrictions on the production and transportation of GM food (and possibly other) crop products.

Technological change is one of the main drivers of overall economic growth, and especially of agricultural output growth. Indeed, ***farm productivity growth has contributed strongly to growth in Australia's farm output since the 1950s, and has outpaced productivity growth in other market sectors of the Australian economy by a considerable margin until recently (Finding 1.1).***

However, ***productivity growth has slowed in the past decade or so in Australia's farm sector relative to its non-farm sectors and to farm sectors in countries that have fully embraced GM crop technologies such as the United States and Brazil (Finding 1.2).***

The introduction of almost every new technology has losers as well as winners though, as does almost every policy or regulatory change, even if the community would be better off overall from the new technology or policy reform. In the case under review, the direct beneficiaries of the GM crop moratorium are those producers and consumers/users of non-GM crops grown in South Australia who wish the State to retain its non-GM status and perceive a risk that GM crop production or transportation might lower the value of those non-GM crop products. Those who lose include farmers who believe the freedom to sow GM crop varieties would boost their net income and hence land value, as well as life science firms and public research institutions that would gain from developing or adapting GM varieties for South Australian crop-growing conditions.

To date, no assessment has been made to the current Government's satisfaction to see (a) whether perceived gains to non-GM farmers in South Australia exceed the losses to those who, in the absence of the moratorium, would take advantage of current and future Commonwealth approvals to use GM technology and, if so, (b) whether there are cost-effective segregation mechanisms available to allow GM and non-GM food crop varieties to co-exist in South Australia such that the identity and thus value of non-GM crop products could be preserved.

Now is an appropriate time to undertake such an assessment because there is a substantial accumulation of empirical evidence in other jurisdictions of the market and trade consequences of allowing GM food crops to be grown alongside non-GM crops.

Australia approved the production of GM cotton in 1996, and since then pesticide use by its cotton farmers has fallen dramatically, yields per hectare have risen by two-fifths, and cotton output has more than doubled (with GM varieties now accounting for 99% of Australia's cotton area). That has kept the Australian cotton industry internationally competitive in the wake of a trend decline in the international price of cotton due to widespread adoption of GM cotton varieties globally.

Canada experienced a similar speed and extent of adoption of GM canola from 1996; and both the United States and Brazil now have average adoption rates of 94% for soybean, maize and canola.

In Australia, where commercial production of GM canola was allowed after 2003, the extent of adoption has been much lower, averaging no more than 20% in aggregate for the three states currently growing it (NSW, Victoria and WA). This fact has an important bearing on both attitudes toward and the estimated economic effects of South Australia's GM crop moratorium.

Community attitudes to the moratorium were captured in the 216 submissions received by the Reviewer. Most submissions argued strongly either to retain or to immediately remove the moratorium, with only a few containing qualifications or nuances. Of those 216, 150 were virtually identical half-page generic statements in opposition to GMOs in general, copied from https://dogooder.co. Of the remaining 66, 29% favoured retaining the moratorium until 2025, and 12% had a nuanced or more ambivalent view. Six of the strongest 'removal' submissions came from key South Australian organizations representing most of South Australia's 9400 farms. That is, ***the majority of submissions, including those from organizations representing most of South Australia's farmers, favour the immediate removal of South Australia's moratorium on GM crop production and transport (Finding 2.3).***

Most of those wishing to see the moratorium remain until 2025 suggested the GM moratorium adds a premium to the price of non-GM food produced in the state and/or greater access to domestic and foreign markets. It was clear that ***there is awareness and appreciation of South Australia's GM food crop moratorium by at least one foreign firm (in Japan) and by several food processing businesses operating in South Australia (Finding 2.1).***

However, apart from one qualified exception, no evidence is provided in those pro-moratorium submissions that would support a view that any current price premium or market access for non-GM South Australian crops would be diminished if GM food crops were allowed to be grown in the state on condition of careful segregation. A qualified exception has to do with Kangaroo Island. Submissions from there claimed that the island's GM-free status has enabled them to access a lucrative GM-free market segment in Japan. They further claimed that even ***if GM food crop production were to be allowed in the rest of South Australia, Kangaroo Island would be able to preserve its unique identity so as to retain access to Japan's high-priced market for GM-free grain*** **provided the island remained a GM-free zone** ***(Finding 2.2).***

A number of submissions also stressed the importance of the state government automatically adopting into law any future amendments to Commonwealth legislation on gene technology, and avoiding duplicating the efforts of the federal bodies authorised and equipped to test the environmental, health and safety attributes of each new GM crop application. Some also emphasized that having common national and state legislation in this area reduces the uncertainty that hampers investment in GM crop and related agricultural biotech R&D. Several submissions stressed that, because the GM moratorium restricted research-to-market pathways, fewer research dollars, scientists and post-graduate students have been coming to (or remained in) South Australia. This suggests ***bringing South Australian legislation into line with other mainland states and the Commonwealth will***

benefit the state by attracting/retaining research dollars, scientists and post-graduate students in South Australia (Finding 2.4).

In the absence of much other hard evidence in submissions, further empirical evidence on market access was assembled for this Review by looking at the bilateral trade pattern of Australia's non-GM canola exports, particularly to the European Union (EU) and Japan. During 2012-17, the shares of canola exports to the EU from the two main exporting states, Western Australia and New South Wales, were only 1 and 3 percentage points lower than South Australia's average of 72%. Evidently, segregation and identity preservation are sufficiently robust that the EU does not discriminate between Australian states in sourcing non-GM canola. That is, ***data on canola exports from Australian states to the European Union do not support the view that South Australians enjoy better access in EU non-GM grain markets (Finding 3.1).***

There is evidence that non-GM canola receives a premium price over that for GM canola varieties currently available. That premium averaged $32/tonne or 6% during 2011/12 to 2017/18, based on sales of both types of canola at Kwinana in Western Australia. Further evidence of a non-GM price premium was assembled by looking at export prices for canola from both Canada (which is GM because Canada does not segregate) and Australia (which presumably is selling non-GM canola to that market). Over the period 2010-17, the Australian export price of canola averaged 4.0% higher than Canada's.

Also pertinent for this Review is whether South Australia's other crop products receive a price premium for being produced in a non-GM state. A recent study submitted to the Review found average prices of wheat, barley and canola in South Australia were no higher than those in Victoria or Western Australia where GM crops are allowed. That is, ***the only data provided in submissions on prices of grain in South Australia versus grain in neighbouring states suggest that since 2012 there has been no premium for grain from South Australia despite it being the only mainland state with a GM crop moratorium. (Finding 3.2).***

Even if a price premium had been found for grain from non-GM South Australia, one needs to ask whether such a price premium would continue in the absence of the GM crop moratorium. That depends on how effective the segregation process would be if the moratorium were to be dropped. Prior to the approval of GM crop production in the eastern states, much was done to establish segregation and identity preservation protocols and codes of practice to ensure that GM and non-GM crops can coexist. Single Vision Grains Australia set up a quality assurance process along the entire supply chain including sampling and testing when needed to verify that the integrity of the processes from planting seed through to grain presented for sale accords with customer specifications and government regulations. The principles and processes have been taken up and managed by the Australian Oilseeds Federation, which maintains and oversees the delivery of market requirements for domestic and export trade. The biggest handler of GM grain, Western Australia's Co-operative Bulk Handling Group, has successfully segregated GM and non-GM canola to internationally acceptable levels such that there have been no contamination issues since the GM crop's introduction in that state in 2010. That is, ***the experience of GM canola production and marketing in other mainland stages over the past decade reveals that segregation and identity preservation protocols and practice codes can and do ensure the successful coexistence of GM and non-GM crops in Australia (Finding 3.3).***

While ever there is a moratorium on GM crop production, there of no local path to market for research aimed at developing new GM varieties suited to that jurisdiction. Without a path to market, even public research funders such as the Grains Research and Development Corporation (GRDC) will not invest in pre-commercial research. Thus an important consequence of South Australia's GM crop moratorium has been not only the withdrawal of private R&D investment by life science companies but also less public sector funding for the state's research institutions. The moratorium also leads young scientists interested in a career in frontier biotech research to move elsewhere or not come to South Australia when there are less-constrained research environments interstate and overseas. With less dollars being spent on R&D and fewer scientists working at the frontier in South Australia, there is also less "spill-in" to the state from the outcomes of crop R&D investments interstate and abroad. In other words, ***the persistence of a GM crop moratorium in South Australia, especially in the face of the removal of moratoria a decade ago in neighbouring states, has discouraged both public and private agricultural R&D investments in this state (Finding 3.4).***

Many of the pro-moratorium submissions claim that there are fewer environmental costs, and in particular there is less chemical use, on South Australian farms because of the moratorium. This claim is denied by those favouring its removal. The reality is that growers of GM crops tend to use less farm chemicals overall than do producers of conventional crop varieties using no-till agriculture. A lower use of weedicide – especially glyphosate – is important following the widespread adoption of no-till cropping, because there is a risk of weeds becoming tolerant to such chemicals. To lower that risk of glyphosate resistance in key weeds, GM growers are advised to alternate Roundup Ready canola with other canola cultivars attuned to herbicide components other than glyphosate. In short, ***the adoption of GM crops typically leads to less rather than more use of farm chemicals, and the risk of herbicide resistance in key weeds can be reduced by alternating between different crop varieties (Finding 3.5).***

To examine the economics of retaining versus removing the GM moratorium in South Australia, the Review initially focused on canola as an illustration. There has been a much slower uptake of GM canola varieties in Australia than in Canada. One reason is that Australia has had access to non-GM hybrid varieties that were developed partly because of the moratoria in this country. Since some of those hybrid varieties fit a no-till farming system, they have reduced the current net economic and environmental benefits of switching to a GM canola variety, as compared with the net benefits that existed back in the mid-1990s in Canada. As well, prices have been slightly lower for GM than non-GM canola varieties, yields currently are not much above the best of non-GM varieties, the technology access fee for GM seed is considered by some farmers to be high, and growers are wary of too much dependence on Roundup and so prefer not to plant Roundup Ready canola in every rotation.

The benefit-cost analysis requires comparing gross margins of non-GM versus GM varieties. The 'counterfactual' used as a comparator is the gross margin for the variety that is currently most common in South Australia, namely triazine-tolerant (TT) canola, for which a gross margin spreadsheet for 2018 is available from PIRSA. The variables likely to affect the comparison of gross margins most are the product price, crop yield per hectare, variable costs (most notably of chemicals and the technology access fee), and the speed and maximum rate of adoption of GM varieties.

The results suggest there would be a small gain today of $38/hectare by allowing the production of Roundup Ready (RR) GM canola in South Australia, based on the current yield

gap of 10% in favour of the GM crop and a price premium of 5.2% in favour of non-GM canola. Were the omega-3 variety of GM canola to become available for 2019 planting and to attract a higher price, the estimated gross margin difference may become considerably greater: it rises to about $95/hectare if the O3 price were to match that for non-GM canola, and to $134/hectare if O3 attracted a price premium of 5% over non-GM canola. These comparisons illustrate the ***sensitivity of the gross margin differences to price assumptions***.

Gross margin differences are also sensitive to assumptions about the gap in yields per hectare. The gap in yields between TT and RR canola in the Wimmera region of Victoria during 2013-17 was 10% (1.35 vs 1.50 tonnes per hectare). However, in South Australia the average yield for non-GM canola over the period since the moratorium was imposed in 2003 is just 1.20 tonnes/hectare, making the gap between it and RR 20%. When that is assumed, the difference between the gross margins for TT and RR becomes $113/hectare, or three times the base case of $38. These comparisons illustrate the ***sensitivity of the gross margin differences to yield gap assumptions***.

In terms of aggregate dollars for South Australia, the differences between GM and TT gross margins apply only to that fraction of the state's canola crop that would switch from a non-GM to a GM variety. Two sets of calculations are presented, assuming the fraction would rise evenly over the first 5 years and then plateau. The first is an historical one, involving estimates for the period 2004-18 of the cost of having a moratorium in the state so far following OGTR approval in 2003. The second set of calculations involves projections from 2019 to 2025, to estimate net benefits foregone by canola farmers should the moratorium remain in place for that period, as currently legislated. The average canola crop area of the state during 2004-16 is used in the historic case (225,000 ha), while the average for just 2011-16 is used in the prospective case (265,000 ha). With these assumptions, ***the cumulative cost to canola farmers of South Australia's GM crop moratorium is estimated to be up to $33 million over 2004-18, and will be at least another $5 million if the moratorium is kept until 2025 – and possibly much more if Omega 3 canola proves to be higher priced and more profitable than current Roundup Ready canola (Finding 4.1).***

That gain foregone by farmers is net of the technology access fee paid to the producer of RR canola seed. Over the 2004-18 period the estimated fee accumulates to $5.4 million, and during 2019-25 to $3 million, plus $424,000 per year thereafter. In so far as a fraction of that $8+ million technology fee revenue is invested by the life science corporation in extra crop R&D in South Australia to provide even more suitable GM varieties in the future, it (plus any extra matching funding attracted from, e.g., GRDC) would be an additional gain to the state. That is, ***gross revenue for the producers of GM canola seed would have been an estimated $5.4m higher during 2004-18 without the SA crop moratorium, and $3m higher during 2019-25 if the current technology access fee is unchanged – at least some of which would have been allocated to new crop R&D investments in South Australia (Finding 4.2).***

Not captured in these calculations are the producer benefits in the crop rotation the season following a GM canola crop, in the form of reduced weed control costs and increased yields. Based on GRDC findings, PIRSA estimates they could amount to between $12 and $36 per hectare. That adds an extra $0.3-0.9 million to the annual benefits of withdrawing from the moratorium even if the GM adoption rate is only 10%. Offsetting this additional benefit might be higher segregation costs if it is more expensive to preserve the identity of GM versus non-GM food crops than it is to do so between different non-GM crops. The above analysis assumes that there would be no extra segregation costs for either non-GM or

GM growers, but some earlier analysts have assumed they could amount to as much as $11.50 per hectare of GM area. With 10% adoption, such a cost would subtract $0.3 million from the annual direct benefits of dropping the GM moratorium. So ***while the above findings ignore farmers' reduced weed control costs and increased yields for the crop that follows GM canola the next season (worth up to $0.9 million per year), they also ignore possible additional segregation costs (up to $0.3 million per year) if the GM moratorium is dropped (Finding 4.3).***

Also not captured in the above calculations are the benefits of having an enhanced number of crop varieties to choose from to best suit each season's weather anomalies and each region's local climatic, agronomic, etc. environment. Those benefits include reductions in the variability across seasons in yields and net farm incomes – something that farmers are valuing more and more as climate changes keep adding to the volatility of their earnings.

Nor do the above calculations show (as they are outside the Review's terms of reference) the environmental benefits of GM versus non-GM canola production from reduced farm chemical use, and any further reduction in tillage and thus in the greenhouse gas emissions associated with that activity. Those environmental benefits have been shown by others to be potentially very large.

In addition to potentially higher gross margins and hence annual farm revenues that would flow from being able to adopt GM varieties, their enhancement of farm productivity also is likely to boost the value of farm land in the state. Any such wealth enhancement would be enjoyed by all farm landowners, including those who chose not to adopt GM varieties (assuming coexistence protocols and codes of practice work as well in South Australia as they have in the other mainland states).

Together these unquantified ***additional farmer benefits from being allowed to grow GM crops, not included in the above calculus, are (a) having more varieties to choose from to best suit specific environments and seasonal weather anomalies, (b) environmental and health benefits from reduced farm chemical applications, and (c) a likely boost to the value of farm land whose productivity and profitability is raised (Finding 4.4).***

Yet another direct economic benefit to South Australia that would result from removing its GM moratorium that is not captured in the above calculations relates to the transporting of GM crop products. Such movements are banned under the current moratorium. If relaxed, there would be a stronger demand for South Australian transit services, should there be a wish to move grain or seed between the eastern states and Western Australia to smooth out seasonal anomalies. South Australian GM growers and GM seed suppliers would be in a stronger position than those in neighbouring states to supply such demands, as they would have less intra-national distance to transport their product east or west than would their more-distant neighbours. That is, ***removing the moratorium on the transport of GM crop products in South Australia would expand the demand for transport services and lead to more interstate shipments of canola (Finding 4.5).***

Should it be decided to remove the GM crop moratorium in the mainland part of the state but not on Kangaroo Island, the ***benefits of allowing GM canola production in South Australia would be reduced by less than 2% if the GM moratorium were to be retained for Kangaroo Island (Finding 4.6).***

The above calculus focuses on canola because that is considered by most commentators to be the only significant GM crop currently of relevance to South Australia should its GM crop moratorium be removed. Canola is a relatively minor crop in this state, however. More significant economically are wheat, barley, pulses and even hay, not to mention grasses for pasture grazing, horticultural crops, and winegrapes. Hence ***the benefits of removing the state's GM moratorium may be far greater than just those from canola as new GM varieties of other crops (and pasture grasses) of relevance to South Australia are developed and approved by the OGTR (Finding 4.7).***

Meanwhile, several exciting new plant breeding avenues are evolving, perhaps the most relevant to this Review being gene editing. Regulations relating to these new techniques are still evolving in Australia and elsewhere. The European Court of Justice ruled in July 2018 that gene editing be regulated in the same way as GMOs, even though gene editing is not transgenic. The OGTR released a guide in October 2018 that outlines how it expects to regulate this new technology in Australia. The guide suggests that, across the spectrum of gene editing interventions, the least invasive applications will be regulated like conventional breeding but the most invasive will be treated like GMOs. Thus ***while new crop breeding techniques such as gene editing offer further benefits to farmers, some of the new varieties may be regulated as if they are GMOs and thus would be unavailable in South Australia while ever the state's GM moratorium remains (Finding 4.8).***

To summarize, the three policy options this Review has considered are (a) maintaining, or (b) modifying, or (c) removing South Australia's moratorium on GM food crop production and transport that is currently scheduled to remain in place until 2025. Most of the submissions to the Review clearly favoured either the 'maintain' option or the 'remove' option. A small number favoured the 'modify' option, most with the specific proposal that the moratorium be maintained for Kangaroo Island even if the government chooses to remove it for the state's mainland regions. The net economic (and environmental) benefits to the state's canola farmers and to providers of GM seed of adopting the 'remove' option would be very considerable, and would be at most only 2% lower if the GM moratorium were to be maintained for Kangaroo Island.

Those favouring the 'maintain' option include people who may have ethical, philosophical or spiritual objections to GM technology, or who worry about as-yet-unknown risks that GM crops may bring in terms of food safety and farmer and environmental health. Those are matters dealt with by Commonwealth agencies and therefore are outside the terms of reference of this Review. Most of the other pro-moratorium submissions suggest the GM crop moratorium provides greater access to domestic and foreign markets and/or a premium price for non-GM food produced in the state. Those favouring the 'remove' option, by contrast, argue the state would be a net beneficiary if the moratorium was dropped because they see little if any evidence of marketing and trade advantages of South Australia staying GM-free. The evidence examined in this Review supports the latter view, while recognizing that there are numerous issues affecting both 'maintain' and 'remove' options that are difficult to quantify.

1

Introduction

The purpose of this Review is to provide the government and people of South Australia with an independent assessment of the economic costs and benefits of maintaining, modifying or removing the South Australian moratorium (which is currently scheduled to continue until 2025) on the production or transport of genetically modified (GM) crops. An independent review is a common step in best-practice assessment of regulatory policies (OBPR 2015), and benefit-cost analysis is a standard way to contribute clarity and transparency to that process, by providing decision makers with quantitative and qualitative information about the likely effects, under various explicit assumptions, of a particular regulation compared with feasible alternatives (OBPR 2016).

The original objective in 2003 of South Australia's moratorium on GM crops was to provide time to assess the risks for the state's conventional and organic growers and consumers/users of non-GM crop varieties that GM crop production in or transportation through South Australia might impose in terms of access to markets and trade. Fifteen years have elapsed since the moratorium was first imposed, and during that time all other mainland states have availed themselves of GM technology (most recently Western Australia in 2009). Hence a considerable body of evidence is now available to make such a reassessment.

This first section of the Review briefly summarizes the legislative history leading to the current regulatory environment, explains why the issue is important for South Australia and worthy of reassessment in 2019, and describes the present review process.

1.1 Background: the current regulatory environment

In 1996, GM crop products appeared on world food markets for the first time. Commercial GM crop production began with corn, soybean, cotton and canola, initially in North America and then South America.[1] By 2017 there were 190 million hectares of cropland (13% of the world's total) sown to GM varieties in 24 countries (Appendix 1). A further 43 countries import GM products. GM varieties accounted in 2017 for 50% of the global area sown to soybean, 31% for maize, 13% for cotton and 5.4% for canola. In just those countries where GM crop production is allowed, adoption rates average 80% for cotton and 77% for soybeans (ISAAA 2017). India is a striking example: it belatedly approved GM cotton in 2002 but 75% adoption was reached within six years. So large were the gains in India, such as doubling or more the incomes of farmers and almost halving their pesticide use, that adoption has been above 90% since 2012 (Qaim 2016, pp. 72-78).

Australia approved the production of GM cotton in 1996, and since then pesticide use by cotton farmers has fallen by up to one-third and growers' incomes between 1996 and 2015 have been boosted by $287 per hectare from insecticide-resistant traits and by $37 per hectare for herbicide-tolerant traits (Brookes 2016). As a result, yields per hectare have risen by two-fifths and cotton output has more than doubled, with GM varieties now accounting for 99% of Australia's cotton area (Cotton Australia 2018). That has kept the Australian cotton

[1] A GM tomato variety, Flavr Savr, was introduced into California in 1994, but it was not a commercial success and so was withdrawn from the market in 1997.

industry internationally competitive in the wake of a trend decline in the international price of cotton due to widespread adoption of this biotechnology (Anderson, Valenzuela and Jackson 2008).

In 2000/01 a nationally consistent legislative scheme for gene technology was introduced with the Commonwealth *Gene Technology Act 2000* and corresponding State and Territory legislation, including South Australia's *Gene Technology Act 2001*.[2]

The federal Act, which came into force on 21 June 2001, was enacted to protect the health and safety of people and the environment. It regulates all dealings with live and viable genetically modified organisms (GMOs) in Australia, including research, manufacture, import, production, propagation, transport and disposal of GMOs. That Act is administered by the Office of the Gene Technology Regulator (OGTR) within the federal Department of Health, which decides whether to approve field trials and then the commercial release of a GMO. Before issuing each such national licence, the Regulator must consult with all relevant local, state and federal government agencies and the public, and prepare a risk assessment and risk management plan (RARMP) that identifies any potential risks, based on credible evidence, and the means of managing those risks.

The OGTR regulates GMOs, as distinct from GM products.[3] The latter are regulated by four other national bodies with specific areas of responsibilities that include GM as well as non-GM products. Each of those bodies must notify the OGTR of any GM product approvals. One is Food Standards Australia New Zealand (FSANZ).[4] It sets standards for the safety, content and labelling of all foods sold in Australia, both domestically produced and imported. Each GM food or ingredient is subjected to a mandatory pre-market safety assessment to ensure it is safe for human consumption; and any GM final-product food with novel DNA or protein present must be labelled as such, according to FSANZ specifications. Labelling is also required for GM foods that have an altered characteristic (e.g., an altered nutritional profile) when compared to a counterpart non-GM food. An example is soybean with increased oleic acid content.

The OGTR maintains a comprehensive record of all GMO and GM product dealings. The list is freely accessible to the public on its website (http://www.ogtr.gov.au). In addition to cotton, GM food crop varieties have been approved for commercial release of canola, beginning in June 2003, and of safflower in June 2018.[5]

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[2] See also South Australia's *Genetically Modified Crops Management Act 2004* and its *Genetically Modified Crops Management Regulation 2008*. The 2004 Act established a GM Crop Advisory Committee that the Minister draws on periodically. On 1 August 2018 the Legislative Council of South Australia established a Select Committee on the Moratorium on the Cultivation of GM Crops in South Australia, and called for written submissions by 19 October 2018.

[3] Genetically modified organisms (GMOs) are defined as organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that has not occurred naturally by mating and/or natural recombination. The technology is called "modern biotechnology" or "gene technology", or "recombinant DNA technology" or "genetic engineering". It allows selected individual genes to be transferred from one organism into another, and also between unrelated species. Foods produced from or using GMOs are referred to as GM foods (WHO 2014).

[4] One of the other three is the Australian Pesticide and Veterinary Medicines Authority (APVMA), which is responsible for the registration, quality assurance and compliance of all pesticide and veterinary medicines up to the point of sale, including those created by or used on GM crops. Another is the Therapeutic Goods Administration (TGA), which ensures the quality, safety and efficacy of medicines, blood and tissues including GM and GM-derived therapeutic products. And the third one is the National Industrial Chemicals Notification and Assessment Scheme (NICNAS), which assesses industrial chemicals including GM products for their effects on human health and the environment.

[5] The OGTR has approved three GM canola varieties: Monsanto's 'Roundup Ready' (glyphosate tolerant), BASF's 'Liberty Link' (glufosinate tolerant), and Bayer's 'In-Vigor' (GM based hybrid system). Also approved are GM varieties of two flowers: blue carnation (in June 2003) and rose (in June 2009) but, since they are not

The Commonwealth's *Gene Technology Act 2000* and its regulatory agencies do not take into account trade or marketing considerations, which are at the discretion of each State or Territory Government. Those governments have responded in a variety of ways over the past two decades. New South Wales and Queensland allowed GM cotton to be grown from the outset (1996), as did Western Australia from December 2008; but during 2003/04 the ACT and most states including South Australia (but not the Northern Territory or Queensland) imposed a moratorium on the growing of GM food crops in general or canola in particular.

The initial objective of those state moratoria was to provide time to assess the risks for conventional and organic growers and consumers/users of non-GM crop varieties that GM crop production or transportation might impose in terms of their access to markets and trade.

Subsequent independent reviews of the moratoria in New South Wales (Armstrong, Adams and Reeves 2007), Victoria (Nossal, Forster and Curnow 2007) and Western Australia (Calcutt 2009) have been followed by policy reforms to allow limited commercial production of GM canola in early 2008 in Victoria and New South Wales and in 2009 in Western Australia, and unlimited production a year later in all three states. In October 2016 Western Australia followed Victoria in broadening its legislation to allow the growing of all GM crops that may be subsequently approved by the OGTR. Meanwhile, a governmental review in Tasmania (TDPIPWE 2013) led to a decision to retain that state's moratorium, despite the government's regularity impact statement finding that an extension of the moratorium to 2019 would have a net cost of $1.5 million, 70% of which would be regulatory costs borne by the state government (TDPIPWE 2014).

The South Australian government first reviewed its moratorium in 2008. It decided to ignore the advice and findings of its Genetically Modified Crop Advisory Committee, which had recommended the lifting of the current moratorium in all regions of South Australia except Kangaroo Island (SA Genetically Modified Crop Advisory Committee 2007). The government again reviewed the legislation in 2014, and decided that its moratorium on GM food crop cultivation and transport would continue until at least 2019. In November 2017 that same Labor Government extended the South Australian moratorium to 2025. The present review was promised by the Liberal Opposition in the lead-up to the March 2018 election, which the Opposition won.

In summary, the current status of GM crop approval by Australian states and territories is as follows:

- **No restrictions** on GM crop production of varieties approved by OGTR: Northern Territory, Queensland, Victoria[6] and Western Australia;
- **Partial restrictions** on GM crop production: New South Wales (currently allows GM varieties of only cotton and canola);
- **Moratorium** on GM crop production: Australian Capital Territory, South Australia and Tasmania (although exemptions are granted for trials in the ACT and SA).

This suggests three options available to South Australia today: to maintain its moratorium through to 2025 as currently legislated, to partially de-restrict GM crop production in the state, or to remove all restrictions on the production and transportation of GM food (and possibly other) crops.

1.2 Why this issue is important and worthy of reassessment now

food crops, they are not subject to moratoria. See the full list of nationally approved GM varieties at http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/cr-1

[6] Victoria's Minister for Agriculture still retains legislative control over the planting of GM crops in that state.

Technological change is one of the main drivers of overall economic growth, and especially of agricultural output growth. In Australia it has been important for more than two centuries, but especially post-World War II when public investment in agricultural research and extension expanded and more recently with the growth of private sector R&D investment and public-private partnerships (Alston and Pardey 2016).

However, the introduction of almost every new technology has losers as well as winners, as does almost every policy or regulatory change. One of the elements of good governance is to ensure any major policy or regulatory change would generate (economic/social/environmental) benefits net of adaptation and adjustment costs sufficient to be able to compensate the losers (again net of adaptation and adjustment costs).

In the case under review, the direct beneficiaries of the moratorium are those producers and consumers/users of non-GM crops grown in South Australia who wish the State to retain its non-GM status and perceive a risk that GM crop production or transportation might lower the value of those non-GM crop products.[7] Those who lose include farmers who believe the freedom to sow GM crop varieties would boost their net income and hence land value, as well as life science firms and public research institutions that would gain from developing or adapting GM varieties for South Australian crop-growing conditions.

To date, no assessment has been made to the current Government's satisfaction to see (a) whether perceived gains to non-GM farmers in South Australia exceed the losses to those who, in the absence of the moratorium, would take advantage of current and future Commonwealth approvals to use this biotechnology and, if so, (b) whether there are cost-effective segregation mechanisms available to allow GM and non-GM crop varieties to co-exist in South Australia such that the identity of non-GM crop products could be preserved.

Now is an appropriate time to undertake such an assessment because there is a substantial accumulation of empirical evidence in other jurisdictions of the market and trade consequences of allowing GM crops to be grown. Specifically, 23 years have elapsed since GM crops entered Australian and global markets, it is 15 years since canola was approved by the OGTR for production in Australia, and it is ten years since GM canola was first produced in New South Wales and Victoria and nine years in Western Australia. There is thus a great deal of experience and empirical evidence to draw on of relevance to South Australia.

How important have new technologies been to agricultural development in Australia? Australian farmers have a well-deserved reputation, built up over the past two centuries, of being innovative. That has enabled them to remain competitive in domestic and overseas markets despite relatively little irrigable land, very high wage rates, declining real prices for farm products through most of the twentieth century, occasional natural disasters, and periodic mining booms that cause the Australian dollar to appreciate against key currencies (Anderson 2017). Those same challenges are expected to continue to be in play during the present century, together with a rise in average temperatures and in the frequency and intensity of extreme weather events thanks to climate change. As well, there are ever-stronger community expectations that farmers will be good stewards of the environment, as part of

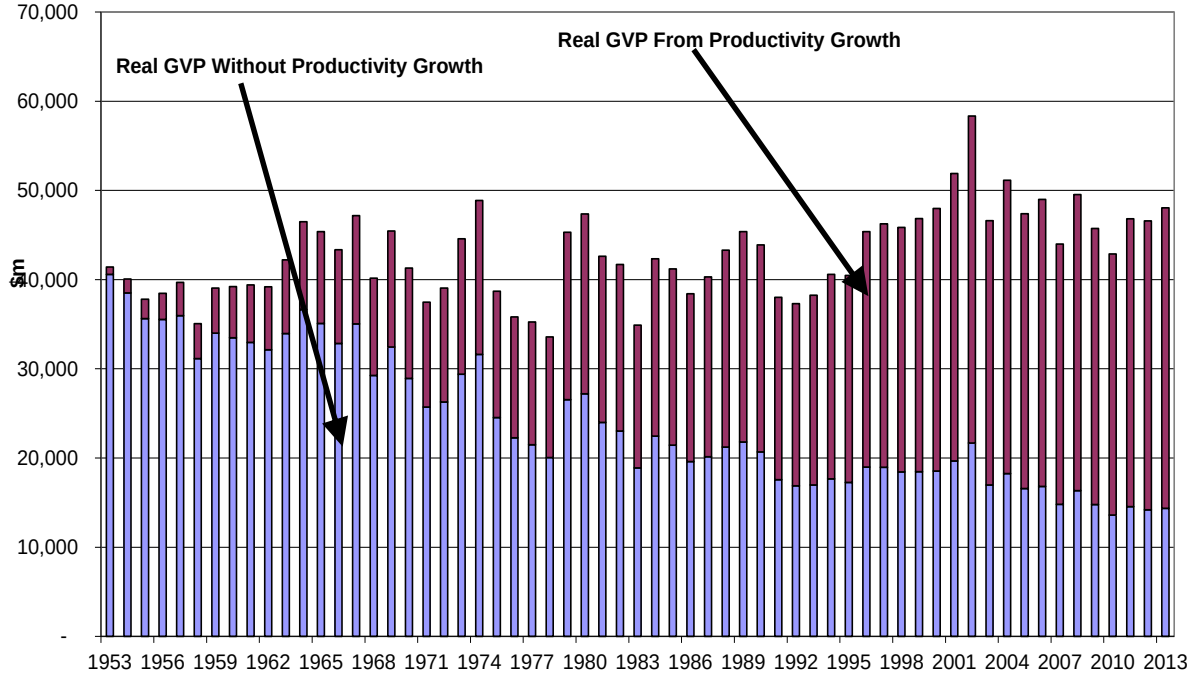
[7] Others in the community who support the moratorium include people who believe GM crops to be unsafe for human and environmental health or who have ethical or philosophical or spiritual objections to GM technology *per se* that perhaps no level of compensation would appease. While such concerns are given due weight in government policymaking (for example, via the periodic reviews of the National Gene Technology Scheme), they are beyond the prescribed scope of this review. The latest such review recommends, among other things, that states give on-going consideration to the economic effects, value and scope of their GM moratoria and that regulation is commensurate with the level of risk to avoid unnecessary regulatory burden (Department of Health 2018, p. 11).

their 'social licence to operate'. Meeting these challenges will be easier, the more new crop varieties can be developed that are more profitable and environmentally friendly not just in 'normal' seasonal weather but also in the face of extreme weather events.

During the first century of European settlement, much of the innovation in Australian agriculture was due to the inventiveness of farmers themselves. Increasingly since then it has been assisted by formal investment in agricultural research and extension, including in the public sector (state departments of agriculture, agricultural colleges, universities and CSIRO). The resulting productivity growth has contributed strongly to growth in farm output since the 1950s (Figure 1). Indeed productivity growth on farms had been outpacing that in other market sectors of the Australian economy, and by a considerable margin until recently (Figure 2).

Finding 1.1: Farm productivity growth has contributed strongly to growth in Australia's farm output since the 1950s, and has outpaced productivity growth in other market sectors of the Australian economy by a considerable margin until recently.

Figure 1: Gross value of agricultural production and the contribution of multifactor productivity growth, Australia, 1953 to 2013 (in 2013 A$million)

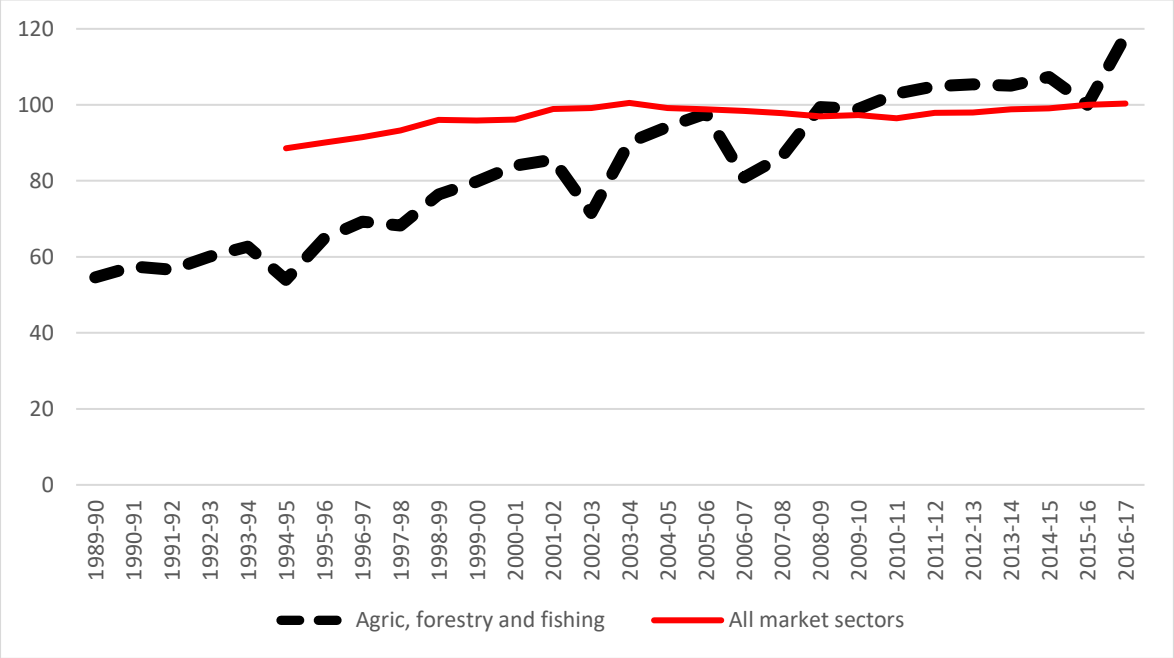


Source: Grafton, Mullen and Williams (2015), derived from ABARES data.

However, that sectoral productivity difference shown in Figure 2 has been much narrower during the past decade or so. Meanwhile in the United States, where GM varieties have been grown increasingly since 1996, productivity growth explains almost all of that country's farm output growth (Wang et al. 2015). Total factor productivity in agriculture during 1991-2010 grew at 1.9% per year in the United States, while in Brazil it grew at a massive 3.2% per year thanks largely to GM adoption, compared with just 1.2% in Australia (Fuglie, Wang and Ball 2012).

Finding 1.2: Productivity growth has slowed in the past decade or so in Australia's farm sector relative to its non-farm sectors and to farm sectors in countries that have fully embraced GM crop technologies such as the United States and Brazil.

Figure 2: Multifactor productivity in agriculture and in all market sectors, Australia, 1990 to 2017 (2015-16 = 100)



Source: Compiled by the author from ABS Cat. No. 5260.0.55.002, accessed 2 October 2018.

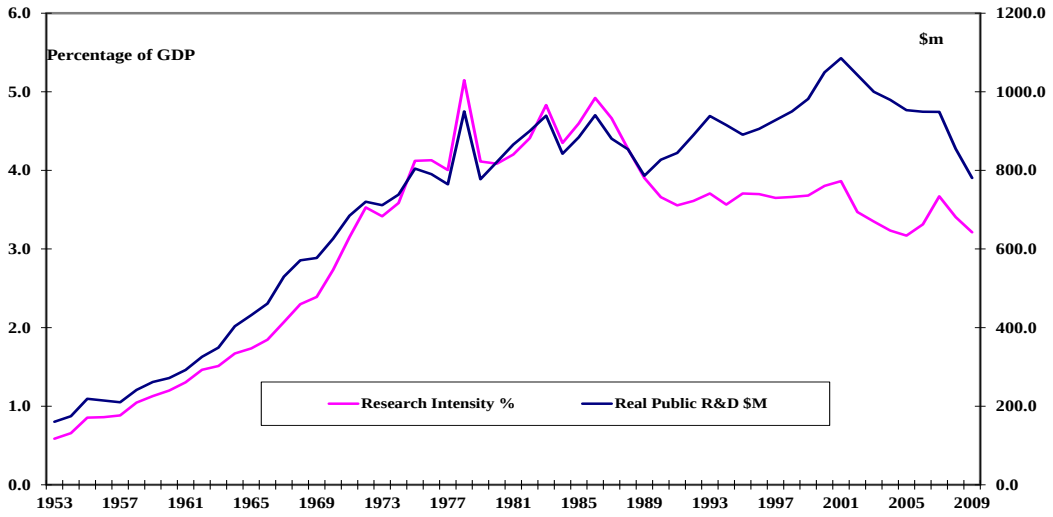
As in other sectors, an increasing proportion of agricultural R&D is being undertaken in the private sector (Fuglie 2016). For high-income countries as a whole, the private share of agricultural and food R&D has risen from 40% to 53% between 2000 and 2011 – and even in middle-income countries it had reached 36% by 2011, at which time those emerging economies accounted for 43% of global agricultural and food R&D, up from 29% in 1980 (Pardey et al. 2016, 2018).[8]

If Australian farmers are to retain their international competitiveness not only against North American farmers but also those in rapidly emerging economies, new technologies will need to be explored, adapted to local conditions, and integrated into producers' farming systems at least as rapidly as in the rest of the world. Yet Figure 3 reveals that public investment in agricultural R&D in Australia has not been growing in real terms, and has been falling since 1985 as a percentage of agricultural value added (GDP). Meanwhile, private investment in agricultural R&D appears to have not been growing as fast in Australia as elsewhere in the world.

One reason for the slowdown in Australia's intensity of agricultural R&D has been the reluctance of the community to allow production of genetically modified foods. GM cotton was approved in 1996 and adopted rapidly, but it took until late 2003 for the next crop (canola) to be approved by the OGTR for commercial production in Australia. Then because state governments wanted time to assess the market and trade implications of allowing GM food production in their state, and so placed temporary moratoria on the planting of GM varieties, there has been a slowdown in agricultural R&D investment. That slowdown has been prolonged in South Australia, it being the last mainland state to have retained its moratorium.

[8] On the growth and concentration of life science firms in global seed markets, see OECD (2018).

Figure 3: Real public investment in and research intensity of Australian agricultural R&D, 1953 to 2009 (A$million and % of agricultural GDP)



Source: Grafton, Mullen and Williams (2015), derived from ABS and ABARES data.

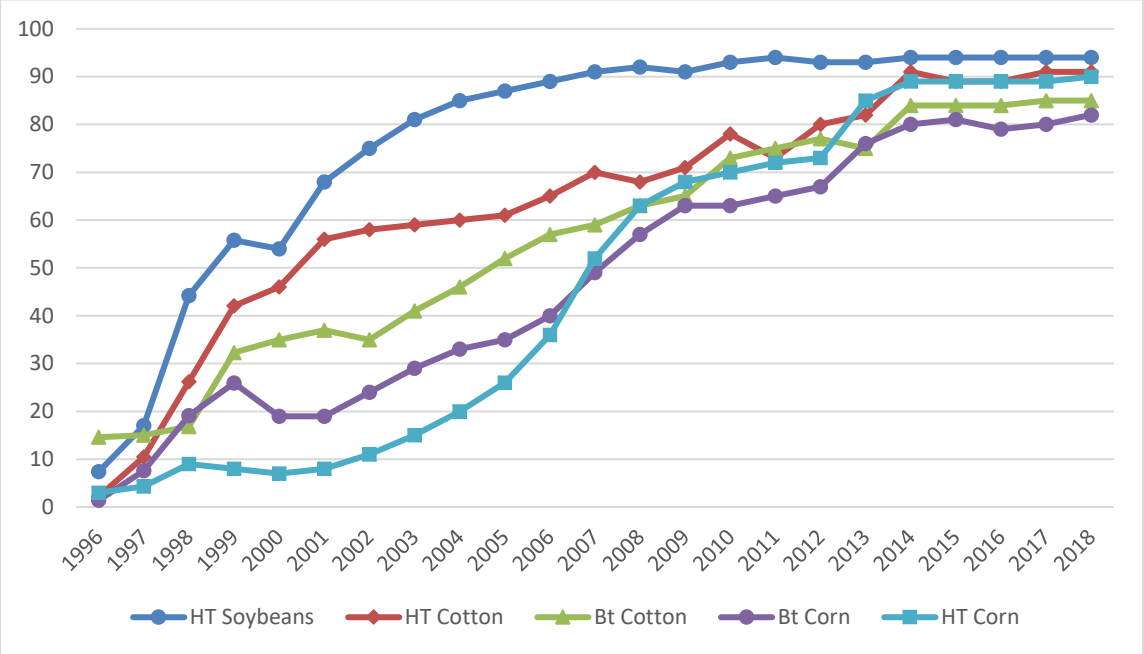
Are the benefits of retaining the moratorium on GM food crop production in South Australia greater than the costs of its retention in terms of opportunities postponed or foregone, bearing in mind any risk-reducing opportunities to mitigate some of those downsides? The costs include foregone expansion in or profitability of production in South Australia of canola (approved in December 2003) and safflower (approved in June 2018) and potentially of other crops the OGTR may approve in the future. Field trials are currently underway in Australia for GM banana, barley, grapevines, Indian mustard, maize, papaya, perennial ryegrass, pineapple, sugarcane, tall fescue, wheat and white clover (ABCA 2017); and FSANZ has already approved the following GM food ingredients for human consumption and for livestock feed: canola, corn, cottonseed and soybean from 2000, potato from 2001, sugar beet from 2002, rice from 2008, and safflower and Omega-3 canola from 2018.

The experience of the United States reveals that, in the absence of bans on GM crop production, adoption of new varieties can be very fast and can approach 90% of national coverage in just 10-15 years (Figure 4).

Canada's experience with GM canola and India's with Bt cotton are even more dramatic, with almost 100% adoption reached within a dozen or so years – and with yields per hectare trending upward considerably faster than before the adoption of GM varieties (Figure 5).

Both the United States and Brazil now have average adoption rates of 94% for soybean, maize and canola (ISAAA 2017). By contrast, Australia's adoption of GM canola not only began later but also has had to date a much slower uptake relative to Canada's (Figure 6).

Figure 4: Share of total area planted to GM varieties, various crops, United States, 1996 to 2018 (%)



Source: Compiled by the author from data at https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/recent-trends-in-ge-adoption/, accessed 8 October 2018

Figure 5: Yields per hectare and share of total area planted to GM varieties, canola in Canada and cotton in India and Australia, 1988 to 2017 (3-year average yields to year shown, and annual %)

(a) Canola in Canada (not including herbicide-tolerant but non-GM Clearview canola)

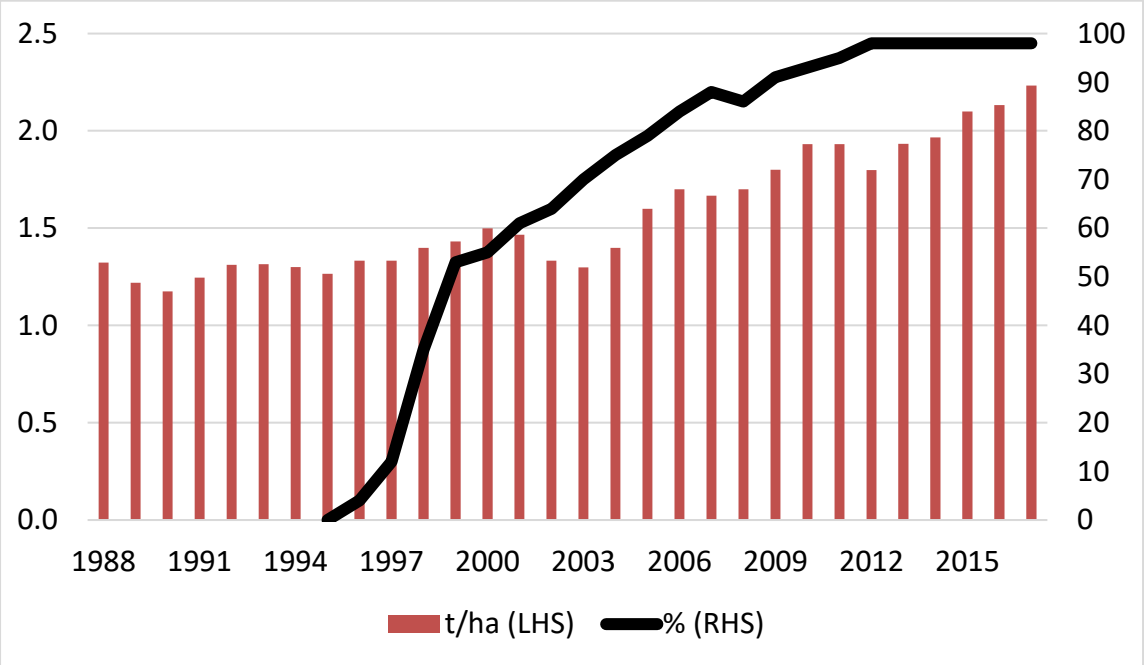
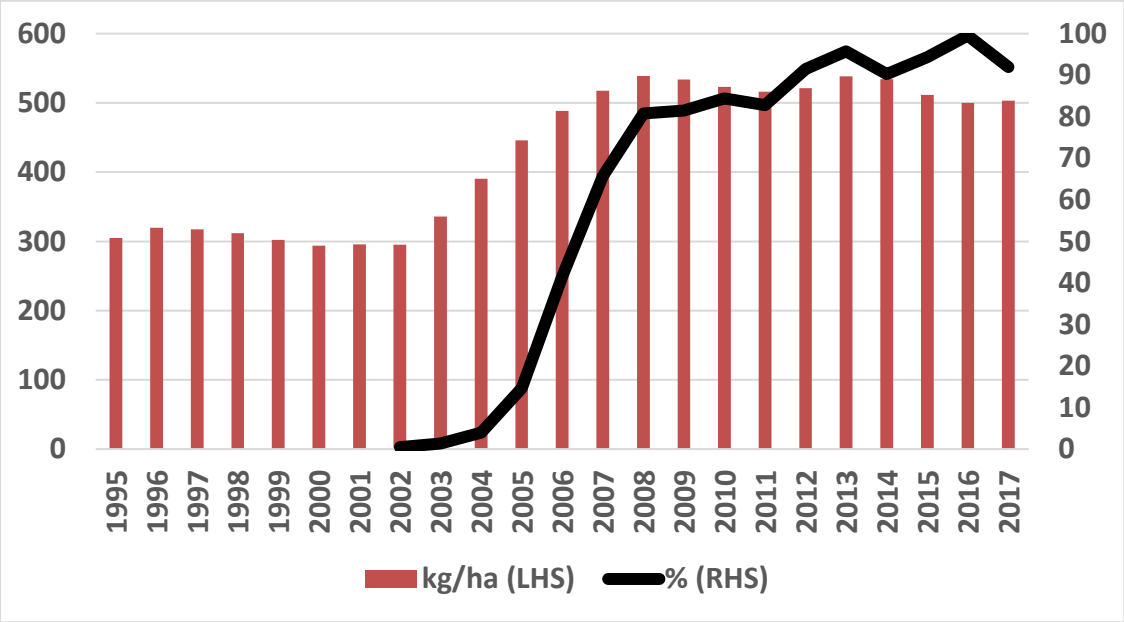
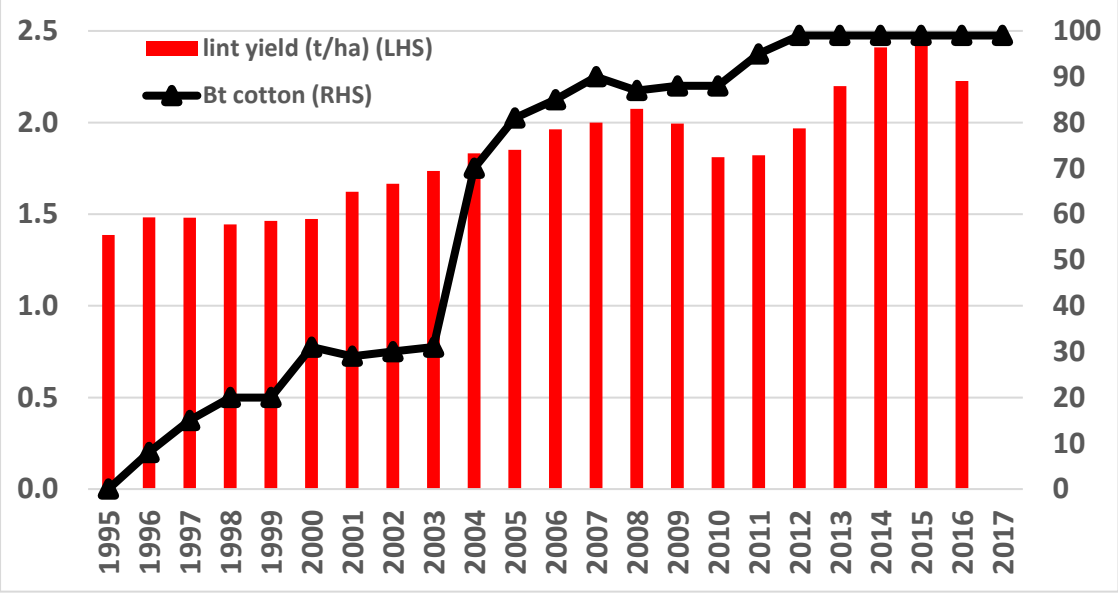


Figure 5 (continued): Yields per hectare and share of total area planted to GM varieties, canola in Canada and cotton in India and Australia, 1988 to 2017 (3-year average yields to year shown, and annual %)

(b) Cotton in India

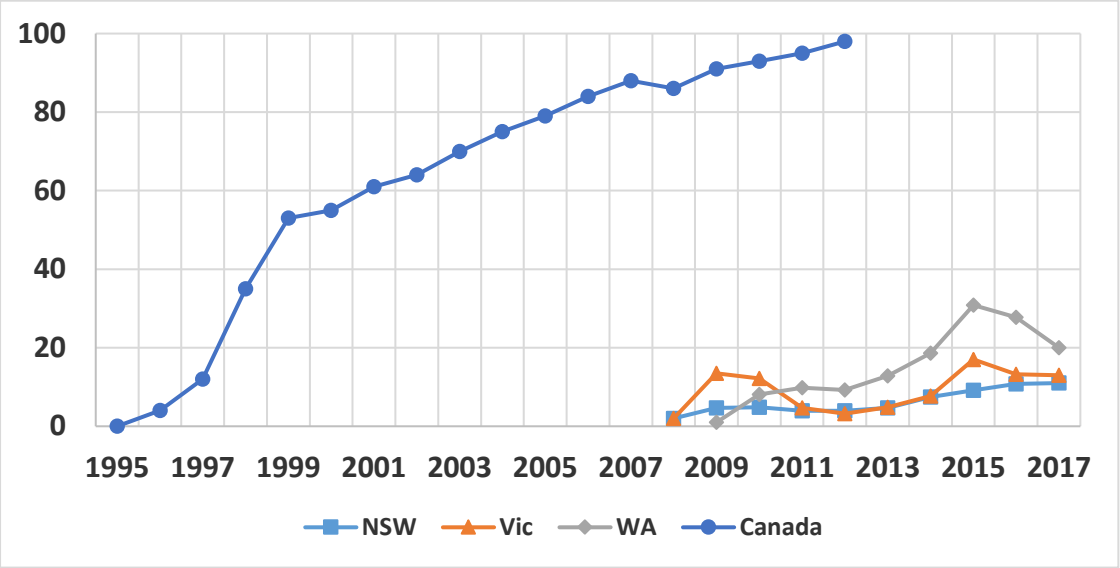


(c) Cotton in Australia



Sources: Compiled by the author from Canola Council of Canada data at https://www.canolacouncil.org/markets-stats/statistics/, and accessed 8 October 2018; for India, (Qaim (2016) and https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads, accessed 12 October 2018; and for Australia, Cotton Australia (personal communication).

Figure 6: Share of total canola area planted to GM canola, Australian States and Canada, 1995 to 2017 (%)



Source: Figure 5 above, ABARES (2017) for total area and, for GM planted area, www.abca.com.au/materials/statistics

Elsewhere in the world, GM varieties of alfalfa, apples, eggplant, papaya, potatoes, squash and sugar beet are already in the market. Other GM crops being researched by public sector institutions include bean, cabbage, cassava, chickpea, cowpea, groundnut, mustard, pigeon pea, rice, sorghum, tomato and sweet potato (Appendices 2-4 and ISAAA 2017). These efforts will lead to varieties with not only better agronomic traits of direct benefit to farmers (resistance to insect damage or viral infections, or tolerance towards certain herbicides or to drought, heat, frost, hail or salt) but also attributes of direct benefit to consumers (Barrows, Sexton and Zilberman 2014). The latter include improved shelf life, decreased allergenicity, and functional foods with boosted levels of phytoserols, carotenoids, antioxidants and essential fatty acids, as well as nutrient-enriched banana, canola, maize, nuts, potato, rice and soybean (ABCA 2017).

1.3 The current review process

The Minister for Primary Industries and Regional Development, the Hon. Tim Whetstone, announced on 14 September 2018 the establishment of an independent review of the moratorium on genetically modified food crop production in South Australia, thus delivering on a pledge to do so within six months of forming government.

Media notices and advertisements the following week called for written submissions from any interested parties up to 26 October 2018. The terms of reference of the review (see page iii) were included in that call for submissions. In particular, it was made clear that the focus is on trade and marketing considerations, and that matters relating to the human health, safety and environmental impacts of GM crops, which are the responsibility of the above-mentioned national regulatory agencies,[9] are outside the scope of this review.

[9] The Commonwealth agencies with those broader responsibilities review the National Gene Technology Scheme periodically to ensure it remains fit for purpose. The most-recent review, in October 2018, is published by the Department of Health (2018). See also FSANZ (2018). Those reviews, like those of other countries,

Primary Industries and Regions South Australia (PIRSA) assisted the Reviewer by receiving written submissions and providing information and technical support at his request. However, in all other respects the Reviewer performed his functions completely independently of the Department, and of the office of the Minister for Primary Industries and Regional Development.

Most submissions argued strongly either to retain or to remove the moratorium, although some contained qualifications or nuances. The next Section summarises those various arguments and associated qualifications.

continue to conclude that the risks associated with GM crops are no greater than with conventional crops. See, e.g., EASAC (2013) and House of Commons (2015). An eminent scientist's view of how genetic engineering is seen as part of the 10,000-year evolution of plant breeding can be found in Federoff (2004). On the political economy of GMOs and the role of non-government organizations and the news media in influencing policy choices, see, e.g., Herring and Paarlberg (2016), McCluskey, Kalaitzandonakes and Swinnen (2016), Smyth, Kerr and Phillips (2017) and Lynas (2018). Trends in community attitudes in Australia to gene technology are traced by the OGTR, see Cormick and Mercer (2017). A very comprehensive overview of the evolution of global seed markets, including the role of genetic modification in that evolution, is provided in OECD (2018).

2

Overview of written submissions

There were 216 written submissions received in the six weeks following a call for them in mid-September 2018 plus the following week to 5 November 2018. Of those 216, 150 are almost identical half-page generic statements in opposition to GMOs in general, copied from https://dogooder.co (most of which arrived, the majority from interstate, after the submission deadline). Of the remaining 66, 29% favour retaining the moratorium until 2025, 59% (several of which represented large numbers of South Australian farmers) favour complete removal of the moratorium, and the remaining 12% have a nuanced or more ambivalent view.[10] Submissions for which consent to publish was granted are available at http://pir.sa.gov.au/primary_industry/genetically_modified_gm_crops/gm_review/public_submissions_to_the_gm_independent_review. This section summarizes the key points raised in the submissions, beginning with those in favour of the current policy.

2.1 Favouring retention of the moratorium to 2025

The duplicated campaign letter from dogooder.co claims that GM crops would deprive other farmers, food processors and consumers of clean, green non-GM food produced with fewer chemicals, would reduce the financial contributions of farms and the food industry to the state, and would involve more agrichemical spraying and so further hurt the environment and add more unwanted residues to our food. These claims were not supported by any evidence, however, and several are inconsistent with the evidence provided above, with evidence reported in submissions favouring removal of the moratorium, and with further evidence presented in subsequent sections of this Review.

Of the other 19 submissions wishing to see the moratorium remain until 2025, four mention as-yet-unknown risks that GM crops may bring in terms of food safety and farmer and environmental health.[11] Those matters are dealt with by federal agencies and so were not

[10] These submissions are thus more supportive of removing the moratorium than the responses by 4341 respondents to a YourSay SA survey on the state's GM moratorium, as reported in the *Sunday Mail* newspaper on 7 October 2018: not quite half of those surveyed (47.4%) were in favour of bringing South Australia into line with other mainland states by allowing GM crop production, while the remaining 52.6% felt such a policy change would have a negative impact on the state's agricultural and food reputation.

[11] The psychology literature (see the survey by Lusk, Roosen and Bieberstein 2014) suggests that a new food technology is perceived as riskier, and is less likely to be accepted, when:
-- there are potential risks with adoption, even low-probability risks deemed inconsequential by experts, because of biases in probability assessment;
-- adoption of the new product is perceived as a loss relative to the status quo;
-- people are risk averse over low-probability losses such as those associated with food technologies;
-- people do not perceive that they have control over whether they consume the new product;
-- the new characteristic is perceived as unfamiliar or unusual;
-- early names given to and discussions of the technology are emotional and negative and are more available to consumers;
-- consumers do not associate appreciable benefits with the new technology; and
-- moral judgments are evoked, and a food technology is perceived as unnatural or impure.
Empirical evidence exists for most of these hypotheses. Some issues (e.g., the issue of naturalness) have been extensively researched. Other issues (e.g., the role of emotions) have received less attention in the food

included in the terms of reference for this Review. Most of the other 15 pro-moratorium submissions suggest the GM crop moratorium adds a premium to the price of non-GM food produced in the state and/or greater access to domestic and foreign markets. Those submissions indicate there is awareness and appreciation of South Australia's moratorium by at least one trading partner (Japan) and by several food processing businesses operating in South Australia. However, no evidence is provided in those submissions that would support a view that any current price premium or market access for non-GM South Australian crops would be diminished if GM food crops were allowed to be grown in the state on condition of segregation (apart from one qualified exception mentioned in the next sub-section).

Finding 2.1: There is awareness and appreciation of South Australia's GM food crop moratorium by at least one foreign firm (in Japan) and by several food processing businesses operating in South Australia.

2.2 Favouring partial removal of the moratorium

Eight nuanced submissions claim there are both pros and cons associated with this issue. The strongest ones in terms of providing evidence have to do with Kangaroo Island. Those submissions claim that the island's GM-free status has enabled access to a lucrative GM-free market segment in Japan. They further claim that if the rest of South Australia were to allow GM food crop production, the island would be able to retain access to that high-priced market provided it remained a GM-free zone within South Australia and continued to employ its strict segregation regime in getting grain from the island to Port Adelaide and onward to Japan.

***Finding 2.2: If GM food crop production were to be allowed in the rest of South Australia, Kangaroo Island would be able to preserve its unique identity so as to retain access to Japan's high-priced market for GM-free grain* provided the island remained a GM-free zone.**

Other nuanced submissions focused on a region or an industry. One that came from the Adelaide Hills states that its producers' clean, green image has been enhanced by the South Australia's current non-GM status, but some of its producers (e.g., apple and pear growers) also realize they could benefit from future GM crop varieties that were more resilient to climate change or that required fewer chemicals. A similar nuanced submission came from a wine industry organization: it believes the image of South Australian wine is enhanced by the state's non-GM status, while also recognizing that the heavy dependence of most of its grapegrowers on chemical sprays might be able to be reduced in future by the adoption of GM varieties yet to be developed. Neither of these submissions placed a monetary value on the perceived benefit of (a) prospective GM fruit tree or vine varieties or (b) the state's current non-GM status as compared with a situation in which GM food crops are allowed to coexist via segregation and identity preservation.

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economics field. Trust is an important factor driving consumer acceptance of new technologies and uptake of information. However, media coverage adheres to its own incentives, triggering heuristic uptake of information and influencing benefit-risk perception. Other factors such as cultural cognitions and worldviews can go a long way in explaining consumers' disparate assessments of new food technologies; individualistic and hierarchical worldviews focus more on benefits, whereas egalitarian ones favour a concentration on risks.

2.3 Favouring full removal of the moratorium

Most of the 39 submissions favouring the removal of the current moratorium on GM crop production and transport in the state have a common set of claims, and many provide evidence to support them. Many also request an immediate policy change rather than one that is phased in, given the positive experiences following reform in the other mainland states a decade ago and the protocols and practices that have established and proven over that period.

Six of the strongest 'removal' submissions are from key South Australian organizations representing most of South Australia's 9400 farm businesses. They include the following: Grain Producers SA (the peak industry body representing around 3000 grain farmers), Livestock SA (the peak industry body representing around 3500 graziers), SA Dairy Farmers (the peak industry body representing around 800 dairy farmers and another 800 in closely associated businesses), Primary Producers SA (an umbrella organization including the Horticultural Coalition of SA and the SA Wine Grape Growers Association in addition to the just-mentioned bodies covering grain, livestock and dairy producers), the Crop Science Society of SA (representing around 400 members from rural and metropolitan regions of the state), and the SA Independent Agricultural Consultants Group (13 firms that together provide management advise to many hundreds of SA farm businesses).

Finding 2.3: The majority of submissions, including those from organizations representing most of South Australia's farmers, favour the immediate removal of South Australia's moratorium on GM crop production and transport.

A number of submissions also stress the importance of the state government automatically adopting into law any future amendments to Commonwealth legislation on gene technology, and avoiding duplicating the efforts of the federal bodies authorised and equipped to test the environmental, health and safety attributes of each new GM crop application. Some also emphasize that having common national and state legislation in this area reduces the uncertainty that hampers investment in GM crop and related agricultural biotech R&D. Several submissions stress that, because the GM moratorium has restricted research-to-market pathways, fewer research dollars, scientists and post-graduate students have been coming to (or have remained in) South Australia.

Finding 2.4: Bringing South Australian legislation into line with other mainland states and the Commonwealth will benefit the state by attracting/retaining research dollars, scientists and post-graduate students in South Australia.

Since many of the claims in the submissions of those favouring the removal of the moratorium contradict those in the pro-moratorium submissions (including the campaign submissions duplicated from dogooder.co), the next section evaluates them in the light of available evidence.

3

Key issues with GM food crops, as raised in submissions

The key claim within this Review's terms of reference of those in favour of retaining South Australia's moratorium on GM crop production and transport is that the current policy provides greater market access and/or price premiums for South Australian crop products and processed foods. This claim is addressed in Section 3.1.

An associated claim is that markets for non-GM and organic food are growing more rapidly than markets for GM food and feed products. Most of those claimants ignore or downplay the role of segregation and identity preservation protocols and codes of practice aimed at ensuring that GM and non-GM food crops can profitably coexist in a region, a claim made by many of those arguing for the moratorium to be removed. This claim and counter-claim are addressed in Section 3.2.

Ignored by most of the pro-moratorium submissions is the claim by some seeking its removal that investment in agricultural R&D and thus farm productivity in South Australia would have been, and in future would be, greater without the moratorium. Since this affects the potential for new GM varieties of relevance to South Australian farmers to come on stream by 2025 (one of this Review's terms of reference), this claim is addressed in Section 3.3.

Many pro-moratorium submissions, including all the dogooder.co duplicated campaign letters, claim that there are fewer environmental costs, and in particular there is less chemical use, on South Australian farms because the moratorium has been in place than there would be without it. Many of those favouring removal of the moratorium make the opposite claim, while acknowledging the importance of ensuring weeds do not become resistant to particular herbicides. These conflicting views are examined in Section 3.4.

Some submissions raise questions about liabilities in the case of unintended presence of GM content in non-GM crops or their products, and how any such disputes would be resolved. These issues are examined in Section 3.5.

3.1 Market access and price premiums

The Review's terms of reference ask for evidence on the market benefits of South Australia's GM crop moratorium for non-GM crops. These could be in the form of greater access to, or a premium price for, non-GM crop products and processed foods and beverages, relative to what would prevail in the presence of GM food crop production in South Australia.

Since this state, and the rest of Australia, exports about three-quarters of its farm production, including canola, the conditions in those markets abroad are what matter most for both non-GM and GM farm products from South Australia. Indeed being a small supplier to international markets, prices for its exports in those markets will be reflected closely in prices in the domestic market.

The only evidence in submissions on market access is presented by both the Japanese buyers and the South Australian sellers of Kangaroo Island Pure Grain. They make it clear that access to that high-priced market in Japan is strictly conditional on such grain being not

just non-GM (which has a small tolerance for GM presence) but entirely GM-free. However, Kangaroo Island Pure Grain also make it clear that it can deliver GM-free grain to that market even if the crop moratorium were to be removed for mainland South Australia. That is supported by its homepage, which says:

> "Kangaroo Island Pure Grain specialises in the production of premium quality grains. Our grain is completely free of any genetically modified content. We grow our products on Kangaroo Island, … , land internationally renowned as one of the most pristine natural environments in the world. All our grain is fully traceable back to the individual farm. We provide a full service from the management of growing our grain, through harvest, to cleaning, storage and shipping to ensure our product arrives at destination in premium condition. We offer grain testing and independent certification on request." (www.kipuregrain.com, accessed 23 November 2018)

In the absence of much other hard evidence in submissions, further empirical evidence on market access was assembled for this Review by looking at the bilateral trade pattern of Australia's canola exports, particularly to the European Union (EU). The EU has some of the strictest regulations regarding genetically modified imports and labelling, even though more than 50 GM crops are approved for use in the EU as food and feed (see http://ec.europa.eu/food/dyna/gm_register/index_en.cfm). Those export data do not support the view that South Australia is able to export more easily to markets that seek to remain GM-free. During 2012-17, the shares of canola exports to the EU from the two main exporting states, Western Australia and New South Wales, were only 1 and 3 percentage points lower than South Australia's average of 72% (Table 1).[12] In Table 2, which provides a more-detailed picture of the destination of South Australia's canola exports, it is clear that during the most-recent two years, the four biggest markets have been European Union countries, with Japan in fifth place. Evidently, segregation and identity preservation are sufficiently robust that the EU does not discriminate between Australian states in sourcing non-GM canola.

Finding 3.1: Data on canola exports from Australian states to the European Union do not support the view that South Australians enjoy better access in EU non-GM grain markets.

Table 1: Shares of volume of canola exports destined to the European Union from Australia and its main canola-exporting States, 2012 to 2017 (% of state total)

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	***6-yr av***	**% of Aust exports**
AUSTRALIA	84	54	47	43	91	86	*69*	100
WA	87	61	58	44	92	82	*71*	44
NSW	83	83	27	34	91	97	*69*	29
Vic	75	34	31	30	76	90	*56*	17
SA	94	46	42	64	96	89	*72*	10

Source: Global Trade Atlas, compiled by PIRSA in October 2018.

[12] Similar evidence is provided in Whitelaw, Dalgleish and Agar (2018, p. 10).

Table 2: Value of canola exports from South Australia and Australia, 2012 to 2017 (A$million)

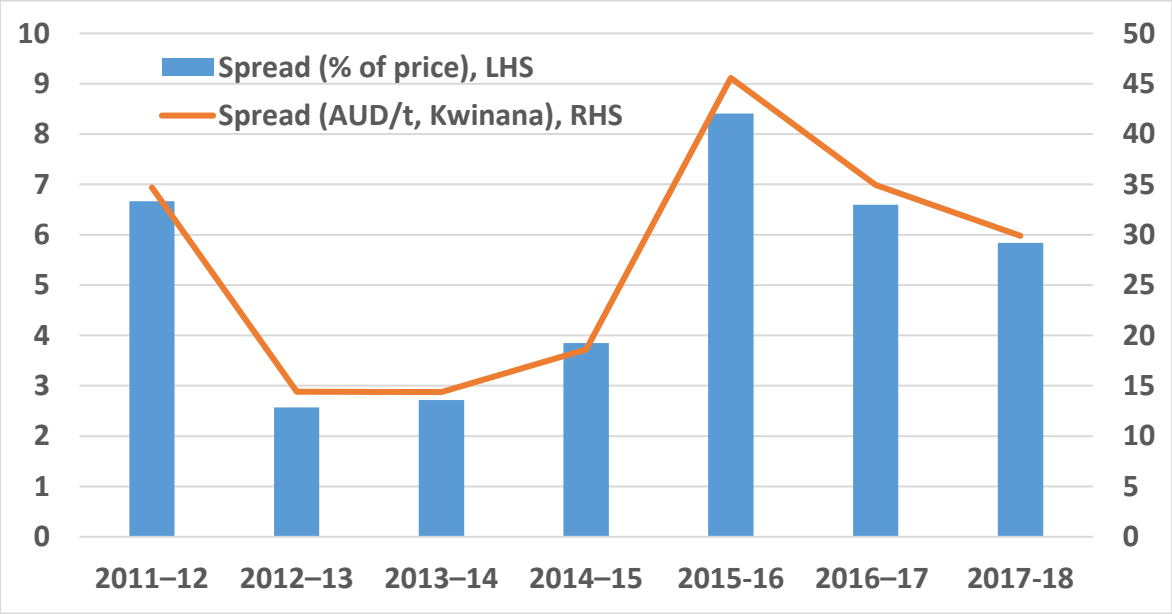
	2012	2013	2014	2015	2016	2017
South Australia						
Bangladesh	0.0	9.7	0.0	0.8	0.0	0.0
Belgium	125.9	68.7	69.6	102.3	37.9	78.0
Canada	0.5	2.0	2.5	2.1	2.5	1.3
China	0.1	0.0	95.2	0.0	0.5	1.1
France	0.0	0.0	17.7	12.3	32.1	32.3
Germany	17.2	0.0	33.9	0.0	56.8	77.8
Indonesia	0.0	0.1	0.0	0.0	0.0	0.0
Japan	15.7	32.4	52.5	33.1	6.7	23.2
Korea, South	0.0	0.0	0.4	0.0	0.0	0.0
Malaysia	0.0	1.6	0.8	0.0	0.0	0.5
Netherlands	49.0	30.0	0.0	0.0	21.3	0.0
New Zealand	0.0	0.0	0.0	0.1	0.1	0.0
Pakistan	0.0	33.6	0.0	0.0	0.3	0.0
Taiwan	0.0	0.0	0.0	0.1	0.1	0.0
UAE	0.0	48.7	24.5	32.9	0.0	0.0
United States	0.0	0.0	0.0	0.4	0.0	0.0
Vietnam	0.2	0.2	3.8	0.3	0.0	0.0
TOTAL	**209**	**227**	**301**	**185**	**158**	**214**
AUSTRALIA	**1600**	**2371**	**2217**	**1631**	**1406**	**2445**
SA % of Aust	*13.0*	*9.6*	*13.6*	*11.3*	*11.3*	*8.8*

Source: Compiled by PIRSA, October 2018.

There is evidence in Australia that non-GM canola receives a premium price over that for GM canola varieties currently available. During the first three years of GM canola adoption in New South Wales and Victoria, for example, non-GM grain was offered a premium of $10-15/tonne (around 2%) above that for GM grain, according to a survey of 512 canola farmers (Hudson and Richards 2013). A more-recent price compilation by Whitelaw (2018) suggests that premium averaged $32/tonne or 6% during 2011/12 to 2017/18, based on sales of both types of canola at Kwinana in Western Australia in the busiest three trading months (Figure 7).

Further evidence of a non-GM price premium was assembled for this Review by looking at export prices for canola from both Canada (which is GM because Canada does not segregate) and Australia (which presumably is non-GM to that market). Over the period 2010-17, the Australian export price of canola averaged 4.0% higher than Canada's. This was checked by calculating Japan's average price of canola imports from those two source countries over the same eight years: again the Australian price averaged 4% above that of GM canola from Canada (COMTRADE 2018).

Figure 7: Difference between the prices of GM and non-GM canola at Kwinana, Western Australia, 2011-12 to 2017-18 ($/tonne November-January, and % of average price per tonne delivered to Melbourne)



Sources: Average monthly spread (for November-January) is from monthly data provided by Whitelaw (2018); average annual price delivered to Melbourne is from ABARES (2018).

Also pertinent for this Review is whether South Australia's other crop products receive a price premium for being produced in a non-GM state. The only evidence provided in submissions on the extent of any price premiums for non-GM crop products from South Australia was already in the public domain (Whitelaw, Dalgleish and Agar 2018). That study found average prices of key crop products received by farmers on delivery to the main port in South Australia were no higher than those received by farmers at their main port in Victoria or Western Australia; if anything, they found grain prices in South Australia to be slightly lower and to have declined since 2012 relative to those in states where GM crops are allowed (Figure 8).

Finding 3.2: The only data provided in submissions on prices of grain in South Australia versus grain in neighbouring states suggest that since 2012 there has been no premium for grain from South Australian despite it being the only mainland state with a GM crop moratorium.

Even if a price premium had been found for grain from non-GM South Australia, one would need to ask whether such a price premium would continue in the absence of the GM crop moratorium. That would depend on how effective the segregation process would be if the moratorium were to be dropped (see next sub-section).

A related issue is whether food processors in South Australia or elsewhere benefit from accessing the state's non-GM crops. A recent study commissioned by PIRSA (GFAR 2016) surveyed Australian food companies that currently have non-GMO or GM-free claims on their labels. That study found that, of the 20 South Australian firms examined, nine had non-GM claims on their labels. It also found that few Australian food businesses were aware

of export market opportunities in non-GMO foods. It suggested that was most likely because Australian consumers are not currently asking for transparency through labelling. They found the firms most aware of and responding to future opportunities were producers of biodynamic dairy products, carob products and specialty flours and pre-mixes.

Figure 8: Difference between grain prices received by farmers on delivery to main port in South Australia and those in Victoria and Western Australia, 2012 to 2017 (%)

(a) Wheat

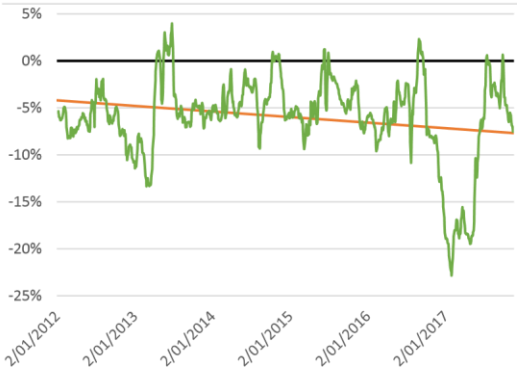
Figure 9: Percentage premium or discount in APW price to Adelaide from Geelong

Figure 10: Percentage premium or discount in APW price to Adelaide from Kwinana

(b) Barley

Figure 15: Percentage premium or discount in F1 Barley price to Adelaide from Geelong

Figure 16: Percentage premium or discount in F1 Barley price to Adelaide from Kwinana



(c) Canola

Figure 21: Percentage premium or discount in Canola price to Adelaide from Geelong

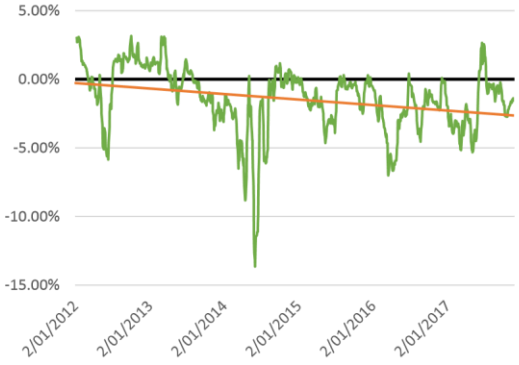
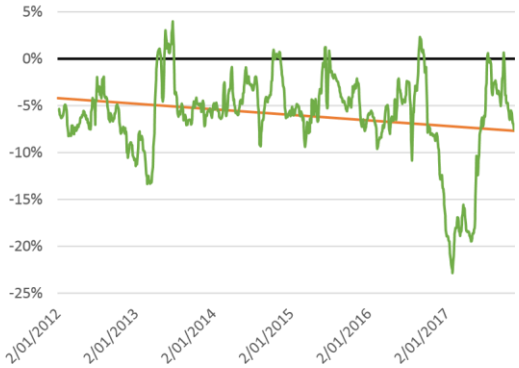


Figure 22: Percentage premium or discount in Canola price to Adelaide from Kwinana



Source: Whitelaw, Dalgleish and Agar (2018).

3.2 Segregation, identity preservation and coexistence

The presence of both GM and non-GM crops in a region introduces the possibility that unwanted GM material could be found in non-GM produce, or vice versa. This could occur in the field, during transport, or when produce is being processed at receiving sites. The *Genetically Modified Crops Management Act 2004,* which gave effect to the South Australian Government's commitment to regulate the cultivation of genetically modified crops in South Australia to protect the State's markets, reflects a somewhat stricter recommendation of the South Australian House of Assembly Select Committee on Genetically Modified Organisms. The Committee recommended that the commercial release of GM crops into South Australian agriculture only be permitted when "coexistence to meet market demands for different classes of crops and products, e.g. GM free, non-GM and GM, can be guaranteed by industry through the establishment of rigorous and cost-effective segregation and identity preservation systems throughout the total production and supply chain." (SA Genetically Modified Crop Advisory Committee 2007).

Cross-contamination that results in an uncompensated loss of marketing advantages is sometimes referred to as a market failure. A key initial question is the extent to which such negative spillovers are effectively managed through market forces, and whether the costs of any residual uncompensated spillovers outweigh the net benefits of allowing the adoption of OGTR-approved GM crop varieties.

A 2007 report on potential impacts of GM canola production on organic farming in Australia concluded that, if GM canola was commercialised in Australia, the direct impacts on organic canola production in Australia most likely would be negligible, the introduction of GM canola would have minimal impact on the organic livestock industry, and the impact on organic honey production would be minimal (Apted and Mazur 2007).[13]

A survey of growers of both GM and non-GM canola even during 2008-10, in the earliest seasons involving GM adoption in New South Wales and Victoria, found that the worst fears relating to coexistence did not materialize: 88% of respondents said they had not received any complaints relating to their growing or transporting of GM canola, and nor had the issue affected their decision as to whether or not to grow GM canola (Hudson and Richards 2014b, p. 10).

That finding, foreshadowed by AOF (2007), is consistent with a series of annual reports on the status of the market for Australian canola, by AOF/GTA (2009, 2010, 2011), and with a report by Alcock (2015).

A subsequent independent impact assessment of GM canola production in New South Wales, Victoria and Western Australia during 2008-12 concluded that "After more than five years of extensive studies, Roundup Ready® (RR) genetically modified (GM) canola has been found to present no greater environmental or agronomic risks than conventional varieties. The movement of the GM trait via pollen declined rapidly with distance and was less than 0.03% at 100m from the source crop. GM canola is not responsible for significantly increased resistance in glyphosate in annual ryegrass or wild radish and does not have greater persistence or weediness in crops, roadsides and natural habitats than non-GM types." (GRDC 2015).

These findings vindicated the work done prior to the approval of GM crop production in those states to establish segregation and identity preservation protocols and codes of

[13] Keep in mind that while the organics market has been growing rapidly (GFAR 2016), in 2017 it was no more than 0.7% of the value of Australia's conventional grains production and 0.3% of livestock fodder and feedstuffs (Lawson et al. 2018, p. 29). Globally, organics comprise just 1% of all agricultural land use (Meemken and Qaim 2018).

practice aimed at ensuring that GM and non-GM crops can coexist in a region.[14] For example, Single Vision Grains Australia (2007a, 2007b) reports that the industry was ready from 2008 to manage GM and non-GM canola within the supply chain to deliver grain to meet customer specifications. It has set up a quality assurance process along the entire supply chain including verification (e.g. sampling and testing) when needed to verify that the integrity of the processes from planting seed through to grain presented for sale accords with customer specifications and government regulations at home and abroad (as outlined in, e.g., Mewett et al. 2008). In accordance with quality assurance requirements, compliance with the systems is capable of being verified by appropriate document reviews and references to standards held by relevant sectors of the industry. The principles and processes have been taken up and managed by the Australian Oilseeds Federation, which maintains and oversees the delivery of market requirements for domestic and export trade.

A submission from Western Australia reinforces the point that the supply chain manages the segregation of different crops efficiently and effectively (see also McCawley, Davies and Wyntje 2018). There the Co-operative Bulk Handling (CBH) Group is responsible for handling 90% of all grain along the state's supply chain, and has successfully segregated GM and non-GM canola to internationally acceptable levels such that there have been no contamination issues since the GM crop's introduction in 2010. Grains are segregated into groupings based on grain type, which include but are not limited to wheat, barley, oats, lupins, non-GM canola, chickpeas, and field peas. Beyond these grain type segregations, there are numerous quality segregations (15 wheat grades; 13 barley grades; four canola grades). The tolerance level, known as the Low Level Presence (LLP) value, has never been exceeded by the CBH Group.[15] This capacity of the post-farmgate grain handling part of the value chain to effectively segregate GM and non-GM canola is not surprising, because varietal segregation has been a normal part of bulk grain transport and storage for decades in Australia (ESCOSA 2017; White, Carter and Kingwell 2018) and most grain-exporting, high-income countries (Kalaitzandonakes et al. 2016).

Finding 3.3: The experience of GM canola production and marketing in other mainland stages over the past decade reveals that segregation and identity preservation protocols and practice codes can and do ensure the successful coexistence of GM and non-GM crops in Australia.

[14] This issue does not arise in Canada, where there is no segregation of GM and non-GM canola, because virtually all of the crop is GM (as is also the case for cotton in Australia).

[15] The European Union, for example, has an LLP of 0.9% for canola. If an unintended LLP of GM canola is detected, each of the load samples that comprise the composite site sample are then tested individually in order to identify the source and location of the unintended LLP of GM canola in the non-GM stock. If testing confirms at any of those stages that a load of non-GM canola contains GM canola above the unintended LLP limit, CBH notifies the relevant grower to ensure they can investigate their relevant farm management practices. Loads that exceed the tolerance for GM canola are extremely rare (0.04% over the past five harvests). Further testing occurs when the grain is transported and received at the port. A sample is taken for every 500 tonnes received at the port and tested for the unintended presence of GM canola. If the test indicates the presence of GM canola, the grain is further tested to determine the quantitative levels of GM canola. If found to be above the tolerance for unintended low-level presence of GM canola, the grain is isolated and, if required, regraded (CBH Group 2018). There are several independent firms whose non-GM certification standard is recognised and accepted globally (see, e.g., http://gmoid.com.au/ and https://www.sgs.com.au/en-gb/agriculture-food/food/food-certification/non-gmo-certification).

3.3 Extent of investment in agricultural R&D

The rates of return to agricultural R&D are very high in most countries, suggesting substantial under-investment in this source of economic growth (Hurley, Rao and Pardey 2014; Hurley et al. 2016; Fuglie 2018). A rise in the private sector's share of investment in global agricultural R&D has helped to reduce the degree of underinvestment (Pardey et al. 2016, 2018), thanks largely to the agricultural biotech revolution. This means that the incentives for attracting such private investment matter more now than in the past.

While ever there is a moratorium on GM food crop production, there of no local path to market for research aimed at developing new varieties suited to that jurisdiction. Without a path to market, even public research funders such as the Grains Research and Development Corporation are disinclined to invest in pre-commercial research. Thus an important consequence of South Australia's GM crop moratorium has been not only the withdrawal of private R&D investment by life science companies but also less public sector funding for the state's research institutions. Public funds for crop biotech research have instead been directed to those states without a GM moratorium.

A further disincentive to invest in biotech research in South Australia is the state-based regulatory process that approves GM field trials. This adds an addition cost and further delays to the development of new GM varieties over and above those required to get OGTR approval.

Yet another adverse impact of the moratorium on research is the signal it sends to young scientists: those interested in a career in frontier biotech research are more likely to move elsewhere or not come to South Australia when there are less-constrained research environments interstate and overseas.

With less dollars being spent on R&D and fewer scientists working at the technological frontier in South Australia, there is less "spill-in" to the state from the outcomes of R&D investments interstate and abroad that could be readily adapted for the local environment. This foregone benefit is difficult to measure, but the magnitude of "spill-ins" has been shown to be non-trivial in the past (Fuglie 2018).

Evidence of the growth in crop biotech research investments in the states that removed their GM moratorium a decade ago was provided in a number of submission to this Review. For example, in 2014 Bayer CropScience opened a $14 million state-of-the-art wheat and oilseeds breeding centre at Longerenong in the Wimmera region of Victoria; and Nuseed recently invested $7 million expanding their research and development capabilities in Horsham. Such investments have been supplemented by the public sector too: the Victorian government has invested in glasshouse facilities and high-tech field-based plant assessment capabilities (phenomics) in Hamilton and Horsham, infrastructure that is supported by the $288 million Centre for AgriBioscience at La Trobe University (a public-private partnership). Meanwhile, funding has shrunk at the University of Adelaide-hosted Australian Centre for Plant Functional Genomics.

Finding 3.4: The persistence of a GM crop moratorium in South Australia, especially in the face of the removal of moratoria a decade ago in neighbouring states, has discouraged both public and private agricultural R&D investments in this state.

3.4 Farm chemical use and herbicide resistance in weed populations

Many of the pro-moratorium submissions, including the duplicated campaign letter via https://dogooder.co, claim that there are fewer environmental costs, and in particular there is

less chemical use, on South Australian farms with the moratorium than would be the case without it. Those favouring its removal have a contrary view, even though they acknowledge the importance of ensuring weeds do not become resistant to particular herbicides used by GM and non-GM crop growers.

The reality is that growers of GM crops tend to use less farm chemicals overall than do producers of conventional crop varieties using no-till agriculture. A lower use of herbicide – especially glyphosate – is important following the widespread adoption of no-till cropping, because there is a risk of weeds becoming tolerant to such chemicals. To lower that risk of glyphosate resistance in key weeds, GM growers are advised to alternate Roundup Ready canola with other canola cultivars attuned to herbicide components other than glyphosate, as part of a comprehensive herbicide resistance management framework. That practice is well developed in Canada, where farmers rotate the use of two GM varieties so that only half as much of each herbicide is used on GM crops per two rotations (Kingwell 2011, p.5; Smyth et al. 2011a,b).

Finding 3.5: The adoption of GM crops typically leads to less, not more, use of farm chemicals, and the risk of herbicide resistance in key weeds can be reduced by rotating between different GM crop varieties.

3.5 Liabilities and dispute resolution

Some attention in the GM debate has focused on the issue of liability relating to the presence of GM content in non-GM crops, even though the use of legal remedies by grain farmers or the grains industry has been rare. Farmers and post-farm grain handlers in states without a GM moratorium have managed to avoid such spillovers by adopting the carefully planned protocols and codes of practice developed and fine-tuned over the past dozen years. In the few cases where spillovers have occurred, farmers have resolved issues typically by talking with their affected neighbours. Failing that, there is the ability of those damaged to seek redress through mediation and the courts if necessary, drawing on common law and existing statutes. The Australian Government has considered the matter, and has chosen not to implement a special liability regime for damage caused by GMOs. This approach is consistent with the approaches adopted in comparator countries, including the United Kingdom, Canada and the United States (Burrell 2006).[16]

[16] Even so, an inquiry is currently under way into mechanisms for compensation for economic loss to farmers in Western Australia caused by contamination by GM material, by the Environment and Public Affairs Committee of the Legislative Council of Western Australia's Parliament. See http://www.parliament.wa.gov.au/parliament/commit.nsf/($all)/CA81A38C140AF895482581EE0081A3CC?opendocument. One group, in their submission to this review and others (www.geneethids.org), proposes that non-GM farmer protection legislation be introduced to ensure non-GM farmers are fully compensated for any and all forms of contamination from GMOs. A classic key problem with such a proposal, as with a contrary one suggesting would-be GM farmers be compensated by society for being denied access to GM technology, is moral hazard.

4

Economic impacts of South Australia's GM moratorium and alternatives

There is a vast literature on the economics of GM adoption, including on measurement of its economic and environmental impacts. This section first provides a brief summary of recent empirical findings globally and for Australia. Standard methodology is then used to estimate key direct economic effects of South Australia's moratorium on the state's canola production historically to 2018, and of retaining the moratorium to 2025. The section concludes by pointing to additional benefits and costs not taken into account in those studies, which are more difficult or impossible to quantify but need to be kept in mind when evaluating the possible impacts of a change in GM policy.

4.1 Background: economic and environmental impacts of GM adoption globally

The adoption of GM crop varieties since the mid-1990s has had a significant impact on the world's agricultural and food production. To repeat this report's opening sentences, by 2017 (following two decades of gradual adoption) there were 190 million hectares of cropland (13% of the world's total) sown to GM varieties in 24 countries (Appendix 1), a little over half of it being in developing countries. A further 43 countries, including Australia, import GM products. In 2017 GM varieties accounted for 77% of the global area sown to soybean, 80% of maize, 32% of cotton and 30% of canola (ISAAA 2017, p. 3).

In those countries in which farmers have been permitted to grow GM crops, most growers embraced this biotechnology rapidly because it raises their net incomes, is having positive agronomic, environmental and health impacts (less tillage, less chemicals), and is providing more-effective weed control.

The most widely cited meta-analysis of 147 empirical studies around the world found that switching to GM varieties had reduced chemical pesticide use on average by 37%, raised crop yields by an average of 22%, and boosted farmers' net profits by 68% (Klümper and Qaim 2014).

In their latest annual global survey, Brookes and Barfoot (2018a) estimate that the net economic benefits at the farm level amounted to US$186 billion in nominal terms during 1996-2016, with two-thirds of those gains coming from gains in yields and the remainder from cost savings. Through yield increases, those GM varieties have added the following to global production over that 21-year period: 405 million tonnes of maize, 213 million of soybeans, 27 million of cotton and 12 million of canola.

Moreover, the adoption of GM insect resistant and herbicide tolerant biotechnology has reduced pesticide spraying by 8% and, as a result, has decreased the adverse environmental impact associated with pesticide use on these crops by one-sixth. GM technology has also facilitated desirable tillage changes and cuts in fuel use. This has lowered the release of greenhouse gas emissions from the GM cropping area by the equivalent to removing 17 million cars from the world's roads (Brookes and Barfoot 2018b).

Perhaps the most sophisticated study of the economic welfare benefits of adoption of GM corn and soybean in the United States is by Ciliberto, Moschini and Perry (2019). They estimate that during 2007-11 and under what they consider their most realistic assumptions, farmers of those two crops were better off by US$2.3 billion per year from having the various GM varieties available by then, despite paying 20-25% more for GM than conventional seed. They also estimate that the GM seed industry's revenue was US$2.9 billion per year during that period, suggesting a little over half (56%) of the direct benefits went to the life sciences companies. These estimates do not include any valuation of the net environmental benefits of this technology versus conventional technologies.

The case of GM canola in Canada is closest to current South Australian interests. A survey of farmer views on its economics was undertaken a decade after its initial adoption. Among the results, compiled by Gusta et al. (2011), are that farmers found management of herbicide resistance in weeds, and efforts to control volunteer canola, if anything were easier with GM canola than with the conventional varieties they rapidly replaced. But more striking is the finding that there were multi-year spillover benefits from weed management in follow-on crops, which added to the direct benefits in the canola growing part of each farmer's multi-year crop rotation.

4.2 Economic and environmental impacts of GM adoption in Australia to date

Following the approval of GM cotton production in Australia in 1996, pesticide use in the cotton industry has fallen (by 90% in the case of insecticides), as have labour and fuel usage, so costs are lower and soils are less disrupted. Moreover, cotton output has more than doubled, with GM varieties accounting for virtually all of Australia's cotton area in the past few years (Cotton Australia 2018 and Figure 5(c) in Section 1 above). Now 95 per cent of the GM cotton varieties used in Australia are stacked traits for insect resistance and herbicide tolerance. The cumulative cash benefits of GM varieties to cotton farmers in Australia (net of the technology access fee) have amounted to an estimated US$1.1 billion in nominal terms during 1996-2016 (Brookes and Barfoot 2018a). Since the nominal value of Australia's cotton production over those 21 years sums to US$22.1 billion (based on data converted at average annual official exchange rates), that is equivalent to a 5% boost to growers' value of production, over and above the boost in their wealth (a rise in the value of cotton land) and in the quality of their environment and health due to the huge reduction in farm chemical use.

Canola is the only other GM crop so far permitted to be grown in Australia (apart from GM blue carnation and rose flowers and, since 27 June 2018, GM safflower). The canola permission was granted by OGTR during 2003, in time for planting from 2004. However, moratoria were introduced in all the states that could grow canola profitably such that adoption was delayed. Following demonstration trial plots a year earlier, the first unrestricted commercial plantings were in New South Wales and Victoria in 2009 and in Western Australia in 2010.

A review of the moratorium on GM canola in Victoria (Nossal, Forster and Curnow 2007) included an Appendix summarizing an ex ante cost-benefit analysis prepared for the Australian Government by ACIL Tasman (2007). That analysis suggested very large potential gains from removing the moratorium. However, some of its key assumptions turned out to be rather optimistic. Most notable were yield/ha increases of 20%, identical prices for GM and non-GM canola, no difference in the cost of getting the crop to a delivery point, and – most important of all – 80% adoption of GM varieties within eight years.

To date there has been a much slower uptake of GM canola varieties in Australia than was the case in Canada, following an initial interest in trying it out (see Figure 6 in Section

1). One reason is that Australia has had access to non-GM hybrid varieties (Clearview, and a Triazine-tolerant variety) that were developed partly because of the moratoria. Since they fit a no-till farming system too, they have reduced the current net economic and environmental benefits of switching to a GM canola variety, as compared with the net benefits that existed back in the mid-1990s in Canada. As well, prices have been slightly lower for GM than non-GM varieties, yields currently are not much above the best of non-GM varieties, the technology access fee for GM seed is considered high (even though the seeding rate and the cost of seed per hectare is lower for Roundup Ready canola), growers are wary of too much dependence on Roundup and so prefer not to plant Roundup Ready canola in every rotation, and hence aggregate adoption rates have been much lower than anticipated by the benefit-cost analysis of ACIL Tasman (2007) that was drawn on by Nossal, Forster and Curnow (2007).

To gauge views of growers after three seasons of access to GM canola, the Grains Research and Development Corporation commissioned surveys in New South Wales and Victoria, covering 1,348 growers in those eastern states during 2008-10 (GRDC 2012). Both non-GM and GM growers were included in the surveys. The results have been comprehensively analysed by Hudson and Richards (2013, 2014a,b). Their findings cover agronomic and environmental impacts and coexistence issues in addition to economic impacts. Among their findings were the following:

- Fewer weed-control programs were adopted in GM canola than in non-GM canola;
- GM canola yields per hectare were not lower than those of non-GM canola;
- GM canola led to reduced use of 'high-risk' herbicides that develop herbicide resistance in weeds or leave residue in soils;
- GM canola growers were more likely to undertake conservation tillage practices;
- GM canola growers used less fuel due to fewer tractor passes over the paddock; and
- No coexistence concerns were evident for GM growers also growing non-GM canola or with their neighbours and the surrounding farming community.

However, GM canola involved higher average variable costs for weed control when the high technology access fee is included. That fee increased from 13% of variable weed-control costs in 2008 to 20% in 2010.

Those surveys also reveal other initial barriers to the uptake of GM canola varieties in New South Wales and Victoria. Hudson and Richards (2014b) list them as:

- A limited number of suitable GM cultivars with a range of maturity types being available in the first year (but concern fell from 36% to 18% by 2010 as the number of cultivars rose from 4 to 10);
- Wanting to see the experiences of other growers before adopting (decreased from 26% in 2008 to 5% in 2010);
- Concern that herbicide resistance in weeds would increase (it worried 15% of respondents);
- Lack of access to sellers of GM seed/technology (decreased from 25% in 2008 to 4% in 2010);
- The need for more and nearer sites to deliver the harvested product, to lower freight costs and raise competition among buyers of GM grain;
- A lower price for GM than non-GM canola; and
- High technology access fees that extracted much of the economic benefit of the technology.

In short, Hudson and Richards (2014b) conclude that the major barrier to early adoption of GM canola in New South Wales and Victoria was the perceived lack of economic value compared with available non-GM varieties. Looking forward, they believe that unless more-profitable GM varieties appear or the technology access fee is lowered, many growers will

sow both GM and non-GM canola and reserve the Roundup Ready variety just for paddocks needing greater levels of weed control.

Western Australia has had a somewhat faster rate of adoption of GM canola. This is despite the Marsh vs Baxter court case that ran for five years before concluding in March 2015.[17] The faster adoption speed in Western Australia may have been partly because GM canola provided better weed management outcomes in their settings than in the eastern states where weed problems are not as severe. It could also have been encouraged by the thorough trials program of 2009, which demonstrated the agronomic viability of the Roundup Ready GM technology under Western Australian conditions. Overall, Western Australian GM canola growers reported that it was worth adopting the additional protocols and practices, not least to ensure effective segregation so that the technology was acceptable to non-GM growers (McCauley, Davies and Wyntje 2012).

4.3 Direct economic impacts on canola of relaxing SA's GM moratorium

GM technology will have different impacts on farm businesses depending on their agronomic and climatic circumstances and their management expertise, as well as the traits of the GM varieties available each season. As with any new technology, farm managers may well use the technology in ways not currently anticipated, and modify farming systems to optimise the benefits of new traits as and when they become available and are judged to be worth trying.

Both the evolutionary nature of technologies, and the farming systems in which they are embedded, are complex. Estimating the likely economic impacts of a new technology therefore necessarily requires numerous assumptions about which there are varying degrees of uncertainty. However, the task of estimating just the main ***direct economic effects*** involves simply comparing costs and benefits of farming under the new technology with those associated with current practice in South Australia (the 'counterfactual' scenario). Hence attention can focus on just those costs and benefits that would differ by switching to growing a GM variety.

Since canola is the only food crop currently approved by the OGTR for growing in Australia (apart from safflower which so far is a very minor crop), this analysis considers just canola as it is the most-immediately relevant example. Discussion of the possibility that other GM crops may be approved in the future, as well as of (possibly even more important) ***indirect economic effects*** of removing the GM crop moratorium, is left to Section 4.4.

Canola is a relatively new crop in southern Australian farming systems, having emerged in the early 1990s. It expanded more rapidly in South Australia than in other states to the early 2000s, but the State's share of the national area has since fallen from one-quarter in 2003 to one-eleventh in 2017 (Figure 9).

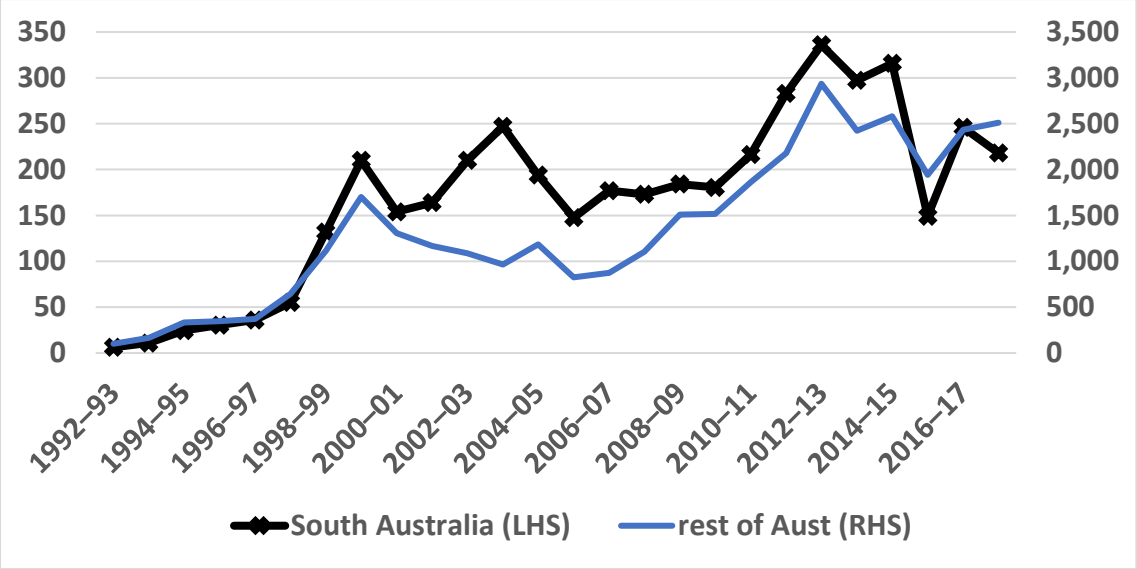
The benefit-cost analysis to be undertaken here requires comparing gross margins of non-GM versus GM varieties. While this is a standard method, keep in mind that it underestimates the GM returns because it is not taking into account the impact of canola varietal choice on the profitability of other crops in the multi-year rotation and of other farming enterprises such as grazing (to be taken up qualitatively in the following Section 4.4).

The 'counterfactual' to be used as a comparator in this analysis is the gross margin for the variety that is currently most common in South Australia, namely triazine-tolerant (TT) canola, for which a gross margin spreadsheet for 2018 has been made publicly available by PIRSA (2018). TT canola typically has a slightly lower yield per hectare and lower oil

[17] See, eg, Supreme Court of WA (2014, 2015) and http://www.appropedia.org/Marsh_v_Baxter

content[18] than Clearfield (the next-most popular non-GM variety) but also – like Roundup-Ready (RR) GM canola – it has slightly lower herbicide costs than Clearfield.

Figure 9: Canola area, South Australian and rest of Australia, 1992-93 to 2017-18 ('000 ha)



Source: ABARES, *Australian Commodity Statistics*, various years.

Studies of GM adoption elsewhere make clear that the variables likely to affect the comparison of gross margins most are the product price, crop yield per hectare, variable costs (most notably of chemicals and the technology access fee), and the speed and maximum rate of adoption of GM varieties. On the basis of numerous submissions to the Review, the analysis assumes that there would be no extra costs of segregation for either non-GM or GM growers if GM crops were allowed to be grown. The relative importance of it and various other assumptions are revealed below via sensitivity analysis.

Steps in the gross margin analysis

Capturing the direct economic effect of a new variety on the gross margin associated with canola production in South Australia requires the following several steps:

- Estimate the on-farm impacts on key variable costs and gross returns per hectare in 2018 of replacing the current TT canola variety with RR canola.
- Assume that the 2018 per-hectare gross margin difference prevails over both a retrospective period (2004-18) and a prospective period (2019-25), so as to estimate (a) the cost of having a moratorium in the state so far following OGTR approval in 2003, and (b) the cost of continuing the moratorium to its current end-year of 2025.
- Multiply the difference between the gross margins per hectare for GM and non-GM canola by the number of hectares that we assume would have gradually transferred to GM varieties each year over those two multi-year periods, to get an estimate of the total direct net benefit or cost to the state's GM canola farmers of the moratorium. In this calculation, we assume conservatively that the state's total area under canola in

[18] Oil content of seed matters because of bonification: there is a premium or discount of 0.15% of the price of canola for every 0.1% of oil above or below 42% (the oil content base rate).

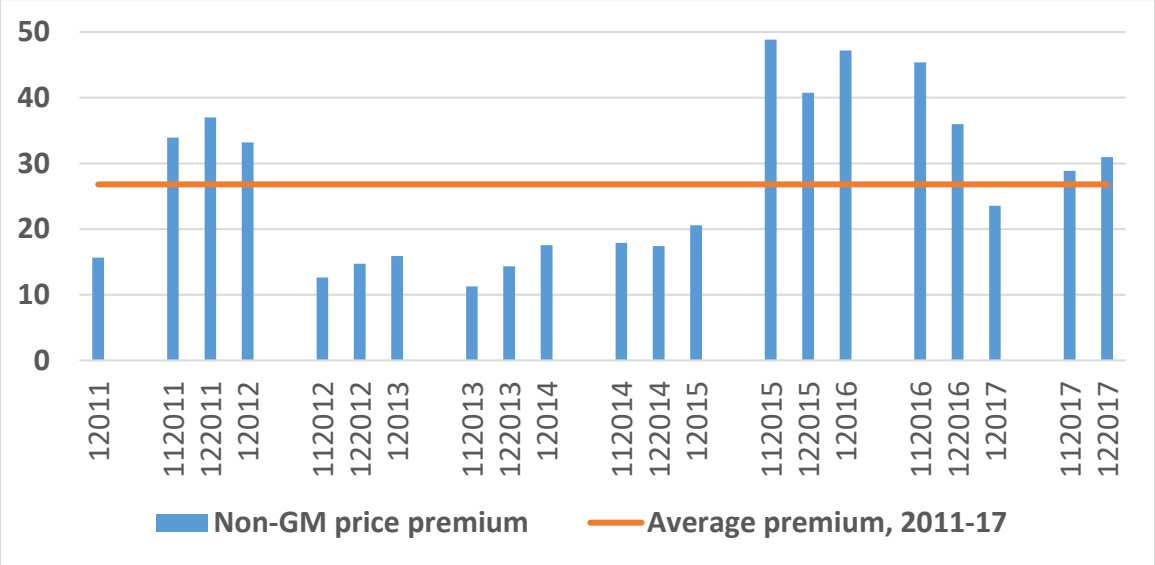
each period would not change if the moratorium was lifted.[19] Since all values are in 2018 AUD, they are able to be added up to get a range of total estimates of the nominal dollar value of net farm income gain that adoption of the available biotechnology would have provided or could provide in the absence of South Australia's GM crop moratorium.

- Calculate for each scenario the volume and value of South Australia's GM and non-GM canola production in 2018 and 2025, and the revenue from the technology access fee (at least some of which might be re-invested in GM crop R&D in the state).
- Undertake some sensitivity analysis by looking at alternative yields per hectare, non-GM canola price premiums, GM adoption rates and plateaus, and additional segregation costs.

Price of canola

The core scenarios assume the prices of GM and non-GM canola each year are unchanged over time, and that the price of (TT) non-GM canola, at $526/tonne (the average price for non-GM canola in Australia over the seven seasons to 2017/18), is $26 (5.2%) higher than the price of Roundup Ready (RR) GM canola each year. That $26 premium is the simple average of two price spreads between non-GM and GM canola during that same 7-year period: the 5.4% one at Kwinana, Western Australia during the biggest selling months of November-January (Figure 10); and the 5.0% one between the prices of Australian (non-GM) and Canadian (GM) canola shipped to Japan.[20]

Figure 10: Price spread between GM and non-GM canola, Kwinana, November-January, 2011 to 2017 (AUD/tonne)



Source: Whitelaw (2018), available also from www.profarmergrain.com.au

[19] Or equivalently, that any increase in the total area of canola is at the expense of other crops that would have generated (almost) as much net earnings.

[20] Average of the spread in f.o.b. prices of exports from the two countries and the c.i.f. prices of Japan's imports from them, taken from the United Nations' COMTRADE database, accessed on 4 November 2018 at https://comtrade.un.org/data/.

Yield per hectare

The yield per hectare of canola in Australia averaged almost 1.37 tonnes during 2011-17, when an average of 12% of the national area was under GM varieties. If the yield of non-GM canola was 10% lower than for RR canola, as it was for the five best RR and five best TT plots in Victoria's Wimmera region during 2013-17 (NVT 2018), then their respective yields would have averaged 1.35 and 1.50 tonnes, respectively.

For sensitivity analysis in the historical scenario, an alternative is to use South Australia's average yield of non-GM canola over the whole period from 2004, which is 1.20 tonnes, thereby doubling the gap between it and the current RR yield to 20%.

Variable costs

RR seed costs about 16% more than TT seed, but only two-thirds as much RR seed is needed compared with TT seed (2kg/ha vs 3kg/ha). There is a technology access fee (TAF) that Monsanto has charged since 2012 on a per kg of RR seed basis. The TAF was $6 in 2012 and it has risen gradually since then and was $8/kg in 2018 (see http://www.roundupreadycanola.com.au/where-to-buy-seed/technology-fee/). Prior to 2012 the TAF had two components and was higher in aggregate and differed between states. Because it is unknown what the TAF would have been historically in South Australia without the moratorium, it is simply assumed the TAF is $8/kg each year. All other costs per hectare are assumed to be the same (and taken from PIRSA 2018) except for weed control costs which, according to Biden, Smyth and Hudson (2018), averaged $22.65/ha more for the non-GM than the GM crop.

GM adoption rate and ceiling

In New South Wales and Victoria, GM varieties currently account for about 10% of the total canola area, while in Western Australia their share had risen to 30% by 2015 (Figure 6 in Section 1). Industry participants expect that, with currently available varieties, South Australia would have a similar adoption rate to the eastern states, rather than to Western Australia where weed problems are more extreme. It is further assumed that the 10% adoption rate would be reached in five seasons, with each year adding the same one-fifth to the interim adoption rate (a linear progression). With a low adoption rate of 10%, it is likely that, as in Victoria, a smaller subset of delivery points in South Australia would accept GM than non-GM canola. Hence it is assumed freight to deliver the harvest to the receival point would be 50% greater per tonne for GM grain.

A new GM canola variety approved in 2018

For sensitivity analysis in the prospective scenario to 2025, a new GM canola variety, approved by the OGTR and FSANZ in February 2018 (and by USDA in August 2018), also is considered. This new canola variety is rich in long-chain omega-3 oil and so could be used as an ingredient in aquaculture feed and in human nutrition.[21] A pair of alternative gross margins is therefore provided in which this GM variety (call it O3) is assumed to attract a higher price and thus a higher adoption rate and ceiling than RR canola (while having the same variable costs including the same technology access fee as for RR canola). With higher adoption, it is further assumed that more delivery points would accept GM canola, in which

[21] https://www.csiro.au/en/Research/AF/Areas/Plant-Science/Bio-based-oils/Omega-3-canola.

case the penalty freight cost would disappear. Two price scenarios are considered by way of example: one in which the price premium for non-GM canola disappears, and another in which a 5% price premium favours the omega-3 GM variety over the non-GM TT variety. It is further assumed that the GM adoption rate by year 5 reaches 20% in the first of those alternatives, and 30% in the second (higher-priced) O3 alternative.

Results

The results for the above GM adoption scenarios, should South Australia' GM crop moratorium be removed, are summarized in Tables 3 and 4. The differences between gross margins for the business-as-usual use of the TT variety and key alternative GM varieties are shown in the last two rows of Table 3.

Table 3: Differences in canola gross margins between non-GM and GM varieties, South Australia, 2018 ($ per hectare)

	TT (non-GM)	RR (GM)	O3 (GM)	O3 (GM)
Assumed canola price ($/t)	526.00	500.00	526.00	552.00
Assumed yield/hectare (tonnes)	1.35	1.50	1.50	1.50
GROSS INCOME/hectare	710.10	750.00	789.00	828.00
Assumed GM adoption rate max.		10%	20%	30%
VARIABLE COSTS THAT DIFFER:				
Seed	64.50	50.00	50.00	50.00
Technology access fee	0.00	16.00	16.00	16.00
Weed control	101.15	78.50	78.50	78.50
Freight to receival point	33.75	56.25	37.50	37.50
GRDC levy (1% of gross income)	7.10	7.50	7.89	8.28
TOTAL of variable costs that differ	206.50	208.25	189.91	190.28
Difference between GM and TT gross margins		38.15	95.51	134.12
or, if the yield gap is 20% instead of 10%:		112.51		

Source: Author's spreadsheet based on assumptions in text above.

Those estimates suggest there would be a small gain today of $38/hectare by allowing the production of Roundup Ready canola, based on the current yield gap of 10% in favour of the GM crop and a price premium of 5.2% in favour of non-GM canola.

Were the omega-3 variety of GM canola to become available by the 2019 season (as the firm Nuseed suggests is possible, see http://www.nuseed.com/au/innovation/omega-3) and to attract a higher price, the estimated gross margin difference becomes considerably greater if the technology access is the same as for RR canola: it rises to about $95/hectare if the O3 price were to match that for non-GM canola, and to $134/hectare if O3 attracted a price premium of 5% (see penultimate row of Table 3). Even if the technology access fee for O3 was twice that for RR, that would lower those gross margin differences by just $16/hectare. These comparisons illustrate the ***sensitivity of the gross margin differences to price assumptions***.

Gross margin differences are also sensitive to assumptions about the gap in yields per hectare. The gap in yields between TT and RR canola in the Wimmera region of Victoria during 2013-17 was 10% (1.35 vs 1.50 tonnes). However, in South Australia the average yield for non-GM canola over the period since the moratorium was imposed in 2003 is just 1.20 tonnes/hectare, making the gap between it and RR 20%. When that is assumed (consider

it an upper-bound estimate of the yield gap), the difference between the gross margins for TT and RR becomes $113/hectare or three times the base case of $38 shown at the bottom of column 2 in Table 3. These comparisons illustrate the ***sensitivity of the gross margin differences to yield gap assumptions***.

What do these gross margin differences amount to in aggregate dollars for South Australia? The differences between GM and TT gross margins apply only to that fraction of the state's canola crop that would switch from a non-GM to a GM variety. With that fraction assumed to rise evenly over the first 5 years and then plateau, two sets of calculations are provided. The first is an historical one, involving estimates for the period 2004-18 of the cost of having a moratorium in the state so far following OGTR approval in 2003. The second set of calculations involves projections from 2019 to 2025, to estimate the canola farmers' net benefits foregone should the moratorium remain in place for that period, as currently legislated. In both cases it is assumed the per-hectare gross margin differences shown in Table 3 prevail over both the retrospective period (2004-18, $38/ha with a 10% yield gap or $113/ha with a 20% yield gap) and the period ahead (2019-25, $38/ha with a 10% yield gap). The average crop area of the state during 2004-16 is used in the historic case (225,000 ha/year), while the average for just 2011-16 is used in the prospective case (265,000 ha/year).

With these assumptions, and assuming conservatively that the GM technology does not add to the total area sown to canola in South Australia, the aggregate direct economic consequences of the moratorium for canola are summarized in Table 4, ignoring inflation and so expressed in 2018 AUD.[22] The most-conservative analysis, assuming a lower price for GM canola, a lower yield gap (10%) and a low adoption rate (10% max.), suggests the state's farmers would have received $11 million more revenue by 2018 from growing canola had the moratorium not been in place from 2004; and that they will forego another $5 million during 2019-25 if the state's current moratorium is unchanged over that period. The historic estimate trebles to $33 million when the more-realistic lower historical yield average is applied to non-GM canola to make a yield gap of 20%. This ***again shows the sensitivity of the estimated direct impact to the yield gap assumption***. With just 10% of non-GM canola being displaced by GM canola, the total annual volume and value of South Australian production of canola in 2018 would each have been greater under this GM scenario, by 4-7 kt or $1-3 million that year (see the first pair of rows of Table 4).

That gain to farmers is net of the technology access fee paid to the producer of RR canola seed. Over the 2004-18 period the estimated TAF payment (at the assumed $8/kg of GM seed and 2kg/ha) accumulates to (15 x 0.36 =) $5.4 million, and during 2019-25 to (7 x 0.424 =) $3 million plus $424,000 per year thereafter.[23] In so far as a fraction of that $8.4+ million TAF revenue is invested by the life science corporation into extra R&D in South Australia to provide even more suitable GM varieties in the future, it (plus any extra matching funding attracted from, e.g., GRDC) would be an additional gain to the state.[24]

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[22] Discounting also is ignored. This is done because per tonne prices and costs vary though time and are unknown for future years, hence the use of representative numbers as of 2018. Were standard discounting to be applied, the negative net present value (NPV) of the moratorium's imposition to date would be greater; and so too would be the NVP of a continuation of the moratorium if its cost beyond 2025 indefinitely were to be included.

[23] Had the TAF been $6 instead of $8/kg of GM seed, the gross margin difference between GM and non-GM canola would have been $4/hectare greater and the transfer from farmers to the life science corporation would have been $1.2 million less during 2004-18. The TAF would have to more than treble before the estimated gross margin for RR GM canola fell to that of non-GM canola.

[24] That $8.4 million TAF revenue, when added to the base-case (11+5=) $16 million extra gross revenue to farmers suggests the life science firms would receive only 35% of the sum of those gains. This compares with the estimate for GM soybean in the US by Ciliberto, Moschini and Perry (2019, p. 32) of 56% of the gains going to the life science firms.

Table 4: Estimated direct economic consequences of the state GM crop moratorium on farm earnings from canola, 2004 to 2018 and 2019 to 2025 ($m), and on the aggregate annual volume and value of GM and non-GM canola production in South Australia, 2018 or 2025 (kt and $m)

	Extra farm receipts, full period ($m)	Difference in volume of canola production, last year of period (2018 or 2025), kt/year			Difference in value of canola production, last year of period (2018 or 2025), $million/year		
		GM	non-GM	Total	GM	non-GM	Total
Historic (2004-18)							
10% RR adoption, 10%yg[a]	11	34	-30	4	17	-16	1
10% RR adoption, 20%yg[a]	33	34	-27	7	17	-14	3
Prospective (2019-25)							
10% RR adoption, 10%yg[a]	5	40	-36	4	20	-19	1
20% O3 adoption	25	80	-72	8	42	-38	4
30% O3 adoption	53	119	-107	12	66	-56	10

[a] yg refers to the yield gap between non-GM canola in South Australia historically since 2004 and the current RR yield.
Source: Author's spreadsheet, based on assumptions in text above.

The prospective results depend heavily on not only the assumed price for GM canola and assumed yield gap but also on the associated speed and maximum extent of GM adoption. Now that a new more-profitable GM canola variety with Omega 3 is commercially available from 2019, the gains from removing the moratorium could be much larger by 2025 than if just the current RR variety of GM canola were to be available. For example, if the Omega 3 variety attracted the same price as non-GM canola, and if that led to 20% instead of just 10% GM adoption, the benefit to farmers over the next seven years would be $25 million instead of $5 million if they grew it rather than RR canola; and if the Omega 3 variety attracted a premium of 5% over non-GM canola and that led to a 30% GM adoption rate, farmers would be better off by $53 million by 2025 (column 1 of Table 4). These increases are based on the higher gross margin differences associated with the O3 variety, shown in the final two columns of Table 3. These comparisons illustrate the ***sensitivity of farm revenue to assumptions about new GM varieties' prices and production costs and the speed and extent of GM adoption***. That greater adoption also would lead to a larger volume (up from 4 kt to 8-12 kt) and value (up from $1m to $4-10m) of the state's annual canola production as of 2025 than if only 10% adoption of (RR) GM canola occurred (columns 4 and 7 of Table 4). Such high levels of oilseed production would increase the probability of a firm building an oil-crushing plant for the first time in South Australia, adding further to the economic gains to the state.

These and the earlier prospective estimates for the period from 2019 assume the technology access fee remains at the current $8/kg of GM seed. If the fee were to be higher, the gain to GM-adopting farmers would be lower but the earnings of the producers of that new GM seed would be higher. For example, if the TAF doubled for Omega 3 canola seed and that constrained its maximum adoption rate to 20%, the cumulative gain to farmers during 2019-25 would drop from $53m (with 30% adoption) or $25m (with 20% adoption) to $19m, while the life science firm's TAF revenue would rise from $9m (with 30% adoption) to $12m (despite an assumed drop in adoption to 20%).

These examples, showing the sensitivity of results to altered assumptions, provide a range of estimates of the past and prospective direct economic costs of the GM crop moratorium to South Australian canola farmers and revenue forgone for life science firms.

Finding 4.1: The cumulative cost to canola farmers of South Australia's GM crop moratorium is estimated to be up to $33 million over 2004-18, and will be at least another $5 million if the moratorium is kept until 2025 – and possibly much more if Omega 3 canola proves to be higher priced and more profitable than current Roundup Ready canola.

Finding 4.2: Gross revenue for the producers of GM canola seed would have been an estimated $5.4m higher during 2004-18 without the SA crop moratorium, and $3m higher during 2019-25 if the current technology access fee is unchanged – at least some of which would have been allocated to new crop R&D investments in South Australia.

Not captured in these calculations are the producer benefits in the crop rotation in the season following a GM canola crop, in the form of reduced weed control costs and increased cereal yields. Based on GRDC findings, PIRSA estimates they could amount to between $12 and $36 per hectare. Applied to an average of 265,000 hectares following each canola season, that adds an extra $0.3-0.9 million to the annual benefits of withdrawing the moratorium even if the GM adoption rate is only 10%.

Offsetting this additional benefit might be higher segregation costs if it is more expensive to preserve the identity of GM versus non-GM crops than it is to do so between different non-GM crops. The above analysis assumes, on the basis of numerous submissions to the Review, that there would be no extra segregation costs for either non-GM or GM growers, but some earlier analysts have assumed they could amount to as much as $11.50 per hectare of GM area (e.g., Biden 2016; Biden et al. 2018). With 10% adoption, such a cost would subtract $0.3 million from the annual direct benefits of dropping the GM moratorium.

Finding 4.3: The above findings ignore farmers' reduced weed control costs and increased yields for the crop that follows GM canola the next season (worth up to $0.9 million per year), but they also ignore possible additional segregation costs (up to $0.3 million per year) if the GM moratorium is dropped.

Also not captured in these calculations is the benefit of having an enhanced number of crop varieties to choose from to best suit each season's weather anomalies and each region's local climatic, agronomic, etc. environment. Zhang et al. (2018a, 2018b) note that there is currently less of a yield gap in low-rainfall areas of South Australia than in higher-rainfall areas such as the Southeast, which suggests regional differences are large. Those benefits include reductions in the variability across seasons in yields and net farm incomes – something that farmers appreciate more and more as climate changes keep adding to the volatility of their earnings.

Nor do the above calculations show (as they are outside the Review's terms of reference) the environmental benefits of GM versus non-GM canola production from reduced farm chemical use, and any further reduction in tillage and thus in the greenhouse gas emissions associated with that activity. Those environmental benefits have been shown by others to be potentially very large (see, e.g., Biden et al. 2018).

In addition to potentially higher gross margins and hence annual farm revenues that would flow from being able to adopt GM varieties, their enhancement of farm productivity is likely to boost the value of farm land in the state. Any such wealth enhancement would be enjoyed by all farm landowners, including those who chose not to adopt GM varieties (assuming coexistence protocols and codes of practice work as well in South Australia as they have in the other mainland states).

Finding 4.4: Additional farmer benefits from being allowed to grow GM crops, not included in the above calculus, are (a) having more varieties to choose from to best suit specific environments and seasonal weather anomalies, (b) environmental and health benefits from reduced farm chemical applications, and (c) a likely boost to the value of farm land whose productivity and profitability is raised.

Yet another direct economic benefit to South Australia that would result from removing its GM moratorium that is not captured in the above calculations relates to the transporting of GM crop products. Such movements are banned under the current moratorium. If relaxed, there would be a stronger demand for South Australian transit services, should there be a wish to move grain or seed between the eastern states and Western Australia to smooth out seasonal anomalies. South Australian GM growers and GM seed suppliers would be in a stronger position than those in neighbouring states to supply such demands, as they would have less intra-national distance to transport their product east or west than would their more-distant neighbours.

Finding 4.5: Removing the moratorium on the transport of GM crop products in South Australia would expand the demand for transport services and lead to more interstate shipments of canola.

Should it be decided to remove the GM crop moratorium in the mainland part of the state but not on Kangaroo Island, the above estimated benefits to farmers and GM seed producers would be reduced by less than 2%, which has been that island's maximum share of the state's canola production in recent years.

Finding 4.6: The benefits of allowing GM canola production in South Australia would be reduced by less than 2% if the GM moratorium were to be retained for Kangaroo Island.

4.4 Additional benefits and costs of retaining the GM moratorium in SA

One of the unquantifiable benefits of retaining the current moratorium is that it preserves the option of South Australia maintaining its GM-free status. Another is that it continues to benefit those who value that status for philosophical, ethical or spiritual reasons. Thirdly, it continues to benefit producers whose brand is enhanced by their buyers recognizing that South Australia is a GM-free zone. Against those unmeasured benefits are the regulatory costs of enforcing the moratorium (also unmeasured for South Australia, but found to be substantial in Tasmania, see TDPIPWE 2014), in addition to the benefits foregone by producers who would profit from the moratorium being dropped.

The illustration in Section 4.3 focuses on canola because that is considered by most commentators to be the only significant GM crop currently of relevance to South Australia should its GM crop moratorium be removed. Canola is a relatively minor crop in this state, however. More significant economically are wheat, barley, pulses and even hay, not to mention horticultural crops and winegrapes (Table 5). Hence if new GM varieties of any of those crops were to emerge, the economic benefit to the state of removing the GM moratorium would be potentially far greater than suggested in Section 4.3.

New GM varieties of a wide range of species are continually being developed around the world (Appendix 2), and permission for controlled-release field trials of new GM prospects in Australia are steadily being sought, and provided by, the OGTR (Appendix 3).

The latter include nutritionally enhanced canola and Indian mustard, disease-resistant wheats and potatoes, more-nutritious perennial ryegrass and sorghum for animals, and abiotic stress-tolerant wheat and barley.[25] In addition, stacked traits are being developed to achieve more than one objective simultaneously (as with Australian GM cotton, which involves both insect resistance and herbicide tolerance).

While neither of the other OGTR-approved GM crops (cotton and safflower)[26] have been significant crops in South Australia in their non-GM forms, the removal of the state's GM moratorium would open up the possibility of them being experimented with for suitability in select locations within the state (see Eco Logical 2014).

Table 5: Shares of farm products in the quantity of grain, total value of agricultural and wine output, and value of all agricultural, food and wine exports, South Australia, 2016-17 (%)

	% of total tonnes of grain (10-year ave.)	% of total ag output value (at farm gate)	% of total ag, food & wine exports
Wheat	58.5	16.9	21.3
Barley	27.2	7.0	9.5
Pulses	4.0	6.8	9.1
Canola	4.2	2.9	3.6
Hay	na	4.5	2.1
Other grain or seed crops	6.1	0.9	0.9
Horticultural crops	na	13.8	4.5
Livestock, wool & dairy	na	38.2	24.3
Winegrapes & wine	na	9.0	24.7
TOTAL (%)	100.0	100.0	100.0
TOTAL (mmt & $billion)	7.9mmt	$5.3b	$6.0b

Source: Compiled by PIRSA, based on value of agricultural commodities produced in South Australia (http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7503.02016-17?OpenDocument), PIRSA *Crop and Pasture Reports*, and South Australia Origin Exports from the Global Trade Atlas Database.

Some South Australia's lucerne seed producers and the hay industry also are hopeful that without the GM moratorium it would be possible to develop a new variety that emulates a GM lucerne grown in the United States that delivers up to 28% more digestibility through decreased lignin. That may enhance the export prospects not only for hay but also for high-valued lucerne/alfalfa seed.[27]

[25] A significant proportion of those Australian field trials of GM crops are being undertaken by public sector institutions. Of the 24 latest field trial licences issued, 18 (75%) are held by public sector agencies such as universities, Commonwealth research and development corporations and the CSIRO.

[26] This new GM sorghum, and Omega 3 canola, are the direct result of CSIRO and GRDC joining forces in 2004 to establish a Crop Biofactories Initiative. The $15 million investment aims to develop a commercially viable plant-based industrial oils industry in Australia by 2020. Omega-3 oil and meal is for use in food production and as a feed for the seafood industry. The super-high oleic safflower produces an oil for use in the high-value oleo chemical industry, where it will replace current sources of oleic oil such as environmentally sensitive palm oil. The oil will be used for products such as lubricants (a substitute for petroleum products, so reducing carbon emissions), transformer oils, cosmetics and medical items.

[27] About one-fifth of the world's seeds now enter international trade (OECD 2018, p. 30). South Australia's participation in the GM part of that market, including for lucerne seed, would become a possibility if the GM moratorium were to be dropped.

Livestock and dairy producers have expressed a strong interest, from a grazing perspective, in the introduction of GM ryegrass. High Metabolisable Energy GM ryegrass has been shown in New Zealand's AgResearch's laboratories to grow up to 50% faster than conventional ryegrass.[28]

To date the wine industry has been wary of adopting GM grape varieties for fear of an adverse consumer reaction. However, European countries are developing GM grape varieties that require less pesticide spraying, partly in response to some traditional sprays being (or soon to be) banned there. Easton (2018) reports that four new cross-bred (though not GM) grape varieties were released in France in 2018, with the expectation that more than 30 new disease-resistant varieties will be available by 2025. Italy is doing likewise.[29] Should wine consumers' GM concerns ease over coming years – for example, because they perceive the heavy use of pesticides as a greater evil – South Australia's wine industry eventually could become a major beneficiary of the removal of the state's GM moratorium.

Finding 4.7: The benefits of removing the state's GM moratorium may be far greater than just those from canola as new GM varieties of other crops (and pasture grasses) of relevance to South Australia are developed and approved by the OGTR.

Meanwhile, several exciting new plant breeding avenues are evolving (Appendix 4). Perhaps the most relevant to this Review involves gene editing.[30] Regulations relating to these new techniques are still evolving in Australia and elsewhere. The European Court of Justice ruled in July 2018 that gene editing is to be regulated in the same way as GMOs in the EU, even though gene editing, as explained by Pennisi (2016), is not transgenic.[31] The OGTR (2016) put out a discussion paper and a request for options as to how this and other new gene technologies should be regulated, and in October 2018 it released a guide that updates how they will be regulated in Australia (OGTR 2018). The guide suggests that, across the spectrum of gene editing interventions, the least invasive applications will be regulated like conventional breeding while the most invasive will be treated like GMOs. Thus South Australia would be able to take full advantage of these new technologies only if and when its GM crop moratorium is removed.

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[28] https://www.agresearch.co.nz/news/key-step-forward-for-game-changing-grass/

[29] http://socialvignerons.com/2018/07/23/resistant-grape-varieties-the-future-of-viticulture/

[30] The most ardent of those who criticise GMOs on ethical grounds may also oppose gene editing. Their view contrasts with that of the scientists developing these new techniques, who believe it is unethical NOT to use these new techniques to improve global food security, nutrition and health. See, e.g., http://www.calyxt.com/

[31] Gene editing technologies allow the high-precision addition, detection or replacement of gene segments or fragments, enabling the introduction of desired genetic variants or the suppression of undesirable ones, for example to improve drought and disease resistance, decrease the use of fertilisers, herbicides, insecticides and fungicides, and increase nutritional profiles. As noted in the Department of Health (2018, p. 24), these techniques produce changes that can be identical to those that are, or could be, produced in nature and are indistinguishable from conventional breeding. Some stakeholders are concerned about off-target effects of gene editing, but those can arise also during conventional breeding. During conventional plant breeding, large numbers of gene variants are introduced by outcrossing or mutagenesis, resulting in undesired traits being inherited together with the trait of interest. Plant breeders then undertake many generations of selective breeding to remove undesirable traits before they finally produce a new commercial variety of the crop with the desired trait. Gene editing can achieve the same result much quicker. For more details on new plant breeding techniques, see OECD (2018, Box 7.2). Some prospective agricultural gene technologies in play in Australia are listed in this Review's Appendix 4 and detailed in a new book by a Queensland-based scientist (Godwin 2019).

Finding 4.8: New crop breeding techniques such as gene editing offer further benefits to farmers, but some of the new varieties may be regulated as if they are GMOs and thus would be unavailable in South Australia while ever the state's GM moratorium remains.

5

Summary of findings and policy options

The three policy options this Review has been asked to consider are (a) maintaining, or (b) modifying, or (c) removing South Australia's moratorium on GM crop production and transport that is currently scheduled to remain in place until 2025.

Most of the submissions to the Review clearly favoured either the 'maintain' option or the 'remove' option. A small number favoured the 'modify' option, most with the specific proposal that the moratorium be maintained for Kangaroo Island even if the government chooses to remove it for the state's mainland regions. The illustration of canola, in Sub-section 4.3, found that the net economic benefits to the state's farmers and to providers of GM seed of adopting the 'remove' option would be at most only 2% lower if the GM crop moratorium were to be maintained for Kangaroo Island.

Those favouring the 'maintain' option include people who may have ethical, philosophical or spiritual objections to GM technology or, like those submitting the duplicated campaign letter from dogooder.co, they worry about as-yet-unknown risks that GM crops may bring in terms of food safety and farmer and environmental health. Those, however, are matters dealt with by Commonwealth agencies and therefore are outside the terms of reference of this Review. Most of the other pro-moratorium submissions suggest the GM moratorium provides greater access to domestic and foreign markets and/or a premium price for non-GM food produced in the state. Those favouring the 'remove' option, by contrast, argue the state would be a net beneficiary if the moratorium was dropped.

This divergence of views is to be expected, since almost every policy or regulatory change has potential losers as well as winners – as does the introduction of most new technologies. The terms of reference for this Review recognise that fact, and provide the logical headings, in what follows, for summarizing the findings of the Review.

5.1. Market benefits of South Australia's moratorium on cultivating GM crops

While some submissions claimed there are market benefits to being seen as a GM-free state, it was mentioned mainly as an additional attribute that could be included in marketing alongside such attributes as being clean and green. Supportive evidence was provided only by traders of Kangaroo Island grains.

Other hard evidence is not supportive, however. Specifically, data on canola exports from the key Australian states to the European Union do not support the view that South Australians enjoy better access in EU non-GM grain markets. Furthermore, data on prices of grain produced in South Australia versus grain produced in neighbouring states suggest there is no premium for grain from South Australia despite it being the only mainland state with a GM crop moratorium.

5.2. Awareness of the moratorium by key trading partners and food processors

There is awareness of South Australia's GM crop moratorium by at least one foreign firm (an importer of Kangaroo Island canola) and by several food processing businesses operating in South Australia. They believe it to be beneficial to be able to claim their product is GM-free. If the moratorium were to be dropped, they therefore would want segregation of GM and non-GM crop products to be robust enough to be able to claim their processed product does not contain GMOs.

5.3. Segregation to retain market benefits from the moratorium

The experiences of GM canola production and marketing in other mainland states over the past decade reveal that segregation and identity preservation protocols and codes of practice can and do ensure the successful coexistence of GM and non-GM crops in Australia. Traders of Kangaroo Island canola are confident they would be able to preserve their grain's unique identity even if GM crop production were allowed in mainland South Australia, provided the GM moratorium was maintained for Kangaroo Island. They and their buyers in Japan believe such an arrangement would be sufficient to retain access to Japan's high-priced market for GM-free grain.

5.4. Potential GM innovations likely to be available for commercial adoption by 2025

A new GM variety of canola that is rich in Omega 3 was approved by the OGTR in 2018 for commercial growing in Australia, as was a new GM variety of safflower that is rich in oleic oil. These are examples of success from a long-term program of research at CSIRO. Currently there are OGTR-approved GM crop field trials (75% by public sector institutions) exploring nutritionally enhanced canola and Indian mustard, disease-resistant wheats and potatoes, more-nutritious perennial ryegrass and sorghum for animals, and abiotic stress-tolerant wheat and barley.

Meanwhile, new crop breeding techniques such as gene editing offer further potential benefits to farmers, but some of them may be regulated as if they are GMOs and thus would be available to South Australia farmers only if and when the state's GM crop moratorium is dropped.

Several submissions stressed that, because of the GM crop moratorium, fewer research dollars, scientists and post-graduate students have been coming to (or remained in) South Australia – a trend that would reverse if the moratorium were to be dropped.

5.5 Economic costs and benefits of maintaining, modifying or removing the moratorium

The cumulative cost historically of the GM food crop moratorium to South Australia's farmers is estimated to be $11-33 million over 2004-18. If the moratorium is kept until 2025, their foregone profits will be at least another $5 million, and possibly much more if Omega 3 canola proves to be more profitable than current Roundup Ready canola. Farmers also would have reduced weed control costs and increased yields for the crop that follows GM canola the next season, which would add up to another $0.9 million per year if the moratorium was dropped.

Other farmer benefits from being allowed to grow GM crops are difficult to value, but they include (a) having more varieties to choose from to best suit specific environments and seasonal weather anomalies, (b) environmental and health benefits from reduced farm chemical applications, and (c) a boost to the value of farm land whose productivity and profitability would be raised.

In addition, gross revenue for the producer of GM canola seed would have been an estimated $5.4m higher during 2004-18 without the moratorium, and $3m higher during 2019-25 if the current technology access fee is unchanged. At least some of that transfer from farmers to the GM seed producer would be allocated to new crop R&D investments in South Australia, which in turn would encourage more public (pre-commercial) agricultural R&D investments in the state.

These prospective benefits of allowing GM canola production in South Australia, and any additional ones from new GM crops that may become available and approved by the OGTR over coming years, would be reduced by less than 2% if the GM moratorium were to be retained for Kangaroo Island.

While difficult to quantify, removing the moratorium on the transport of GM crop products in South Australia would expand the demand for transport services and lead to more interstate shipments of canola.

Bringing South Australian GM legislation into line with other mainland states and the Commonwealth, including automatically adopting into South Australian law any future amendments to Commonwealth gene technology legislation, will be less costly to the state, including in terms of attracting/retaining research dollars, scientists and post-graduate students in South Australia.

Many of the submissions favouring the removal of the current moratorium on GM crop production and transport in the state – which include those from all the key farmer organizations – requested an immediate policy change. Given the positive experiences following reform in the other mainland states a decade ago, and the segregation protocols and codes of practices that have been established and proven over that period to ensure identity preservation for non-GM crop products at low cost, industry participants did not see a need for a one-year trial period as in Western Australia in 2009.

Appendix 1: Global area of GM crops by country in 2017

Rank	Country	Area (million hectares)	Biotech crops
1	USA	75.0	Maize, soybeans, cotton, canola, sugar beets, alfalfa, papaya, squash, potato, apples
2	Brazil	50.2	Soybeans, maize, cotton
3	Argentina	23.6	Soybeans, maize, cotton
4	Canada	13.1	Canola, maize, soybeans, sugar beets, alfalfa, potato
5	India	11.4	Cotton
6	Paraguay	3.0	Soybeans, maize, cotton
7	Pakistan	3.0	Cotton
8	China	2.8	Cotton, papaya
9	South Africa	2.7	Maize, soybeans, cotton
10	Bolivia	1.3	Soybeans
11	Uruguay	1.1	Soybeans, maize
12	Australia	0.9	Canola, cotton
13	Philippines	0.6	Maize
14	Myanmar	0.3	Cotton
15	Sudan	0.2	Cotton
16	Spain	0.1	Maize
17	Mexico	0.1	Cotton
18	Colombia	0.1	Maize, cotton
19	Vietnam	<0.1	Maize
20	Honduras	<0.1	Maize
21	Chile	<0.1	Maize, canola, soybeans
22	Portugal	<0.1	Maize
23	Bangladesh	<0.1	Brinjal/Eggplant
24	Costa Rica	<0.1	Cotton, pineapple
	total	**189.8**	

Source: (ISAAA 2017).

Appendix 2: Selected GM crop technologies at field-trial stage globally as of 2015

Crop	Trait	Type of research institution	Countries
Apple	Reduced bruising/browning	Private sector	Canada
Banana	Provitamin A content	Public sector	Uganda
	Bacterial resistance	Public sector	Uganda
	Insect/nematode resistance	Public sector	Uganda
Bean	Virus resistance	Public sector	Brazil
Cabbage	Insect resistance	Public sector	China, India
Canola	Herbicide tolerance with multiple modes of action	Private sector	Australia, USA, Canada
	Omega-3 content	Private sector	USA
	Nitrogen use efficiency	Private sector	USA
Cassava	Virus resistance	Public sector	Kenya, Indonesia, Uganda
	Provitamin A content	Public sector	Nigeria, Kenya, Uganda
Chickpea	Insect resistance	Public-private partnership	India
Cotton	Stacked insect resistance and herbicide tolerance	Private sector	Burkina Faso, Cameroon, Ghana, India, Kenya, Malawi, Pakistan, USA
Cowpea	Insect resistance	Public-private partnership	Burkina Faso, Ghana, Nigeria
Eggplant	Insect resistance	Public-private partnership	India, Philippines
Groundnut	Virus/fungal resistance	Public sector	India
Maize	High phytase (quality)	Public-private partnership	China
	Stacked drought tolerance and insect resistance	Public-private partnership	Kenya, South Africa, Uganda
	Stacked insect resistance and herbicide tolerance	Private sector	India, Indonesia, Pakistan, South Africa, USA, Vietnam
	Nitrogen use efficiency	Private sector	USA
	Abiotic stress and yield	Private sector	USA
Mustard	Male sterility	Private sector	India
Orange	Bacterial resistance	Private sector	USA
Pigeonpea	Insect resistance	Public sector	India

Potato	Fungal resistance	Public sector	Bangladesh, Indonesia, India
	Virus resistance	Public-private partnership	Argentina
	Various quality traits	Private sector	USA
Rice	Insect resistance	Public sector	China
	Insect resistance	Private sector	India
	Nitrogen use efficiency, water efficiency, salt tolerance	Public-private partnership	Colombia, Ghana, Nigeria, Uganda
	Nitrogen use efficiency	Private sector	USA
	Iron content	Public sector	India
	Provitamin A content	Public sector	Bangladesh, India, Indonesia, Philippines
	Stacked insect resistance and herbicide tolerance	Private sector	Argentina, USA
Safflower	High oleic acid	Public sector	Argentina, Australia
Sorghum	Stacked provitamin A, iron, zinc	Public-private partnership	Kenya, Nigeria
Soybean	Modified fatty acids	Private sector	USA
	Yield enhancement	Private sector	USA
	Multiple pest resistance	Private sector	USA
Sugarcane	Stacked insect resistance and herbicide tolerance	Private sector	Australia, USA
	Drought tolerance	Public-private partnership	Brazil, Indonesia
Tomato	Fungal resistance, insect resistance	Private sector	Argentina, Chile, Guatemala, India
	Fungal resistance, insect resistance	Public sector	China, Egypt
Wheat	Drought tolerance	Public sector	Australia, Egypt
	Insect resistance	Public sector	UK
	Fungal resistance	Public sector	China
	Virus resistance	Public sector	China
	Herbicide tolerance	Private sector	USA
	Improved grain quality	Public sector	Australia

Source: Qaim (2016).

Appendix 3: Recent GM crops licenced for limited and controlled release (field trials) in Australia

Organisation	Title of Project	Parent Organism	Modified Trait	Issue Date
Monsanto Australia Ltd	Limited and controlled release of canola genetically modified for herbicide tolerance	Canola	Herbicide tolerance	Under evaluation
Nuseed Pty Ltd	Limited and controlled release of canola genetically modified for altered oil content and herbicide tolerance	Canola	Composition - food (human nutrition), animal nutrition, herbicide tolerance	6-Sep-18
CSIRO	Limited and controlled release of bread wheat and durum wheat genetically modified for enhanced rust disease resistance	Bread wheat and durum wheat	Disease resistance	11-Jul-18
Department of Economic Development, Jobs, Transport & Resources	Limited and controlled release of perennial ryegrass genetically modified for fructan biosynthesis	Perennial ryegrass	Composition – animal nutrition, yield	6-Mar-18
Royal Melbourne Institute of Technology University	Limited and controlled release of buffalo grass genetically modified for herbicide	Buffalo grass	Herbicide tolerance, plant development-altered plant architecture	11-Apr-18

	tolerance and dwarf phenotype			
University of Queensland	Limited and controlled release of sorghum genetically modified for grain quality traits	Sorghum	Composition - animal nutrition, yield	25-Jul-17
University of Adelaide	Limited and controlled release of wheat and barley genetically modified for abiotic stress tolerance and yield improvement	Wheat and barley	Abiotic stress tolerance; enhanced yield	17-Jul-17
CSIRO	Limited and controlled release of wheat genetically modified for disease resistance, drought tolerance, altered oil content and altered grain composition	Wheat	Disease resistance, drought tolerance, Composition - food (processing), food (human nutrition)	1-May-17
Queensland University of Technology	Limited and controlled release of potato genetically modified for disease resistance	Potato	Disease resistance	20-Feb-17
Nuseed Pty Ltd	Limited and controlled release of Indian mustard (Juncea)	Indian mustard	Composition - food (human nutrition),	14-Feb-17

http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/ir-1

Appendix 4: Prospective agricultural gene technologies

The Australian Academy of Science, in its submission to the Independent Review, drew attention to a number of current and developing gene technologies likely to be of relevance to South Australian agriculture by 2025. They include:

• **Gene editing:** Gene editing is an umbrella term for techniques which make small, targeted changes to an organism's DNA, using precise genetic tools such as the CRISPR/Cas9 system or other site-directed nucleases. Gene editing is now in wide use in agricultural research and several examples are in the early stages of deployment by industry. This technique has high precision and the outcomes are often indistinguishable from traditional breeding methods. Because of these factors, the review of the *Gene Technology Act 2000* currently underway is considering whether gene editing techniques should be considered gene modification technologies.

• **Topical RNAi technology:** RNA interference, or RNAi, is a technique which uses RNA constructs to modulate the expression of genes. This allows control of aspects of the development of an organism which may or may not alter the organism's genome. Topical or exogenous RNAi does not involve altering the organism's genome and by most definitions would not be considered a gene modification technology.

• **Disabled Cas9 enzymes:** Disabled Cas9 enzymes make use of Cas9's highly specific DNA binding properties but do not cut the DNA. This allows other targeted modifications, such as using a methyltransferase enzyme to make epigenetic modifications, or deaminases to make point changes to DNA without cutting it. Under present definitions, it is not clear if such applications would be considered a gene modification technology.

• **Cas9 ribonucleases:** Higher specificity of Cas9 gene editing can be achieved using delivery systems to provide Cas9 ribonucleoproteins directly to the cell rather than using transgenic methods, because of the high turnover of the ribonucleoprotein.

Extensive testing of genetic modification technologies has not demonstrated that they pose any risk to agricultural products compared to conventionally produced products. For this reason, the Academy considers that restricting use of these technologies through mechanisms such as the South Australian moratorium ultimately disadvantages consumers and producers through loss of access to new products or traits.

For more details of next-generation genetic modification and gene editing, see the new book by the University of Queensland's Director of Crop Science (Godwin 2019).

References

ABARES (2017), *Australian Commodity Statistics 2017*, Canberra: ABARES, December.

ABARES (2018), *Australian Commodities, September 2018*, Canberra: ABARES, September.

ABCA (2017), *The Official Australian Reference Guide to Agricultural Biotechnology and GM Crops*, Melbourne: Agricultural Biotechnology Council of Australia.

ACIL Tasman (with the assistance of Innovation Dynamics((2007), *GM Canola: An Information Package*, Report prepared for the Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, August. http://www.agriculture.gov.au/SiteCollectionDocuments/ag-food/biotech/gm-canola-info-package.pdf

Alcock, K.T. (2015), "The Current Status of GM/Non-GM Canola Coexistence in Australian Broadacre Farming Systems and Likely Future Challenges", Contributed paper at the Seventh International Conference on Coexistence between GM and non-GM based Agricultural Supply Chains, Amsterdam, 17-20 November.

Alston, J.M. and P.G. Pardey (2016), "Antipodean Agricultural and Resource Economics at 60: Agricultural Innovation", *Australian Journal of Agricultural and Resource Economics* 60(4): 554–568.

Anderson, K. (2017), "Sectoral Trends and Shocks in Australia's Economic Growth", *Australian Economic History Review* 57(1): 2-21, March.

Anderson, K. E. Valenzuela and L.A. Jackson (2008) "Recent and Prospective Adoption of Genetically Modified Cotton: A Global CGE Analysis of Economic Impacts", *Economic Development and Cultural Change* 56(2): 265-96, January.

AOF (2007), *Delivering Market Choice with GM Canola* (An industry report prepared under the Single Vision Grains Australia process), Sydney: Australian Oilseeds Federation. http://aof.clients.squiz.net/Technical_Info/industry_reports/gm_canola

AOF/GTA (2009), *Market Choice in the Canola Industry: 2008/9 Final Stakeholders Report*, Sydney: Australian Oilseeds Federation and Grain Trade Australia,. http://www.australianoilseeds.com/__data/assets/pdf_file/0018/5931/Market_Choice_Stakeholder_Report_Final_Nov09.pdf

AOF/GTA (2010), *Market Choice in the Canola Industry: 2009/10 Season*, Sydney: Australian Oilseeds Federation and Grain Trade Australia. http://www.australianoilseeds.com/__data/assets/pdf_file/0008/7937/GM_Stakeholder_Report_09.10_Season_V4_Final.pdf

AOF/GTA (2011), *Market Choice in the Canola Industry: 2010/11 Season*, Sydney: Australian Oilseeds Federation and Grain Trade Australia, October. http://www.australianoilseeds.com/__data/assets/pdf_file/0007/8827/GM_DRAFT_Interim_Stakeholder_Report_10.11_Season_FINAL.pdf

Apted, S. and Mazur, K. (2007), "Potential impacts from the introduction of GM canola on organic farming in Australia", ABARE Research Report 07.11, Canberra: ABARES, May. http://www.agriculture.gov.au/ag-farm-food/biotechnology/reports/gm_canola_potential_impact

Armstrong, I., K. Adams and T. Reeves (2007), *Gene Technology (GM Crop Moratorium) Act 2003 Review: Independent Panel Report,* Submitted to the NSW Minister for Primary Industries, Sydney.

Barrows, G., S. Sexton, and D. Zilberman (2014), "Agricultural Biotechnology: The Promise and Prospects of Genetically Modified Crops", *Journal of Economic Perspectives* 28(1): 99–120, Winter.

Biden, S. (2016), *Comparing the Adoption of Genetically Modified Canola in Canada and Australia: The Environmental and Economic Opportunity Costs of Delay*, Master of Science Thesis, University of Saskatchewan, Saskatoon.

Biden, S., S.J. Smyth and D. Hudson (2018), "The Economic and Environmental Cost of Delayed GM Crop Adoption: The Case of Australia's GM Canola Moratorium", *GM Crops & Food* 9(1): 13-20.

Brookes, G. (2016), "Adoption and Impact of GM Crops in Australia: 20 Years' Experience", https://www.croplife.org.au/wp-content/uploads/2016/05/CL_20-YearsGM_Lores.pdf

Brookes, G. and P. Barfoot (2018a), "Farm Income and Production Impacts of Using GM Crop Technology, 1996–2016", *GM Crops and Food* 9(2): 59–89.

Brookes, G. and P. Barfoot (2018b), "Environmental Impacts of Genetically Modified (GM) Crop Use 1996–2016: Impacts on Pesticide Use and Carbon Emissions", *GM Crops and Food* 9(3): 109-39.

Bucat, J. and A. Blake (eds.) (2018), *Canola Agronomy Research in Western Australia*, Perth: WA Department of Primary Industries and Regional Development, August. https://www.agric.wa.gov.au/sites/gateway/files/Canola%20Agronomy%20Research%20in%20WA.pdf

Burrell, M.L.R. (2006), *A Farmer's Choice: Legal Liability of Farmers Growing Crops,* Report prepared for the Department of Agriculture, Fisheries and Forestry by the Australian Centre for Intellectual Property in Agriculture, Canberra. http://acipa.edu.au/pdfs/a-farmers-choice-legal-liability-of-farmers-growing-crops.pdf

Calcutt, G. (2009), *Western Australian Genetically Modified Crops Free Areas Act 2003: Report on the Review of the Act under Section 19*, Perth: Department of Agriculture and Food, November.

CBH Group (2018), "Transcript of Evidence by CBH Group Taken at Perth Wednesday, 11 April 2018", Standing Committee on Environment and Public Affairs Inquiry into Mechanisms for Economic Loss to Farmers in Western Australia Caused by Contamination by Genetically Modified Material, Perth. http://www.parliament.wa.gov.au/Parliament/commit.nsf/(Evidence+Lookup+by+Com+ID)/CEFBA0D98B112CE34825829E002192D0/$file/ev.ngm.180411.tro.001.CBH.pdf

Ciliberto, F., G. Moschini and E. Perry (2019), "Valuing Product Innovation: Genetically Engineered Varieties In U.S. Corn And Soybeans", CEPR Discussion Paper 13525, Centre for Economic Policy Research, London, February.

COMTRADE (2018), United Nations merchandise trade statistics, Accessed 12 November at https://comtrade.un.org/data/

Cormick, C. and R. Mercer (2017), "Instinct and Reason: Community Attitudes to Gene Technology", Prepared for the Office of the Gene Technology Regulator, Canberra. Accessed 31 October at http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/Content/327437B632158967CA257D70008360B1/%24File/FINAL%20Report%20-%202017%20Community%20Attitudes%20to%20Gene%20Technology%20261017.pdf

Cotton Australia (2018), "Biotechnology and Cotton in Australia", accessed 11 October at https://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-biotechnology

Daly, J., K. Anderson, R. Ankeny, B. Harch, A. Hastings, A. Rolfe and R. Waterhouse (2015), *Australia's Agricultural Future,* Melbourne: Australian Council of Learned Academies.

Department of Health (2018), *The Third Review of the National Gene Technology Scheme,* Canberra: Department of Health, October. http://www.health.gov.au/internet/main/publishing.nsf/Content/gene-technology-review

EASAC (2013), *Planting the Future: Opportunities and Challenges for Using Crop Genetic Improvement Technologies for Sustainable Agriculture*, Policy Report 21, European Academies Science Advisory Council, Halle.

Easton, S. (2018), "Gene Therapy for a Sustainable Future", *Winestate* 12: 20-21, September/October.

Eco Logical Australia (2014), "Potential for Growth in the Australian Cotton Industry", Prepared for Cotton Research and Development Corporation. Accessed 31 October at: https://www.crdc.com.au/sites/default/files/pdf/Potential%20for%20Growth%20in%20the%20Australian%20Cotton%20Industry%20-%20Volumes%201%20and%202_0.pdf

ESCOSA (2017), *Inquiry into the South Australian Bulk Grain Export Supply Chain Costs*, Draft report, Adelaide: Essential Services Commission of South Australia, August. Accessed 1 November 2018. https://www.escosa.sa.gov.au/ArticleDocuments/1074/20180807-Inquiry-BulkGrainExportSupplyChainCosts-DraftReport.pdf.aspx?Embed=Y

Fedoroff, N. (2004)**,** *Mendel in the Kitchen**:** A Scientist's View of Genetically Modified Foods*, Washington DC: National Academy Press.

FSANZ (2018), *Review of Food Derived Using New Breeding Techniques: Consultation Outcomes*, Canberra: Food Standards Australia New Zealand, August.

Fuglie, K. (2016), "The growing Role of the Private Sector in Agricultural Research and Development World-wide", *Global Food Security* 10: 29-38.

Fuglie, K. (2018), "R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture", *Applied Economic Perspectives and Policy* 40(3): 421-44.

Fuglie, K.O., S.L. Wang and V.E. Ball (eds.) (2012), *Productivity Growth in Agriculture: An International Perspective*, London: CABI.

GFAR (2016), *Identification and Assessment of Added-value Export Market Opportunities for Non-GMO Labelled Food Products from South Australia*, Adelaide: Centre for Global Food and Resources, University of Adelaide, June.

Godwin, I.D. (2019), *Good Enough to Eat? Next Generation GM Crops,* London: Royal Society of Chemistry.

Grafton, R.Q., J. Mullen and J. Williams (2015), "Australia's Agricultural Future: Returns, Resources and Risks", background paper prepared for the Australian Council of Learned Academies (Daly et al. 2015).

GRDC (2012), *GM Canola Impact Study, New South Wales and Victoria: Final Report 2008–2010*, Canberra: Grains Research and Development Corporation.

GRDC (2015), *Impact Assessment for Genetically-Modified Canola in Cropping Systems*, Canberra: Grains Research and Development Corporation. [This is the publicly released summary of GDRC (2012) and GRDC (2014).] Accessed 12 October 2018 at https://grdc.com.au/resources-and-publications/all-publications/publications/2014/03/gm-canola-impact-survey

Gusta, M., S.J. Smyth, K. Belcher, P.W.B. Phillips and D. Castle (2011), "Economic Benefits of Genetically-Modified Herbicide-Tolerant Canola for Producers", *AgBioForum* 14: 1-13.

Herring, R. and R. Paarlberg (2016), "The Political Economy of Biotechnology", *Annual Review of Resource Economics* 8: 397-416.

House of Commons (2015), *Advanced Genetic Techniques for Crop Improvement: Regulation, Risk and Precaution*, Fifth Report of Session 2014–15, Science and Technology Committee, House of Commons, UK Parliament, London.

Hudson D. and R. Richards (2013), "The Agronomic, Environmental, Economic and Co-Existence Impacts of GM Canola", Trial results, Grains Research and Development Corporation, Canberra.

Hudson D. and R. Richards (2014a), "GM Canola Impact Survey: Information for Growers, Advisors and Industry", Grains Research and Development Corporation, Canberra. Accessed 12 October 2018 at https://grdc.com.au/__data/assets/pdf_file/0021/74721/gm-canola-impact-survey-pdf

Hudson D. and R. Richards (2014b), "Evaluation of the Agronomic, Environmental, Economic and Co-Existence Impacts following the Introduction of GM Canola to Australia (2008-2010)", *AgBioForum* 17(1): 1–12.

Hurley, T.M., P.G. Pardey, X. Rao and R.S. Andrade (2016), "Returns to Food and Agricultural R&D Investments Worldwide, 1958-2015", InSTePP Brief, St. Paul MN: International Science & Technology Practice & Policy Center, August.

Hurley, T.M., X. Rao and P.G. Pardey (2014), "Re-examining the Reported Rates of Return to Food and Agricultural Research and Development", *American Journal of Agricultural Economics* 96(5): 1492-1504.

ISAAA (2017), *Global Status of Commercialized Biotech/GM Crops in 2017: Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years*, ISAAA Brief No. 53, Ithaca NY: International Service for the Acquisition of Agri-biotech Applications.

Kalaitzandonakes, N., P.W.B. Phillips, J. Wesseler, and S.J. Smyth (eds.) (2016), *The Coexistence of Genetically Modified, Organic and Conventional Foods: Government Policies and Market Practices*, New York: Springer.

Kingwell, R. (2011), "Farmers' Use of Genetically Modified Crops: Trends and Issues for Australia", *Farm Policy Journal* 8(1): 1-9, March.

Klümper, W. and M. Qaim (2014), "A Meta-Analysis of the Impacts of Genetically Modified Crops", *PLoS ONE* 9(11): e111629, November.

Lawson, A., A. Cosby, D. Baker, S. Leu, E. Lefley, Euromonitor International, A. Sahota, and N. Bez, (2018), *Australian Organic Market Report 2018*, Brisbane: Australian Organic Ltd.

Lusk, J.L., J. Roosen and A. Bieberstein (2014), "Consumer Acceptance of New Food Technologies: Causes and Roots of Controversies", *Annual Review of Resource Economics* 6: 381–405.

Lynas, M. (2018), *Seeds of Science: Why We Got it So Wrong on GMOs*, London: Bloomsbury Sigma.

McCauley, R., M. Davies and A. Wyntje (2012), "The step-wise approach to adoption of genetically modified (GM) canola in Western Australia", *AgBioForum 15*(1): 61-69.

McCluskey, J.J., N. Kalaitzandonakes and J.F.M. Swinnen (2016), "News Media Coverage and Public Perceptions: Insights from New Food Technologies", *Annual Review of Resource Economics* 8: 467-86.

Meemken1, E.-M. and M. Qaim (2018), "Organic Agriculture, Food Security, and the Environment", *Annual Review of Resource Economics* 10: 39–63.

Mewett, O., K.R. Emslie, H. Johnson, J. Lizzio, K.L. Dibley, E.J. Murby and P. Hattersley (2008), *Maintaining Product Integrity in the Australian Seed and Grain Supply Chain: The Role of Sampling and Testing for GM Events*, Canberra: Australian Government Bureau of Rural Sciences.

NVT (2018), *2018 Victorian Winter Crop Summary*, Melbourne: Agriculture Victoria, based on GRDC's National Variety Trials. Accessed 31 October 2018 at https://www.nvtonline.com.au/

Nossal, G., C. Forster and M. Curnow (2007), *Review of the Moratorium on Genetically Modified Canola in Victoria,* Melbourne: Victorian Department of Primary Industries, November.

OBPR (2015), *User Guide to the Australian Government Guide to Regulation*, Office of Best Practice Regulation, Department of Prime Minister and Cabinet, Canberra, October. https://www.pmc.gov.au/sites/default/files/publications/001_User_Guide_0.pdf

OBPR (2016), *Cost-Benefit Analysis: Guidance Note*, Office of Best Practice Regulation, Department of Prime Minister and Cabinet, Canberra, February. https://www.pmc.gov.au/sites/default/files/publications/006-Cost-benefit-analysis.pdf

OECD (2018), *Concentration in Seed Markets: Potential Effects and Policy Responses*, Paris: OECD, December.

OGTR (2016), "Discussion Paper: Options for Regulating New Technologies", Office of the Gene Technology Regulator, Canberra, October.

OGTR (2018), "Updating Gene Technology Regulation in Australia: Consultation Quick Guide", Office of the Gene Technology Regulator, Canberra.

Pardey, P.G., J.M. Alston, C. Chan-Kang, T.M. Hurley, R.S. Andrade, S.P. Dehmer, K. Lee, and X. Rao (2018), "The Shifting Structure of Agricultural R&D: Worldwide Investment Patterns and Payoffs", pp. 13–39 in *From Agriscience to Agribusiness: Theories, Policies and Practices in Technology Transfer and Commercialization*, edited by N. Kalaitzandonakes, E.G. Carayannis, E. Grigoroudis, and S. Rozakis, New York: Springer. https://doi.org/10.1007/978-3-319-67958-7_2.

Pardey, P.G., C. Chan-Kang, S.P. Dehmer and J.M. Beddow (2016), "Agricultural R&D is on the Move", *Nature* 537: 301-303, 15 September.

Pennisi, E. (2016), "The Plant Engineer", *Science* 353(6305): 1220-24, 16 September.

PIRSA (2018), *Farm Gross Margin and Enterprise Planning Guide 2018,* Adelaide: Primary Industries and Regions South Australia. (Spreadsheet freely downloadable at http://www.pir.sa.gov.au/__data/assets/pdf_file/0008/235844/Farm_Gross_Margin_and_Enterprise_Planning_Guide_2018.pdf)

Qaim, M. (2016), *Genetically Modified Crops and Agricultural Development*, London and New York: Palgrave Macmillan.

SA Genetically Modified Crop Advisory Committee (2007), *Genetically Modified Crops Management Act 2004 Review: Report of the Genetically Modified Crop Advisory Committee*, Adelaide: Parliament of South Australia, 24 October.

Single Vision Grains Australia (2007a), *Delivering Market Choice with GM Canola*, Canberra: Single Vision Grains Australia, July. Available at http://australianoilseeds.com/__data/assets/pdf_file/0019/2935/Delivering_Market_Choice_with_GM_canola_-_FINAL_-_1MB.pdf

Single Vision Grains Australia (2007b), *Principles for Process Management of Grain within the Australian Supply Chain: A Guide for Industry in an Environment where GM and Non-GM Grain is Marketed*. Canberra: Single Vision Grains Australia, August. http://www.australianoilseeds.com/__data/assets/pdf_file/0020/2981/Principles_for_Process_Management_Final.pdf

Smyth, S.J., M. Gusta, K. Belcher, P.W.B. Phillips and D. Castle (2011a), "Changes in Herbicide Use Following the Adoption of HR Canola in Western Canada", *Weed Technology* 25: 492–500.

Smyth, S.J., M. Gusta, K. Belcher, P.W.B. Phillips and D. Castle (2011b), "Environmental Impacts from Herbicide Tolerant Canola Production in Western Canada", *Agricultural Systems* 104: 403–10.

Smyth, S.J., W. Kerr and P.W.B. Phillips (2017), *Biotechnology Regulation and Trade*, New York: Springer.

Supreme Court of WA, Civil (2014), *WASC 187 Marsh vs Baxter Negligence and Private Nuisance Action – Judgement Summary*. Available from: http://decisions.justice.wa.gov.au/supreme/supdcsn.nsf/byApplicant.xsp?SessionID=E3TDS1OP12

Supreme Court of WA, Court of Appeal (2015), *WASCA 169 Marsh vs Baxter Negligence and Private Nuisance Action – Judgement*. Available from: http://decisions.justice.wa.gov.au/supreme/supdcsn.nsf/PDFJudgments-WebVw/2015WASCA0169/%24FILE/2015WASCA0169.pdf

TDPIPWE (2013), *Review of the Moratorium on Genetically Modified Organisms (GMOs) in Tasmania: Final Report*, Hobart: Tasmanian Department of Primary Industries, Parks, Water and Environment, December. https://dpipwe.tas.gov.au/Documents/Final%20Report_v.final_16-12-13.pdf

TDPIPWE (2014), *Genetically Modified Organisms Control Act Amendment Bill 2014: Decision Regulatory Impact Statement (RIS) Summary*, Hobart: Tasmanian Department of Primary Industries, Parks, Water and Environment. https://dpipwe.tas.gov.au/Documents/Decision%20Regulatory%20Impact%20Statement%20-%20GMO%20Amendment%20Act%202014%20Summary.pdf

Wang, S.L., P. Heisey, D. Schimmelpfennig and E. Ball (2015), *Agricultural Productivity Growth in the United States: Measurement, Trends and Drivers*, ERR-189, Washington DC: Economic Research Service, U.S. Department of Agriculture, July.

White, P., C. Carter and R. Kingwell (2018), *Australia's Grain Supply Chains: Costs, Risks and Opportunities*, South Perth: Australian Export Grains Innovation Centre, October.

Whitelaw, A. (2018), Personal communication from Mecardo, 22 October.

Whitelaw, A., M. Dalgleish and O. Agar (2018), *Analysis of Price Premiums under the South Australian GM Moratorium*, Report prepared by Mecardo for the GPSA and ABCA, Adelaide: Grain Producers of South Australia and Melbourne: Agricultural Biotechnology Council of Australia, March. https://www.abca.com.au/wp-content/uploads/2018/03/Analysis-of-price-premiums-under-the-SA-GM-moratorium.pdf

WHO (2014), http://www.who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/, May. Accessed 8 October 2018.

Zhang, H., J. Berger, M. Seymour, J. Bucat and R. Malik (2018a), "Yield of Different Herbicide-tolerant Canola Varieties: Are There Any Differences Among TT, RR, Clearfield and Conventional Canola Technologies?", pp. 14-16 in in Bucat and Blake (2018).

Zhang, H., J. Bucat, M. Seymour and J. Berger (2018b), "Hybrid versus Open-Pollinated TT Canola: Which One Wins Where?" pp. 17-19 in Bucat and Blake (2018).

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