GM technology and the Australian canola market*

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In this paper, we use a simulation model to measure the potential market and welfare effects of recently introduced genetically modified (GM) canola in Australia. The short-run results indicate that non-GM canola may emerge as a niche product commanding a premium. In the long run, GM technology appears to enhance aggregate welfare. However, when production cost savings are trivial and consumers become highly concerned about GM food products, aggregate welfare may decline. The policy implications of the analysis are explored.

Key words: canola market, genetically modified crops, segregation, welfare.

1. Introduction

Genetically modified (GM) canola is making its debut in Australia. Although the welfare implications remain less certain, consumer concerns have been a key issue sparking wide-spread controversy and placing unknown market ramifications. For Australian farmers, GM technologies offer many agronomic benefits, enhancing their ability to compete at the global level using technologies comparable to those employed by their competitors. However, individual producer decisions are likely to differ considerably. On the whole, the market implications appear ambiguous and warrant careful consideration.

While the large body of literature suggests that considerable analyses have already been conducted, studies in Australia have often taken a 'top-down' approach that do not detail subsystems. This paper seeks to explore the problem, taking a 'bottom-up' approach. The underlying microeconomic issues at the consumer and producer level are specified in greater detail and are linked together to analyse the problem in aggregate. More specifically, it aims to analyse and quantify the short-run and long-run affects of introducing GM canola in Australia. The equilibrium condition for both types of grain markets are described, assuming heterogeneity among consumers and producers. This will help provide direction for policy makers.

To this end, a simulation of a real world economic system is estimated. The short-run model examines the behaviour of farm and retail prices and price premiums in response to relative supplies. The long-run model explores responses in market prices, output, consumer and producer surplus under various scenarios compared to a market without GM technologies.

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2. Background

The emergence of modern biotechnology has seen many countries such as Canada, Argentina and China embracing the technology, facilitating considerable improvements in agronomy and providing environmental benefits. The advancement of GM crop varieties are likely to allow more sustainable farming systems, reduced variability in supply and more importantly, adaptation to changing climatic conditions. In Canada 1994, GM tomatoes and GM canola were the first commercially grown and released food crop with research and development (R&D) activity increasing over 30 fold between the years 1996 and 2001 (Stone *et al.* 2002). Currently, GM canola represents approximately 85 per cent of Canada's canola production (AOF 2007). In Australia, however, State and Territory governments, excluding Northern Territory and Queensland, introduced a GM moratorium on the commercial cultivation of GM crops. This constituted a response to concerns about the potential impacts on market access and trade. In February 2008, the green light was given to New South Wales and Victoria, where GM canola is now commercially grown. The first GM canola crop has come off in early 2009 and, presently, experiences by a farmer in Victoria suggest that GM canola have permitted farmers to sustain small profits in unfavourable climatic conditions. This is a result of superior weed control and the ability for dry-sowing (GRDC 2009).

On the supply side, canola has become a major part of crop rotations. As such, canola has become much less substitutable in production and does not appear to be heavily influenced by its own price. There are three types of producers that represent the entire canola market in Australia and may potentially adopt GM technology depending on their cost structures. These include triazine tolerant (TT), imidazolinone tolerant (IT) and conventional producers (Norton 2003). The on-farm benefits particularly relevant to these farmers include improved yields and reduced chemical costs. GM canola provides greater weed control that will likely reduce yield losses and increase farm output. This is crucial as research indicates that canola yields in Australia lags behind Canada following the introduction of GM varieties. The five year average canola yields in Canada increased by 15.8 compared to Australia which declined by 13.9 per cent between 1995/96 to 2005/06. Side by side field trials conducted by Monsanto Australia and Bayer Crop Science for GM and non-GM canola show that glyphosate-tolerant varieties provide yield gains of 8 to 38 per cent compared to non-GM varieties (ACIL Tasman 2007). In addition, GM canola reduces the requirements for complex herbicide regimes avoiding the on-farm operating costs for pest and weed management that conventional canola would necessitate. Bt cotton, for example, has allowed farmers to reduce pesticide use by between 56 to 75 per cent in Australia (Fitt 2003; Knox *et al.* 2006).

Adopting GM technology also involves various costs. The most common costs include restrictive user agreements, seed premiums and the ongoing cost of segregation and co-existence. Adopting GM technology typically requires compliance to a technology user agreement such as mandatory buffer zones which take up productive land (Acworth *et al.* 2008). Seed premiums charged by suppliers are also a cost found to be positively correlated to the cost savings associated with GM seeds (Gómez-Barbero and Rodríguez-Cerezo 2007). In addition, segregation is vital to preserving the integrity and the status of non-GM grains along the supply chain through traceability and testing (Matthews 2006) (DAFF 2007; Norton and Roush 2007). This is required to ensure that adventitious presence of GM canola does not exceed the thresholds that are accepted in the marketplace. These additional costs will be largely borne by non-GM farmers, as these costs would only be incurred if they could potentially be passed on to consumers (ACIL Tasman 2007). Foster (2006) estimates these costs to add up to approximately $14.48 per tonne of non-GM canola produced, representing roughly 4-6% of the farm gate price in 2005 and 2006. It is worth noting that Australia has already established methods and protocols for segregation through its cotton supply chain (Agrifood Awareness Australia Limited 2007). Farmers opting to grow certified non-GM canola are likely to establish a niche market attracting a premium sufficient to cover the additional costs of segregation. However, a segregation system is justified only if the additional value created, in the form of higher valued grain, exceeds the cost of segregation.

There is significant demand for Australian canola oil, meal, and other valued-added products in both domestic and international markets. This demand is driven by greater nutritional awareness by consumers and their desire to replace unhealthy oils (Australian Oilseeds Federation 2008). Consequently, canola oil is becoming less substitutable. The end uses of canola can be broadly classified into four groups including human, animal, industrial and export consumption. Domestic crush demand represents approximately 30 per cent of canola production and in excess 70 per cent is exported. The balance is crushed at around 42 per cent canola oil and 58 per cent protein meal (ACIL Tasman and Farm Horizons 2007). Roughly 90 per cent of this processed oil is for human consumption and the remaining 10 per cent for industrial consumption.

The key barrier to GM technology in Australia has been the resistance to the technology itself. GM canola is perceived to have wide impacts on trade and market access, with Canada losing access to the EU market after the introduction of GM crops. This caused government bodies to place bans. The regulatory framework is also viewed as the major source of controversy. In a survey reported in ACIL Tasman (2007c), 76 per cent of respondents indicated that the inconsistency between the commercial release approved by federal agencies versus the imposition of GM moratoria by state governments was the most significant barrier. The presence of consumer concerns has significant market ramifications and is explored further below.

Studies conducted by ABARE demonstrate that for the bulk of non-GM canola, no significant price premium exists apart from niche markets. Additionally, in traditional import markets such as Japan, Bangladesh, China, Mexico and Pakistan, GM canola is being accepted as readily as conventional canola. This is supported by the Australian Oilseeds Federation (AOF) detecting no noticeable change in price relationships for Canadian and Australian canola between 1999 and 2006. The preference for livestock not fed on GM materials is also regarded a niche market confined to dairy products as Australia’s food and meat markets already engage in extensive use of imported GM soybean and domestically produced GM cottonseed for food and feed consumption (DAFF 2007). There is no strong preference for non-GM canola by consumers and major importing nations do not appear to differentiate between GM canola and non-GM canola (AOF 2003). For most purposes, GM canola is being priced very similar to those received for conventional canola.

3. Previous studies

Extensive studies have been conducted on the impacts of GM technology. These studies have paved the way to understanding the economics of GM technology adoption. The literature indicates that the two common approaches adopted are based on the partial and general equilibrium frameworks. The former is modelled using *ex ante* or *ex post* estimation techniques such as simulations and the production function frameworks, whereas the latter commonly employs models such as the Global Trade Analysis Project (GTAP) Model.

3.1 Partial equilibrium framework

The partial equilibrium framework concentrates on a single sector of the economy, and operates under the premise that all other variables are treated as constant (exogenous) in the analysis. The basic economic surplus model examines welfare distribution under a closed economy with no technology spillovers and intellectual property right (IPR) rents, referred to in Alston *et al.*(1995, p.209).

The *ex ante* surplus approach helps to assess how the benefits of technology are distributed between consumers and producers. These studies provide valuable policy guidelines by making considerable alterations to the basic model to capture the key relevant variables. The benefits depend largely on the assumptions made about the behaviour of consumers and producers, and thus the underlying supply and demand functions. However, disaggregation of the demand and supply curve into individual consumer and producer groups are required for the analysis to be more plausible. This concept was pioneered by Hayami and Herdt (1977) and Binswanger (1980). Although *ex post* approaches are not adopted here, it is important to recognise that *ex post* approaches can be useful in developing policy tools when the market of interest has similar characteristics to markets that have already adopted GM technology. However, evidence suggests that Australia's characteristics are likely to differ considerably from those of other countries.

There are several limitations of the economic surplus model. Most evidently, the approach only captures the direct effects of technology in the market under consideration and technology spillovers are excluded. As a result, welfare gains are likely to underestimate the true long-term benefits of GM technology. Given the potential impacts on other sectors, critics often question whether the optimality conditions are fulfilled elsewhere in the economy. That is, whether price equals marginal cost in the rest of the economy (Little 1957), although Alston *et al.* (1995, p.213) show that extensions can be made to capture indirect effects. Secondly, the economic surplus model assumes that the economy is competitive. However, this assumption may be implausible. Various authors, for example, Moschini and Lapan (1997), Qaim (1999) and Moschini (2001) stress the importance of explicitly modelling the market under a monopolistic regime as it directly impacts on the prices charged for inputs. Thirdly, many authors assume a linear demand function which does not stem from any commonly-used consumer preference in economic theory. Moreover, technology adoption will affect differently the inframarginal 'low average cost' producers and 'high average cost' producers (Lindner and Jarrett 1978). The phenomenon may bring a parallel, divergent, or convergent supply shift that must be specified with care, and requires demand and supply to be modelled with a greater degree of disaggregation (Carter *et al.* 1986).

Ex ante estimation techniques help to quantify the effects of a technology and often involve one of the following four methods: benefit-cost analysis, simulation models, mathematical programming, and real options approach. Benefit cost analysis has provided an understanding of the extent of concerns surrounding biotechnology and identified the different consumer segments within the population (Falck-Zepeda *et al.* 2008). Although willingness-to-pay (WTP) and willingness-to-accept (WTA) studies provide some insight into the valuations people place on GM crops, they often do not reflect how consumers behave in a real market

(ACIL Tasman 2007). The mathematical programming (or optimisation) approach is used to determine the optimal allocation of resources for a given budget (Norton and Davis 1981). Assuming a perfectly competitive market, the equilibrium estimated in this model achieves the best outcomes for society (Samuelson 1952). However, the approach faces major difficulties in guiding resource allocation, as preference functions must be specified with care.

The preceding methods have not taken into account the uncertainty and irreversibility associated with GM technologies. This problem can be alleviated by employing the real options approach. This approach models uncertainty and irreversibility of future benefits and costs of technology, and also managerial flexibility. Overall, the analysis using the real option approach lacks the fundamental components of a market that should be disaggregated. It must be noted that the real option valuation should not be used alone. It is often applied as an additional analysis to aid decision makers (Michailidis and Mattas 2007).

Finally, the simulation approach reproduces a complex real-world economic system. Simulation models are ideal for contemporary issues such as biotechnology, as assumptions can be made about the behaviour of economic agents where prices and quantities are simultaneously determined. In comparison to other estimation techniques, as the model becomes more stochastic and non-linear, the advantage of using simulation models increase. Simulations of public agricultural research provide valuable insights into the effects of technology on prices, income and other variables. More importantly, the flexibility of this approach allows for comprehensive analysis at the national, commodity, or program level (Norton and Davis 1981). Core to this study is the ability to allow the demand and supply functions to be specified with greater degrees of disaggregation. The simulation model has been employed in numerous studies such as Carter *et al.* (1986), Berwald *et al.* (2006), Lence and Hayes (2005; 2008), and Lu *et al.* (1978).

Ex post assessments are also important as they help to justify the use of funds (Babu and Rhoe 2003). Econometric models such as the production function framework are commonly used to estimate *ex post* surplus models. The production function framework is a deterministic approach usually adopted for analysis at the farm level requiring *ad hoc* farmer survey data, field trial data and expert opinions to calculate yield changes. However, *ad hoc* farmer surveys make it inappropriate to extrapolate results to the broader population, and therefore challenges the reliability of the analysis for policy purposes. The availability of data remains a major constraint.

3.2 General equilibrium framework

The general equilibrium framework, or computable general equilibrium (CGE) model, considers the entire economic system by simultaneously determining prices and quantities in other markets assuming perfect competition. The approach addresses the shortcomings of the partial equilibrium framework and offers a more complex option that forms a bridge between the two branches of economic theory, microeconomics and macroeconomics (Quirk and Saposnik 1968). In the biotechnology literature, the global trade analysis project (GTAP) model has been widely adopted. The major strength of this approach is that approximation errors are overcome by adding more individual agents to the GTAP database and the ability to capture the vertical and horizontal linkages between supply sectors and product markets (Stone *et al.* 2002; Huang *et al.* 2004; Anderson *et al.* 2005). However, the most significant limitation is that demand functions are based on assumptions about the population which is characterised by a single representative consumer. Despite the extended abilities of the general equilibrium approach, it often faces computational difficulties. The approach requires substantial amounts of data, not publicly available in Australia. The price to be paid for the wide applicability of the general equilibrium approach across many markets is that economic theory becomes correspondingly non-specific. On the whole, the generality of the analysis leads to abstract theorising that is based on logic rather than empirical evidence (Quirk and Saposnik 1968, p.2-4).

4. Model

The study of GM technology introduces several issues at the consumer and producer levels, leading to a set of equations that determine the nature of the resulting demand and supply functions. An interesting feature is the asymmetry with which consumers respond to changes in market conditions. The analysis will focus on consumer characteristics on the demand side and the agronomic producer characteristics on the supply side. A model for heterogeneity based on Lence and Hayes (2005) is used, assuming rational agents.

4.1 Short-run model

In the short-run model, supply is assumed fixed as a result of the producers' inability to respond instantaneously to changing market conditions. Moreover, supply is dictated by State moratorium and the availability of GM seeds. As such, Figure 1 exhibits a vertical supply function, denoted $\bar{S}_{gm}$. The cost of segregation, C per tonne, creates a wedge between the price consumers pay for non-GM canola at the retail level (P^{r}_{ngm}) and the price that non-GM canola producers receive at the farm gate (P^{f}_{ngm}) and is assumed to be constant. With no protocols in place to preserve identity, non-GM canola can only be traded as GM canola at the GM price.

Given fixed supplies, the results are driven by demand side factors, namely, consumer preferences captured by observing δ-type consumers ($0 \leq \delta \leq 1$) and their willingness to substitute non-GM canola for GM canola. The measure, δ, is a discount factor that represents consumer preferences between both differentiated commodities. For example, agents with $\delta = 0.75$ will buy GM canola if its price is less than 75 per cent of the price of non-GM canola, that is, if $P_{gm} < 0.75\, P^{r}_{ngm}$. In the extreme cases, consumers who cannot be induced to consume GM canola have $\delta = 0$, and consumers who are indifferent have $\delta = 1$. The demand for GM or non-GM canola by δ -type consumers is represented by:

$$D_{\delta} = d_{\delta}(P_{\delta}) \tag{1}$$

where $P_{\delta} \equiv P^{r}_{ngm}$ if $P_{gm} \geq \delta\, P^{r}_{ngm}$, and $P_{\delta} \equiv \delta^{-1} P_{gm}$ if $P_{gm} \leq \delta\, P^{r}_{ngm}$. The total canola demand, D, is thus the aggregation of all individual demands, that is, $D \equiv \sum_{\delta} D_{\delta}$. The demand schedules by δ-type consumers are represented by (2) and (3), respectively:

$$D_{\delta gm} = \begin{cases} d_{\delta}\left(\delta^{-1} P_{gm}\right) & if\ P_{gm} < \delta\, P^{r}_{ngm} \\ d_{\delta}\left(\delta^{-1} P_{gm}\right) - D_{\delta ngm} & if\ P_{gm} = \delta\, P^{r}_{ngm} \\ 0 & if\ P_{gm} > \delta\, P^{r}_{ngm} \end{cases} \tag{2}$$

$$D_{\delta ngm} = \begin{cases} d_\delta(P^r_{ngm}) & if\ P_{gm} > \delta P^r_{ngm} \\ d_\delta(P^r_{ngm}) - D_{\delta gm} & if\ P_{gm} = \delta P^r_{ngm} \\ 0 & if\ P_{gm} < \delta P^r_{ngm} \end{cases} \quad (3)$$

when $P_{gm} = \delta P^r_{ngm}$, expressions (2) and (3) imply that consumers are indifferent between how much of GM and non-GM canola to consume. Given that the fixed supplies of GM and non-GM canola can be established, the conditions for market-clearing require (4) and (5):

$$\bar{S}_{gm} = D_{\delta^* gm} + \sum_{\delta>\delta^*} d_\delta(\delta^{-1}P^*_{gm}) \quad (4)$$
$$\bar{S}_{ngm} = D_{\delta^* ngm} + \sum_{\delta<\delta^*} d_\delta(P^{r*}_{ngm}) \quad (5)$$

where $\delta^* \equiv P^*_{gm}/\ P^{r^*}_{ngm}$ is the market-clearing discount for GM canola. Given that, the market-clearing prices P^*_{gm} and $P^{r^*}_{ngm}$ can be determined and the equilibrium producer price can be obtained as $P^{f^*}_{ngm} = P^{r^*}_{ngm} - C$. In equilibrium, consumers with a strictly lower (higher) preference for GM canola (non-GM canola), that is $\delta < \delta^*$ ($\delta > \delta^*$), will only consume non-GM (GM) canola. Consumers with $\delta=\delta^*$ are indifferent between consuming either types of canola, and will consume the amounts that balance the subsequent supplies.

Figure 1 illustrates the aggregate demand curves for non-GM canola with heterogeneous consumers. The aggregate demand function, given all δ-type consumers, is depicted as the bold stepped function, D_{Agg}. Analogously, the aggregate demand curves for GM canola would behave inversely. Furthermore, if there is a distribution of type-δ consumers, one would realise that the function becomes smoother.

In the example presented below in Figure 2, the market equilibrium in a two product market for two polar consumers is explored, that is consumers of type δ =0 and δ =1. In Figure 2, the distance between the two vertical axes is equal to the total supply of canola, S_{gm}+S_{ngm}. The price of GM canola (P^*_{gm}) is measured by the left axis and the right axis measures the price of non-GM canola (P^*_{ngm}). The demand curve for GM canola by δ=1 type consumers (hereafter, type-1 consumers) is denoted as D_{1gm}. On the other hand, the primary demand curve for non-GM canola by δ=0 type consumers (type-0 consumers) is denoted as D_{0ngm}, and the derived demand is situated below D_{0ngm} by a vertical distance equal to the segregation cost.

Given the hypothetical fixed GM supply curve ($\bar{S}$), the equilibrium prices can be established at points *B* and *F* respectively, where $P^*_{gm} < P^*_{ngm} + C$. When the price of non-GM is at P^*_{ngm}, the GM demand curve is kinked at point *E*, because GM canola is not consumed when $P^*_{gm} > P^*_{ngm}$. The GM demand curve is the dashed line with a choke price of P^*_{ngm}. Figure 2 depicts a situation where there is a large supply of GM canola relative to non-GM canola. As only type-1 consumers are willing to consume GM canola, P^*_{gm} must be very low and non-GM canola, behaving like a niche market, commands a premium in excess of the segregation costs ($P^*_{ngm} > P^*_{gm} + C$) to clear the market and meet condition (6). In this illustration, the consumer surplus for type-1 consumers can be represented by triangle ABP^*_{gm}, while the surplus for type-0 consumers is given by triangle DFP^*_{ngm}.

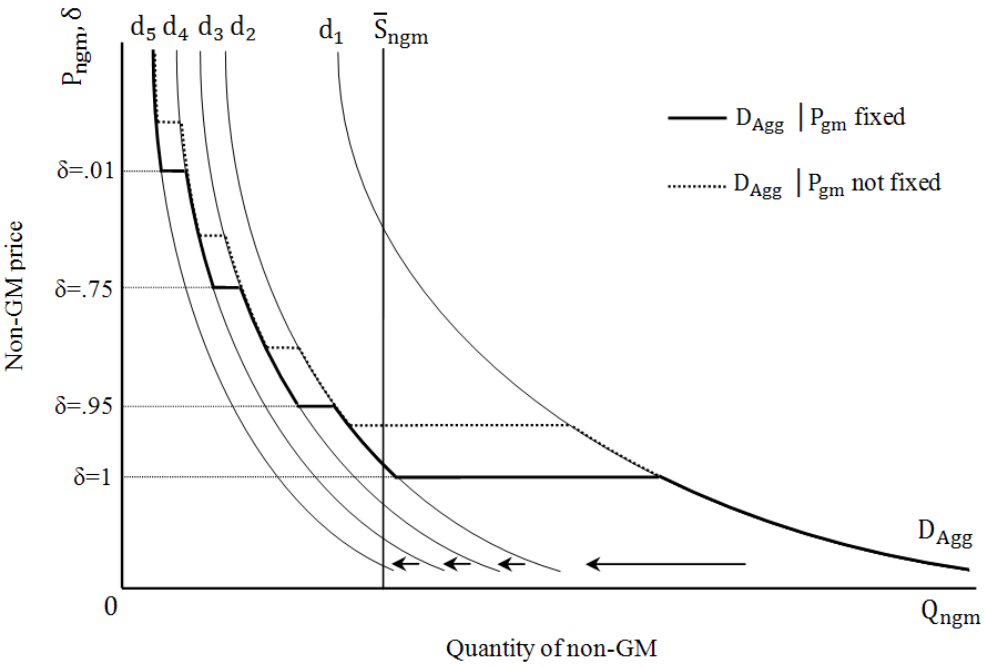


Figure 1 Aggregate demand function

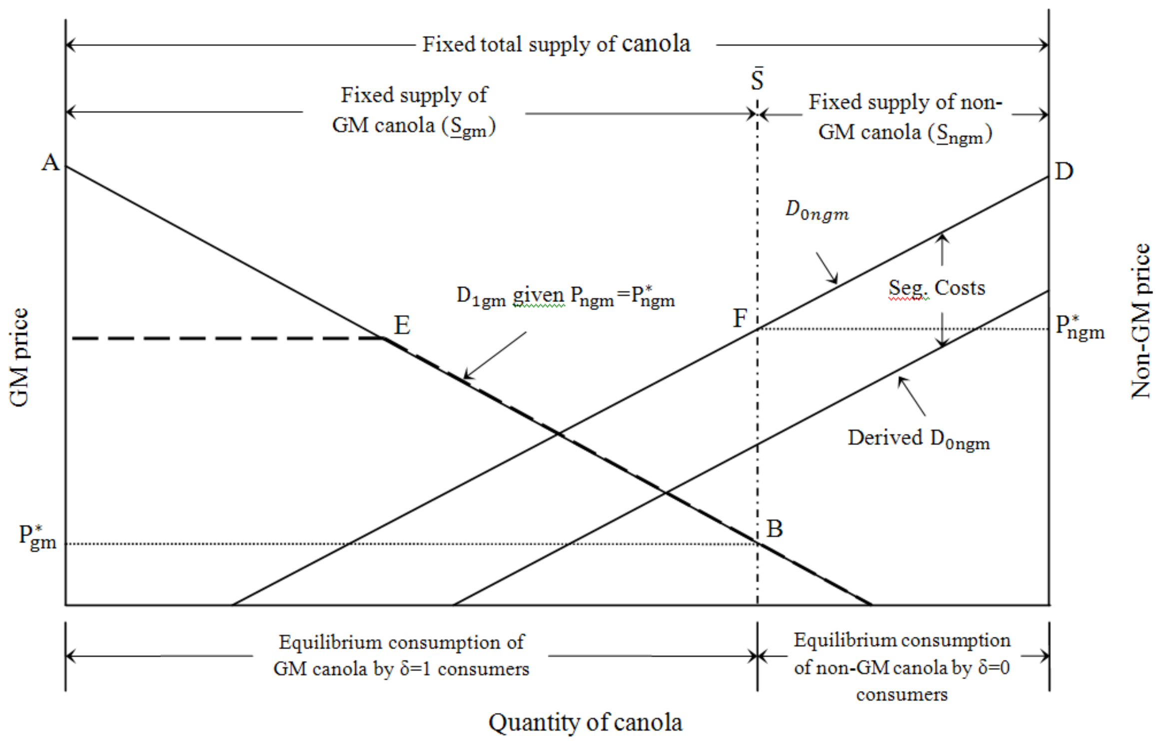


Figure 2 Market equilibrium with a large fixed supply of GM canola relative to non-GM Canola, including segregation costs

4.2 Long-run model

The long-run model assumes that supply can adjust to meet consumer demand and focuses on the supply side effects of innovation. The scenario presented is analogous to the demand side. To capture heterogeneity among producers, suppose that producers of type-σ (σ > 0) can produce GM canola at a fraction σ of the cost of producing non-GM canola (including additional seed and technology costs). Thus, (1 - σ) is a clear measure of the net cost advantage of adopting GM technology. When the $P_{gm} > \sigma P_{ngm}^{f}$, producers will adopt the technology due to the relative cost advantage, and *vice versa*. There are also cases where weed pressures are not a severe problem and thus, producers are better off not adopting GM technology, that is, where σ > 1. The aggregate supply of GM and non-GM canola by type-σ producers is represented by:

$$S_{\sigma} = s_{\sigma}\,(P_{\sigma}) \tag{6}$$

where $P_{\sigma} \equiv P_{ngm}^{f}$ if $P_{gm} \leq \sigma P_{ngm}^{f}$, and $P_{\sigma} \equiv \sigma^{-1}P_{gm}$ if $P_{gm} > \sigma P_{ngm}^{f}$. The supply function is also assumed to be well-behaved (e.g., $\partial s_{\sigma}/\partial P_{\sigma} > 0$) with GM supplies increasing with cost savings. The supply schedules for σ-type consumers based on (6) are as follows:

$$S_{\sigma gm} = \begin{cases} s_{\sigma}(\sigma^{-1}P_{gm}) & if\ P_{gm} < \delta P_{ngm}^{f} \\ s_{\sigma}(\sigma^{-1}P_{gm}) - S_{\sigma ngm} & if\ P_{gm} = \delta P_{ngm}^{f} \\ 0 & if\ P_{gm} > \delta P_{ngm}^{f} \end{cases} \tag{7}$$

$$S_{\sigma ngm} = \begin{cases} s_{\sigma}(P_{ngm}^{f}) & if\ P_{gm} > \delta P_{ngm}^{f} \\ s_{\sigma}(P_{ngm}^{f}) - S_{\sigma gm} & if\ P_{gm} = \delta P_{ngm}^{f} \\ 0 & if\ P_{gm} < \delta P_{ngm}^{f} \end{cases} \tag{8}$$

Here, the long run condition for market-clearing comparable to (4) and (5) becomes equations (9) and (10), respectively:

$$\bar{S}_{\sigma^{*}gm} + \textstyle\sum_{\sigma<\sigma^{*}} s_{\sigma}(\sigma^{-1}P_{gm}^{*}) = D_{\delta^{*}gm} + \sum_{\delta>\delta^{*}} d_{\delta}(\delta^{-1}P_{gm}^{*}) \tag{9}$$

$$\bar{S}_{\sigma^{*}ngm} + \textstyle\sum_{\sigma>\sigma^{*}} s_{\sigma}(P_{ngm}^{f*}) = D_{\delta^{*}ngm} + \sum_{\delta<\delta^{*}} d_{\delta}(P_{ngm}^{D*}) \tag{10}$$

Figure 3 illustrates the aggregate supply functions for non-GM canola. The σ for producer groups reflects the relative marginal cost of producing GM (MC_{gm}), as opposed to non-GM (MC_{ngm}), that is, the cost structures. Adoption is determined endogenously and occurs where the relative market prices justify adopting GM technology in the long-run given cost structures. That is, where $P_{gm}^{*}/P_{ngm}^{*} \geq MC_{gm}/MC_{ngm}$ (i.e., a relative cost advantage), and *vice versa*. Thus, the resulting aggregate supply function given all type-σ producers is depicted as the bold stepped function, S_{Agg}. The aggregate supply curves for GM canola can be analogously represented.

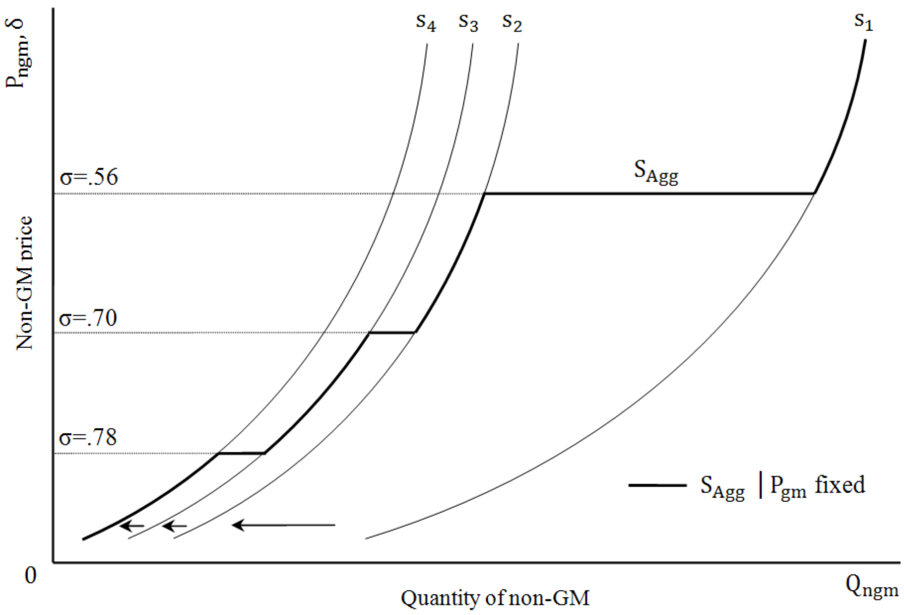


Figure 3 Aggregate supply function

5. Empirical models, data and estimation procedures

A simulation model is employed to quantitatively model the effects of GM adoption. The short-run and long-run empirical models are specified, and the data required and methods aimed at ensuring the reliability of the results achieved are discussed.

5.1 Short-run empirical model

To make the demand function (1) operational, an iso-elastic demand function (11) is chosen to perform the quantitative analysis:

$$d_\delta(P_\delta) = k_\delta P_\delta^{-\varepsilon_\delta} \tag{11}$$

where k_δ is a scaling parameter and ε_δ denotes the constant demand elasticity of type-δ consumers. The values of k_δ and ε_δ are consistent with available information. To calibrate k_δ, the following expression is used:

$$k_\delta = m_\delta \times D \times P_\delta^{\varepsilon_\delta} \tag{12}$$

where P_δ reflects the price faced by type-δ consumers. The market share of type-δ consumers is $m_\delta = D_\delta/D$, where D_δ equals the amount of canola consumed by type-δ consumers during the period, and $D = \sum_\delta D_\delta$ is the total consumption of both GM and non-GM canola. The scaling parameter k_δ is expressed as market shares to help facilitate sensitivity analysis when the market shares are not well known. The market shares must also satisfy the properties of a probability distribution, i.e., $m_\delta \geq 0$ and $\sum_\delta m_\delta = 1$.

An iso-elastic function of Cobb-Douglas type is adopted due to the wide use in market models and simplicity of interpretation. One inherent problem is that assuming a power function means that the approximations at the extremes become unrealistic. However, the model adopted is governed by assumptions to ensure that the prices and quantities retrieved are regular and realistic. Overall, if plausible data for demand and supply elasticities are available, postulating iso-elastic functions will allow for realistic simulations (Jechlitschkaj *et al.* 2007).

The values of ε_δ, m_δ, and δ. The elasticity parameters for canola demand are retrieved from the FAPRI elasticity database and are presented in Table 1 below. A geometric average is calculated for the demand elasticity; $\varepsilon_D = [\pi(\varepsilon_\sigma + 1)^{m_\sigma}] - 1$, where π is the product of the elements. By calculation, the own-price demand elasticity used in the simulation is $\varepsilon_D = -0.2185$.

Table 1 Own-price elasticity of demand

Demand for Australian canola	Own-price elasticity of demand (ε_δ)
Demand canola oil (food)	-0.38
Demand canola meal (feed)	-0.35
Demand canola oil (industrial use)	-0.25
Demand canola (export)	-0.15
Geometric average	-0.2185

Source: Food and Agricultural Policy Research Institute, Elasticity Database (2008)

As previously indicated, in Australia, there are predominantly four major end uses of canola; human, animal, industrial and export consumption. To facilitate more specific modelling, human consumption is divided into five different classes of consumer attitudes in order to accurately reflect consumer preferences in this group. A survey by ACNielsen for Biotechnology Australia (2006) on Australia's attitudes to eating GM foods in 2006 helped to identify the size of each class as a percentage of total human consumption. The market shares are presented in Table 2.

Table 2 Market share of type-δ consumers

Consumer groups	Market share, $M_\delta = D_\delta / D$
Human consumption	0.1134
Very likely to consume GM	0.0102 (9 per cent)
Likely to consume GM	0.0318 (28 per cent)
Neither	0.0102 (9 per cent)
Unlikely to consume GM	0.0318 (28 per cent)
Very unlikely to consume GM	0.0295 (26 per cent)
Animal consumption	0.1740
Industrial consumption	0.0126
Export market	0.7
	$\sum M_\delta = 1$

Source: Richards (2008)

The values for δ are often difficult to specify as consumers often behave differently when purchasing goods and services in reality (Fernandez-Cornejo and Caswell 2006). A wellinformed set of parameters for δ is presented in Table 3, and a sensitivity analysis is performed to test other possible scenarios. For human consumption, the delta values range from those who are very likely to consume GM canola (assuming δ=1), to those who are strongly opposed to GM canola due to religious or food safety reasons (δ=0.01).

Table 3 Delta values for consumer groups

Consumer groups	Delta (δ)
Human consumption	
Very likely to consume GM	δ = 1
Likely to consume GM	δ = 0.90
Neither	δ = 0.75
Unlikely to consume GM	δ = 0.20
Very unlikely to consume GM	δ = 0.01
Animal consumption	δ = 0.95
Industrial consumption	δ = 1
Export market	δ = 1

Finally, studies by Foster (2006) and GrainCorp (2007) estimate the cost of segregation and identity preservation (SIP) to represent approximately 5 per cent of the average farm gate price for canola. This figure assumes that the unintended presence of GM in non-GM canola is comfortably below the 0.9 per cent threshold. The cost of segregation is assumed constant when calibrating the scenarios.

5.2 Long-run empirical model

Analogous to the demand case, an iso-elastic canola supply function is adopted which is represented by equation (13):

$$s_\sigma(P_\sigma) = k_\sigma P_\sigma^{\varepsilon_\sigma} \tag{13}$$

where k_σ denotes a supply scaling parameter and ε_σ is the constant supply elasticity that corresponds to type-σ producers. The scaling parameter k_σ is retrieved in a similar fashion to the demand side and encompasses similar properties, estimated by expression:

$$k_\sigma = m_\sigma \times S \times P_\sigma^{-\varepsilon_\sigma} \tag{14}$$

The supply is fairly inelastic with production being much less substitutable and almost not influenced by price. This closely resembles the characteristics of Australian producers and is thus a plausible representation.

Table 4 Own-price elasticity of supply

Supply of Australian canola	Own-price elasticity of supply (ε_σ)
Supply canola	0.26

Source: Food and Agricultural Policy Research Institute, Elasticity Database (2008)

The market shares of type-σ producers are retrieved from studies by expert agronomists. However, it is estimated that adoption rates will be around 80 per cent (ACIL Tasman 2007). These non-adopters are likely to be conventional producers that suffer less severe weed burdens. These shares are presented in Table 5.

Table 5 Market share of type-σ producers

Producer groups	Market share, $M_\sigma = S_\sigma / S$
Conventional	0.05►
Imidazolinone tolerant	0.15*►
Triazine tolerant	0.60*
Non-adopters	0.20^
	$\sum M_\sigma = 1$

Source: *Norton and Roush (2007), and ► R. Norton expert advice, University of Melbourne, Agronomist (2008), ^ACIL Tasman (2007).

To retrieve the value of σ for each producer group, the expected yield improvements and cost reductions are translated into a cost per hectare value. From gross margin analyses by Norton (2003), and Norton and Roush (2007) on Australian farming systems, the values of σ can be calculated and are presented in table 6.

Table 6 Sigma values for producer groups

Producer groups	Cost ($/ha)	Yield (t/ha)	Cost ($/ha) incl. yield effects	Sigma (σ)
GM canola	$212	2.2	$96.36	
Conventional	$222	1.8	$123.33	σ = 0.7813
Imidazolinone tolerant	$289.85	2.1	$138.02	σ = 0.6982
Triazine tolerant	$232.50	1.35	$172.22	σ = 0.5595
Non-adopters	-	-	-	σ = 1.05

Source: *Norton (2003), and Norton and Roush (2007)

For TT producers the calculated σ=0.5595 implies that TT producers will experience the largest cost savings from adoption due to the 25 per cent yield penalty and will likely be the first movers. This is also supported by Richards (2008) stating that TT producers will receive an automatic jump in yields.

5.3 Estimation

To make the model more realistic, a discrete cumulative distribution function (*cdf)* is fitted for the value of δ to capture small differences in preferences that may exist among the broad consumer groups. More importantly, the demand function is smoothed to ensure that shifts in consumer preferences (or consumer switching pressure) do not occur in a lumpy fashion which may distort equilibrium prices, avoiding the lumpiness introduced by using aggregate industry data. A sensitivity analysis is also performed on the beta distribution for δ to account for uncertainty in consumer preferences. For example, a 'very high concern' *cdf* is analysed to observe situations where shocks such as the StarLink® incident may place a significantly negative effect on consumer attitudes (see Foster and French 2007). In the long run, two beta distributions are postulated for the value of σ. As Australian producers experience significant cost savings, the *cdf* for the Australia's current market is named 'high-cost savings *cdf*'. A 'low-cost savings *cdf*' is also explored in the analysis.

In the actual market, the prices of GM and non-GM canola in both markets adjust freely. As a result, an algorithm is required to ensure that the relationship between both markets is sustained and that the results are consistent with the equilibrium conditions. Firstly, the algorithm is designed to identify equilibriums that may possibly occur at the point of indifference. The second complication arises as non-GM canola can be seen as two goods in the eyes of a GM consumer. Thus, arbitrage by consumers or intermediaries will ensure that the price of non-GM canola will equate to the price of GM canola plus the segregation costs ($P^*_{ngm} = P^*_{gm} + C$).

To avoid the controversy surrounding consumer surplus as a measure of consumer welfare, consumer welfare issues are addressed using quasi-linear utilities. The total welfare effect in the long run is the sum of all type-δ consumers and type-σ producers' surpluses. The change in net welfare (ΔW) is thus measured as the sum of the total change in consumers' surpluses (ΔCS) and producers' surpluses (ΔPS). The focus of the long-run analysis is on the impact of the shift in the supply schedule from $s^0_\sigma(.)$ to $s^1_\sigma(.)$. The change in producers' surpluses is therefore measured using the inverse of the supply function:

$$\Delta PS = \left[\sum_\sigma \int_{\underline{B}^1_\sigma}^{P^1_\sigma} s^1_\sigma(x)dx\right] - \left[\sum_\sigma \int_{\underline{B}^0_\sigma}^{P^0_\sigma} s^0_\sigma(x)dx\right] \quad (15)$$

where P^0_σ (P^1_σ) is the type-σ price corresponding to the initial (final) equilibrium prices P^0_{gm} and P^{f0}_{ngm} (P^1_{gm} and P^{f1}_{ngm}), $\underline{B}^0_\sigma$ ($\underline{B}^1_\sigma$) is the lower bound for the quantity range of $s^0_\sigma(.)$ ($s^1_\sigma(.)$). The first bracket measures the final total producers' surpluses and the second is the initial total producers' surpluses.

The total change in consumers' surpluses is calculated in a similar fashion and is measured as:

$$\Delta CS = \left[\sum_\delta \int_{P^1_\delta}^{\bar{B}^1_\delta} d^1_\sigma(x)dx\right] - \left[\sum_\delta \int_{P^0_\delta}^{\bar{B}^0_\delta} d^0_\sigma(x)dx\right] \quad (16)$$

where $\bar{B}^0_\delta$ ($\bar{B}^1_\delta$) represents the upper bound for the domain $d^0_\sigma(.)$ ($d^1_\sigma(.)$) and the other notations are analogous to equation (15) above.

6. Results

The short-run results are presented with emphasis on the implications of consumer preferences on the conduct of prices between GM and non-GM markets. Further, the long-run results capture the impacts of adoption and consumer attitudes on aggregate welfare.

6.1 Short-run results

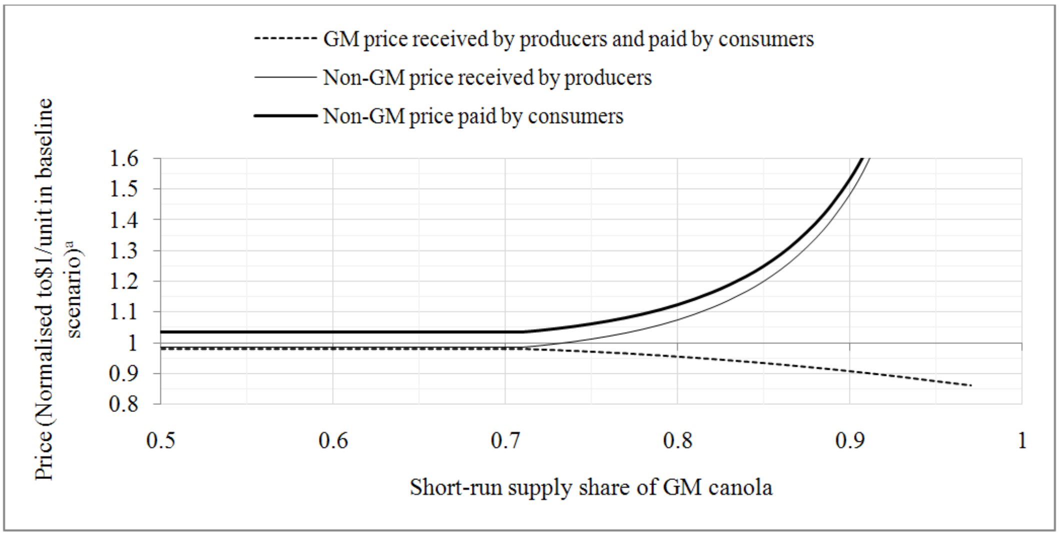
The figures presented show the impact of changes in the available supply of GM and non-GM canola on prices. The horizontal axis measures the percentage of the short-run supply made up of

GM canola. For example, a value of 0.8 indicates that 80 per cent is made up of GM canola. The baseline scenario is depicted as the vertical axis, where prices are normalised to $1/unit.

In Scenario1, the results are based on data that represent current consumer preferences in Australia with a *cdf* given by Beta ($\delta|$ α=0.8710, β=0.1095, δ_{min}=0, δ_{max}=1) with a mean δ=0.8884. This is presented in Figure 4. When consumers are willing to pay the cost of segregation, non-GM canola is made available by producers at a premium that equals this cost, driving a wedge between the price that consumers pay and the price that farmers receive. Here, the farm-level prices of GM and non-GM canola are identical as long as the supply share of GM in the market does not exceed 71 per cent. For the market shares to the left of 0.71, arbitrage by consumers or intermediaries ensure that the price of non-GM canola equates to the price of GM canola plus the cost of segregation. For example, if the short-run supply of GM canola is equal to 65 per cent, those consumers with a $\delta<\delta^*=0.9470$ (=0.9806/1.0355) are willing to pay a premium to identify some portions of non-GM canola, which is preserved for the niche market and the remaining portions enter the pooled market. Farmers who choose to bear the additional segregation costs will be compensated so long as there is sufficient demand, allowing farmers to pass these additional costs onto consumers (ACIL Tasman 2007). On the other hand, when the available supplies of non-GM canola becomes relatively tight, as depicted to the right of the 71 per cent point in Figure 4, the demand by consumers willing to pay a premium that equals or exceeds the segregation costs is greater than the actual supply of non-GM canola available for consumption. Given this shortage, the price of GM canola is discounted in order to induce demand for consuming GM canola, and at the same time, the price of non-GM canola is increased at the retail level. These price adjustments allow the market to clear and reach equilibrium. As observed, the short-run results strongly support the findings by Foster and French (2007) that premiums for certified non-GM canola will develop beyond the cost of segregation if there is a niche market.

In Scenario 2, a scenario with a high concern factor is analysed and presented in Figure 5. This assumes that each consumer group requires an additional 2 per cent discount compared to Scenario 1. The *cdf* is given by Beta ($\delta|$ α=0.9405, β=0.2901, δ_{min}=0, δ_{max}=1) with a mean δ=0.7643. Here, it can be observed that the premium in excess of segregation costs emerge at a small GM market share of only 42 per cent. This is explained by the additional discount causing all consumer groups to prefer non-GM canola to some degree, irrespective of the magnitude of discount required. As such, the demand by consumers willing to pay the premium is likely to outstrip the available supply of non-GM canola and consumers will bid prices up. Simultaneously, the farm level discount grows rapidly and is 17.7 per cent when, the GM supply share is 60 per cent, and increases exponentially. This price diversion causes non-GM canola farmers to receive premiums in excess of segregation costs and force GM farmers to discount their product to sell to the marginal (high δ) consumer.

In addition, Scenario 3 observes the Australian canola market under a very high-concern *cdf* to assess the impacts of possible shocks such as the StarLink® incident where a GM corn variety approved only for animal feed was found in taco shells for human consumption. As Australia is one of the few exporters of non-GM canola, a global shock may force inflationary price pressures on the price of non-GM canola. The distribution will assume that each consumer group require an additional 5 per cent discount compared to Scenario 1 with a postulated *cdf* given by Beta ($\delta|$ α=0.9199, β=0.3661, δ_{min}=0, δ_{max}=1) and a mean of δ=0.7153. Here, the responses observed in Scenario 2 are amplified. A premium for non-GM canola develops at a GM market



[a]Baseline scenario is represented by a scenario with zero supply of GM canola, so that P_{ngm}=P_{gm}=1.

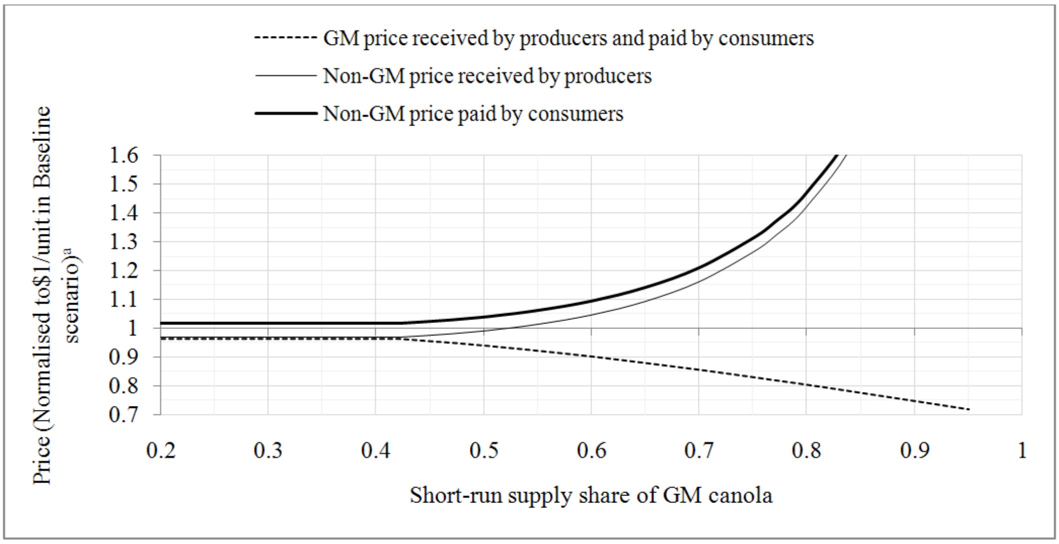
Figure 4 Prices of GM and non-GM canola, given current market *cdf*, δ=0.8884

share of only 33 per cent, and the prices for both types of canola diverge significantly. More prominently, Scenarios 2 and 3 provide a contrast to the results conveyed by Foster and French (2007) and Scenario 1. Market premiums in excess of segregation costs may develop for non-GM canola irrespective of a niche market. The results suggest that any conclusions regarding premiums for non-GM canola in the global market may be influenced considerably by slight or drastic changes in consumer preferences, and should be interpreted with care.

Finally, Scenario 4 models a case with low concern where each consumer group is assumed to require a 2 per cent lesser discount compared to Scenario 1. The *cdf* proposed is given by Beta (δ| α=1.0325, β=0.1112, δ_{min}=0, δ_{max}=1) with a mean δ=0.9028. It can be observed that a premium above the segregation costs occurs at similar GM market shares, that is, at 72 per cent compared to 71 per cent in Scenario 1. This reveals that Australian consumers already have a relatively low concern.

When observing the price of non-GM canola received by producers, the price is expected to be appreciated due to bidding pressure under a high concern *cdf*. However, the results reported are counterintuitive. This paradox can be explained by the increased discriminatory behaviour against GM canola given high consumer concerns, placing strong downward pressure on the price of GM canola. Increased competition from inexpensive GM canola results in reduced non-GM prices at the retail level and thus the price that farmers receive. A sensitivity analysis is also conducted on the own-price elasticity to ensure the robustness of the results. The own-price elasticity of demand used in Scenario 1 is doubled and also halved. The analysis shows that the results are in essence identical to those for Scenario 1 to the third decimal place. Thus, the short-run results are robust under a range of demand elasticities.

While GM canola is being grown commercially in New South Wales and Victoria, it is more than likely that its supply will be relatively small in the short to medium term due to limited commercial quantities of seed and the bans that exist in Australia's largest producing



[a]Baseline scenario is represented by a scenario with zero supply of GM canola, so that P_{ngm}=P_{gm}=1.

Figure 5 Prices of GM and non-GM canola, given high-concern *cdf*, δ=0.7643

states Western Australia and South Australia. As a result, premiums in excess of segregation costs are unlikely to materialise in the near term. This supports other analyses that have asserted from their estimation that no premiums are likely to materialise.

6.2 Long-run results

The results of 12 scenarios are presented for the long run where supply is flexible. This is summarised in Table 7 by observing different consumer preference and producer cost structure sets (Scenarios 1-8). The sensitivity of the results to the elasticity values are also analysed for the long run (Scenarios 9-12). The baseline scenario for the long run is a market where GM technologies are not available, and thus the market consists only of non-GM canola. The long-run results assume a constant segregation cost of 5 per cent of the baseline market price, which is normalised to equal 1. The *cdf* for the current market σ is named 'Large savings' and is represented by Beta (σ| α=1.0623, β=1.7781, σ_{min}=0.45, σ_{max}=1.15) and a mean σ=0.7118. On the contrary, the 'small savings' *cdf* is represented by Beta (σ| α=1.1649, β=1.3826, σ_{min}=0.45, σ_{max}=1.15) with a mean σ=0.7701. Both distributions are postulated such that they reflect possible adoption rates of around 80 per cent in Australia for the long run (ACIL Tasman 2007).

Scenario 1 in Table 7 presents a market given Australia's current consumer preferences and the large production cost advantages from growing GM canola. The results show that non-GM canola production represents 18.89 per cent of the market and a consumption share of 10.70 per cent. The introduction of GM canola also causes the total production of canola (both GM and non-GM) to be larger than the baseline by 4.60 per cent. Production is enhanced due to the cost savings from GM canola outweighing the lower prices received by farmers. The price of GM canola is a significant 19.78 per cent lower than in the baseline price of non-GM canola. Similarly, the price of non-GM canola at the farm and retail level is, respectively, 19.78 per cent and 14.78 per cent lower than compared to the baseline. The results are surprising as the introduction of GM canola should, *a priori*, push the price of non-GM canola at the retail level above the price in the baseline scenario due to higher costs of segregation. This can be explained by the lower production costs, leading to the widespread adoption of GM canola. In effect, the increased competition from low-priced GM canola places downward pressure on the price of non-GM canola at the farm and retail level. The result is for prices to fall below those in the baseline.

As all long-run results satisfy the conditions of arbitrage, the prices of GM and non-GM canola are always equal at the farm gate, and the price of non-GM canola is higher by the segregation cost at the retail level. The market "σ*" reported implies that producers with $\sigma<1$ will adopt GM technology, that is roughly 80 per cent of Australian producers. The "indifferent" column depicts that farmers with a net cost advantage of 19.78 per cent experience no changes in welfare. Farmers with a relatively small cost advantage (i.e., a cost advantage between 0 and 19.78 per cent) will lose, despite the savings associated with adopting GM technology. This is due to Australia's large composition of TT growers that are likely to shift to GM technology, reducing the cost of a competitive industry leading to a fall in the price of GM canola. Thus, in the long run, the cost advantage is not large enough to compensate for the lower farm level price received for GM canola. In the same way, farmers not adopting the technology may also suffer as farm prices for non-GM canola also fall. On the other hand, farmers with a cost advantage of greater than 19.78 per cent (i.e., $\sigma<0.8022$) experience welfare gains. Here, the gains accruing to the latter group are sufficient to yield a 'net gain' of 9.12 per cent of baseline revenues. This implies that the introduction of GM canola induces intrasectoral effects compared to intersectoral effects. This explains why the controversy involves different consumer and producer groups, in particular, the concerns being voiced by non-GM growers. However, in aggregate, the introduction of GM technology results in net welfare gains of 11.93 per cent in Scenario 1. By comparing the results of Scenario 1 to 3, it is clearly apparent that sustaining the long-term production benefits are vital to improving net social welfare.

The "δ*" indicates that consumers with a $\delta<0.9413$ (requiring a discount more than 5.87 per cent), will be willing to pay the cost of segregation to identify non-GM canola. Consequently, around 10.70 per cent of non-GM canola is identity preserved. The total consumer surplus is observed to be larger in Scenario 1 than compared to the baseline scenario by 2.81 per cent of baseline expenditures. This is a result of the lower prices paid for GM and non-GM canola compared to the baseline (respectively, 0.8022 and 0.8522 versus 1). Thus, all consumers gain from the introduction of GM canola due to the supply side cost reductions being permeated through to consumers in the form of lower prices.

In Scenarios 1 to 7, the sum of producer and consumer surpluses is higher than in the baseline scenario irrespective of cost savings and consumer concerns. This suggests that under many possible scenarios, the producer benefits from being able to spread fixed costs over larger production volumes are likely to outweigh any adverse price impacts of increased supply and consumer concerns. In contrast, Scenario 8 presents a case, where the net welfare is lower than the baseline. The rationale for this is that the additional costs imposed on the new market system are larger than the production advantages and, therefore, acts as a deadweight loss. This outcome is counterintuitive, as rational farmers act collectively to adopt a technology that makes them worse off, implying that individual welfare effects in these situations require greater analysis.

The sensitivity of the long-run results to the demand and supply elasticities of canola is examined in Scenarios 9-12. In Table 7, comparing Scenarios 1 and 9, a 1 per cent increase in the own-price elasticity of demand causes equilibrium GM prices to increase by 4.98E-04 per cent. Although this variation is minimal, the price change permeates through to changes in total output levels, and the number of groups consuming and producing GM and non-GM canola. As a result, net welfare is reduced by 5.41 per cent. Similarly, changes in supply elasticities may also have sizeable impacts on welfare. Overall, welfare measures in the long run are sensitive to the elasticity values compared to the short-run analysis. Therefore, the results must be interpreted with caution, and particular attention should be paid to the elasticity values used for calibration.

7. Policy implications

Several policy implications emerge from the analysis. Firstly, the Australian oilseeds industry should exert greater efforts to assist farmers to better promote and establish emerging markets, which may develop preferences for non-GM canola. Based on the results obtained, the strategy will help to induce sufficient demand for non-GM canola providing Australian non-GM farmers greater potential to capture premiums. Furthermore, this will ascertain the benefits of producing non-GM canola, whilst insulating them from reductions in the prices received that are caused by cost reducing technology. As canola is an important crop in a farmers' rotation with wheat, the benefits of improved abilities to market their grains will flow to wheat farmers where it is currently a crucial issue. In the wake of the Australian Wheat Board being abolished, programs helping canola growers to market non-GM canola will indirectly benefit the wheat sector.

Secondly, the long-run results show that society loses only when production cost-savings are trivial, and when consumers are very concerned about GM canola. As a result, efforts to ensure the long-term sustainable use of the technology become equally important as reducing the extent of concerns about GM technologies. Policies governing industry bodies to enforce Crop and Resistance Management Plans for example and improved farming practices to ensure cost minimization (or profit maximization) are necessary. This will allow Australian farmers to be able to realise continued production cost savings in the long run and ensure integrity of the grain supply chain. This is supported by experiences in North America, which demonstrate the importance of strict integrated weed management and adhering to strict agronomic practices to prevent resistance to herbicides (GRDC 2009). This is reflected by comparing Scenario 1 to 5, where the loss of agronomic benefits can dramatically deter societal welfare. Additionally, in Australia, consumer attitudes toward GM foods are generally negative in comparison to many other countries. However, previous studies indicate that attitudes are changing as a result of information on GM foods becoming more widespread. Stone *et al.* (2002) found that as the information and knowledge of the technology increases, consumer concerns diminished. As such, increased expenditure to improve accessibility and availability of information on GM technology will promote confidence in GM technologies. The results imply that efforts to reduce consumer concern will dampen the deflationary effects on the price received for GM canola and improve welfare. However, as a significant portion of Australia's production is absorbed internationally, these improvements are also contingent on global attitudes and activities. In addition, as one of the major concerns in Australia relates to the inconsistency between Federal and State decisions, greater collaboration and coherence between these two regulatory levels will ensure that consumer concerns are minimised. On the whole, policies that help reduce concerns will pave the way for future GM crop technologies to be more readily accepted.

Thirdly, as the relative share of non-GM canola in world trade continues to dwindle, it will provide an opportunity for Australian non-GM farmers. The oilseed industry should encourage investment into establishing an efficient traceability system. This will aid non-GM producers to deliver confidence in the international market and thereby attract better premiums. As herbicide tolerant (HT) crops permit greater weed control, this system may also help promote cleaner harvests which may attract a premium at the farm gate (Acworth *et al.* 2008). Although, these premiums are negligible (Serecon Management Consulting Inc and Koch Paul Associates 2001). In addition, an efficient handling system will help to ensure that the production advantages from GM canola outweigh the deadweight losses associated with identity preservation in the new market system. In addition, efforts to improve GM crop traits will also help to enhance the benefits without increasing the deadweight loss, serving to better the net cost advantages to the producers.

Finally, the inherent nutritional profile of conventional canola in which Australia has developed a reputation is a key advantage that should be advocated by producers. In the medium to long term, the increased development of foods will increase product differentiation as a method of retaining value. In a perfectly competitive industry, the demand elasticities imply that Australian producers can inflate their gains through appropriate means of product differentiation. In fact, this will reduce the substitutability of canola as general purpose cooking oil. However, as a consequence, greater demand for more differentiated products by variety, quality, place and method of production may increase the requirements for large scale segregation, causing a larger deadweight loss (Lin 2002; Wilson and Dahl 2005). In summary, social welfare may well be maximised if the labelling of GM canola were not required given the short-run supply conditions and the long-run arbitrage behaviour. However, enforcing a labelling regime also makes clear sense particularly in Australia where consumer concerns appear to be relatively greater than in other countries.

The findings of this study are consistent with theory and past studies reported in the literature. However, there are several limitations that could be addressed to ensure the plausibility of the results. One key limitation is the inability to separately model the differences in demand elasticities across consumer groups, and similarly with the supply side due to computational difficulties and data limitations. The use of more powerful simulation software such as MATLAB may make this possible.

8. Concluding comments

The market price, production, consumption and welfare impacts of introducing GM canola have been analysed. The findings for the short run suggest that in Australia, the farm prices of GM and non-GM canola will be identical as GM canola supplies are likely to remain relatively small. However, these findings are sensitive to consumer preferences. In the long run, access to GM technology improves producer welfare via significant cost reductions and long run productive efficiency, while benefits to consumers are passed on in the form of lower prices. In most cases, the production gains will outweigh any adverse effects caused by consumer attitudes. However, consumer attitudes can potentially place significant downward pressure on the prices received by producers. Although the possibilities of demand side shocks such as the StarLink® incident are explored, supply side variations are not analysed closely and warrant further research. These include re-investment into GM technology helping to enhance long-run benefits, and the possibility of weed and pest resistance developing reducing the long run benefits (Kennedy and Whalon 1995; Hilder and Boulter 1999; Benbrook 2003). The study also neglects the substantial beneficiaries to other sectors, most eminently, the wheat sector that is emphasised by Norton and

Roush (2007). Future research may also require explicit modelling of the market under a monopolistic regime. In addition, further research into the proposition that segregation costs increase as the relative market share of GM canola rises should be undertaken (Kalaitzandonakes *et al.* 2001). Finally, from recent harvests, the oil content of non-GM and GM canola is, respectively, 33 per cent and 40.4 per cent (GRDC 2009). Where growers are paid against an oil content of 42 per cent and a 1.5 per cent premium is paid (discounted) when the percentage point is above (or below) that guideline, these represent significant factors determining the overall benefits, prompting several avenues for further research. The model may also be applied to explore the implications of second-generation GM canola in near future. Overall, it appears that at the heart of GM technology, its introduction into the Australian canola market offers societal benefits for farmers, and potentially for consumers.

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Table 7 Long-run effects from introducing GM technology (canola)

Scen.	Elasticity Sup.	Elasticity Dem.	Prod. Cost[a]	Cons. Attitude[b]	Non-GM quantity Output	Non-GM quantity Consump.	Tot. Output	GM Price	Non-GM price Farm	Non-GM price Retail	σ*	δ*	indiff[c]	Surplus change[d] Prod.	Surplus change[d] Cons.	Surplus change[d] Net Welfare
1	0.26	-0.2185	L.Savings	AUS.Concern	0.1889	0.1070	1.0460	0.8022	0.8022	0.8522	1.0000	0.9413	0.8022	0.0912	0.0281	0.1193
2	0.26	-0.2185	L.Savings	L.Concern	0.1821	0.1059	1.0464	0.8037	0.8037	0.8537	1.0000	0.9414	0.8035	0.0903	0.0282	0.1185
3	0.26	-0.2185	L.Savings	H.Concern	0.1884	0.1163	1.0380	0.7931	0.7856	0.8356	1.0000	0.9409	0.7955	0.0837	0.0210	0.1047
4	0.26	-0.2185	L.Savings	V.H.Concern	0.1796	0.1402	1.0299	0.7727	0.7698	0.8198	1.0000	0.9401	0.7853	0.0633	0.0100	0.0733
5	0.26	-0.2185	S.Savings	AUS.Concern	0.2062	0.1070	1.0380	0.8073	0.8073	0.8573	1.0000	0.9432	0.8309	0.0562	0.0023	0.0585
6	0.26	-0.2185	S.Savings	L.Concern	0.2059	0.1058	1.0385	0.8059	0.8059	0.8559	1.0000	0.9433	0.8322	0.0525	0.0023	0.0548
7	0.26	-0.2185	S.Savings	H.Concern	0.2021	0.1163	1.0340	0.7988	0.7890	0.8390	1.0000	0.9428	0.8239	0.0255	-0.0008	0.0247
8	0.26	-0.2185	S.Savings	V.H.Concern	0.1969	0.1405	1.0287	0.7763	0.7763	0.8263	1.0000	0.9421	0.8134	-0.0053	-0.0063	-0.0116
9	0.26	-0.2207	L.Savings	AUS.Concern	0.1889	0.1069	1.0462	0.8026	0.8026	0.8526	1.0000	0.9414	0.8029	0.0946	0.0174	0.1120
10	0.2626	-0.2185	L.Savings	AUS.Concern	0.1887	0.1070	1.0462	0.8014	0.8014	0.8514	1.0000	0.9413	0.8014	0.0894	0.0134	0.1029
11	0.26	-0.2207	S.Savings	AUS.Concern	0.1906	0.1062	1.0383	0.8315	0.8315	0.8815	1.0000	0.9433	0.8315	0.0493	0.0073	0.0566
12	0.2626	-0.2185	S.Savings	AUS.Concern	0.1905	0.1062	1.0382	0.8072	0.8072	0.8572	1.0000	0.9432	0.8302	0.0497	0.0063	0.0560

Notes:
The baseline scenario assumes that GM technology is not available, and thus GM canola is not produced. The baseline is calbrated with equilibrium supply and equilibrium non-GM prices (at the farm and retail level) equal 1.

[a]The Beta distributions for σ are:
Large Savings (low-σ) is Beta(x|1.0623, 1.7781, 0.45, 1.15)
Small Savings (high-σ) is Beta(x|1.6949, 1.3826, 0.45, 1.15)

[b]The Beta distributions for δ are:
Australian Concern is Beta(x|0.8710, 0.1095, 0, 1)
Low Concern (High-δ) is Beta(x|1.0325, 0.1112, 0, 1)
High Concern (Low-δ) is Beta(x|0.9405, 0.2901, 0, 1)
Very High Concern (very low δ) is Beta(x|0.9199, 0.3661, 0, 1)

[c]The "indifference" column indicates the δ of consumers (σ of producers) whose welfare remains unchanged by the introduction of GM technology.
Consumers with δ> (<) "indifference" experience a welfare gain (loss). Similarly, producers with σ< (>) "indifference" experience a welfare gain (loss).

[d]The "surplus changes" indicate changes in surplus in the final equilibrium compared to the initial (baseline) equilibrium