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Commercial release of first-generation genetically modified food products in New Zealand: using a partial equilibrium trade model to assess the impact on producer returns in New Zealand

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In the present paper, the impact of genetically modified (GM) food production on producers, consumers and trade in New Zealand is simulated under various scenarios using the Lincoln Trade and Environment Model (LTEM). The LTEM simulates, against various assumptions of proportions of GM/GM-free production, the impact of various scenarios relating to preference for or against GM production. The results from this preliminary analysis show that the greatest positive impact on New Zealand income is from following a GM-free strategy, where it is assumed such markets as the European Union and Japan have a large switch in preference away from GM food, followed by the scenario when there is a 20% preference for GM-free.

1. Introduction

The commercial release of genetically modified (GM) food production is of considerable international debate and in New Zealand has been subject to a Royal Commission enquiry (Royal Commission on Genetic Modification 2001). The present paper addresses the economic impact on New Zealand of releasing GM food commercially. A problem with the evaluation of releasing GM products relates to the current state of the technology. Currently, only first-generation GM products are available for commercial release. These generally affect the production system and potentially benefit the producer by reducing production costs. These products include corn resistant to insect infestation and herbicide-resistant canola and soybean, thus allowing the use of cheaper herbicides. Second-generation GM food is anticipated to influence the product itself and to have the greatest potential benefits for consumers; for example, improved taste or additional nutrients.

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However, the potential benefits of second-generation GM food are virtually impossible to assess, given that they have yet to be released commercially and are still the subject of research. There are also possible costs and/or risks of genetic modification that are potentially large and difficult to assess. These include factors such as potential environmental problems or problems of cross-pollination.

Because it is impossible to evaluate the potential risks and benefits of second-generation GM crops, the present paper will concentrate on evaluating the short- and medium-term impact of the commercial release of currently available first-generation GM crops. Thus, the present paper initially reviews studies that have evaluated the impact of the introduction of GM technology, both on the producer and the consumer. The paper then reviews published literature that analyses the international trade effects of introducing first-generation GM crop production, specifically by focusing on partial and general equilibrium applied trade models. The general characteristics of the Lincoln Trade and Environment Model (LTEM) and the approach used to incorporate trade effects of genetic modification are then explained. This is followed by results from a number of model simulations based on varying proportions of uptake of GM production against varying preferences of consumers and producers in the major countries involved with GM production and/or consumption around the world. The implications of these different scenarios for New Zealand producer returns are then considered, in particular for maize, raw milk, apples and kiwifruit.[1] While the last three products were selected because they are key exports for New Zealand, maize was chosen because it is a product commonly focused on in other applied studies in the published literature.[2]

2. Impact of GM food production on producer and consumers

The economic/financial impact of the commercial release of genetically modified organisms (GMOs) depends on the interaction between, and the

[1] Definition of GM: before any analysis of the potential risks and benefits to NZ of releasing GM, what is meant by GM has to be defined. Moreover, because most of New Zealand's food production is exported, New Zealand has to consider overseas definitions of GM. The definition of GM-free varies across countries, mainly in line with attitudes and the practicalities of implementing labelling laws. While allowable contamination rates vary, most allow a small percentage (ranging from 1 to 5%) of GM product. Even currently in New Zealand there are GM imports of feed and GM in enzymes for cheese production. Thus, in discussing GM-free production, this is assumed to allow for small amounts of GM as defined by labelling law.

[2] However, a comparison of the results in the maize market with the other studies must be performed with great caution because New Zealand is included as part of another country group or region in other studies rather than as itself, as opposed to in the present study.

responses of, producers and consumers of GM food within the international trading environment. This section addresses the impact of introducing GM food production on domestic producers and consumers in isolation, then assesses the trade impacts.

2.1 Producer impacts of genetic modification

As stated, the current commercial release of first-generation GM food affects the production system. The main commercially released GM crops are insect-resistant maize and herbicide-tolerant soybeans and canola. Thus, most of the current benefits of GM products accrue to the supply side and relate to potential increases in yield and/or reduction in costs. However, it should be emphasised that the evidence so far on the impact of GM crop production techniques can only be treated as preliminary, because the crops have not been grown commercially over a long period.

The results from various studies show that the impact of GM crop production on yield varies according to the crop type (Furman Seltz 1998; Duffy 1999; Gianessi and Carpenter 1999). In the case of soybeans and canola, there has been little change in yield; in the case of soybeans, there have actually been recorded falls in the yield of the GM crop compared with non-GM crop. This result is perhaps not surprising, because these currently released GM soybeans and canola are not targeted at the productivity of the plant but, rather, at changes in input use, so expected gains should be from savings in input costs. In the case of maize, there are reported increases in yield, which vary according to the level of insect infestation in the particular year. These gains in yield have been estimated to range from 0.26 to 1.88 tonnes/ha depending upon the degree of infestation and the study.

There is a reduction in the total costs of herbicides in the case of GM soybeans and canola, of up to 30% in the case of soybeans. The cost of seed was higher for all GM crops, as expected. Another benefit from GM crop production reported by producers was increased flexibility in production, such as a more flexible spraying schedule. For example, it was found that 12% of farmers surveyed cited increased flexibility as a reason for converting to GM crop production (Duffy 1999). This increased flexibility might lead to lower costs, but these are difficult to quantify.

The impact of any changes in yield and costs on gross margins (assuming no impact on demand and, therefore, prices) has so far been indeterminate. For GM soybeans, the fall in herbicide costs was reported to be offset by rises in seed costs, with the net returns to land and labour being slightly more for non-GM soybeans (Duffy 1999). This is supported by a United States Department of Agriculture (USDA) study, which reported that while there was some positive impact on yield and reductions in herbicide use from GM crop production, net returns did not change (Fernandez-Cornejo and McBride 2000). It is more difficult to assess the impact on gross margins for GM maize given that it is highly dependent on the level of insect infestation and, thus, the potential losses in yield have to be set against the higher price for GM insect-resistant seed. A study by Furman Seltz (1998), shows a gain in returns from using GM maize, especially under heavy insect infestation. Duffy (1999) also found a small gain. However, Gianessi and Carpenter (1999) found mixed results from using GM maize, with a gain in returns in 1997 but a loss in 1998. In the case of canola, results are again mixed, with Fulton and Keyowski (1999) reporting lower returns with GM canola, whereas the results from a study in Alberta in 1999 found that GM gave lower returns on one type of soil but higher returns on another (CEC 2000).

2.2 Consumer impacts of genetic modification

The consumer response to GM food, the other side of a market analysis, has thus far been mixed. Given recent food scares, particularly in Europe, it is not surprising that consumers have concerns regarding changes to the genetic make-up of their food.

To address these concerns, governments and food suppliers have developed various strategies. Several countries are regulating the production and/or marketing of GM foods, either with mandatory GM food labels, as in Australia and New Zealand, with voluntary GM-free labels, as in the USA and Canada (Phillips and McNeill 2000), or with outright bans, as in Brazil (Phillips and McNeill 2000). In the private sector, major European and New Zealand supermarket chains have been positioning themselves as selling only GM-free house-brand products and some food companies are declaring their intentions to source non-GM ingredients (CEC 2000; Chapple 2001).

Information about consumer responses comes from the considerable number of studies into attitudes towards genetic engineering in general and GM food in particular. The results are difficult to summarise because of differences in purpose, methodology and quality. However, it is fair to say that the acceptability of GM food varies regionally with, for example, genetic modification being more acceptable in North America than in Europe, and substantial regional variation within Europe itself. Surveys also suggest that transgenics, transferring genes across species, and the manipulation of genes of humans and animals are less acceptable than gene manipulation in plants (Campbell *et al*. 2000).

There have been fewer studies that have attempted to quantify the effect that consumers' concerns may have on demand. James and Burton (2001) used choice modelling to estimate willingness to pay (WTP) for non-GM food among Australian consumers and found that 'food bills would have to drop by more than 20% before food produced using [plant-only] gene technology would be purchased'. This is an average value; some market segments have even stronger aversions to GM food. Frequent purchasers of organically grown food in the UK, for example, show such high WTP to avoid GM food that they are effectively rejecting it at any price (given no other benefits from the technology; Burton *et al.* 2001).

These two principal negative consumer or retail responses to GM food (rejecting it entirely or requiring large discounts) erode any potential benefits from improved crop production. Moreover, the sensitivity of markets to GM food is not stable. European labelling rules, for example, will become more stringent (European Commission 2001) and consumer attitudes towards GM food have, in general, become increasingly negative (Campbell *et al.* 2000). It is uncertain how future developments will affect markets for GM food and whether consumer acceptance will change in the near term.

3. Trade impacts of GM production

An important facet of the trade in those commodities that comprise nearly all the acreage planted in GMOs (soybeans, maize, cotton, canola) is that the part of production intended for human consumption is small compared with other uses. Even when the crop is for human consumption, the final product (canola oil, soybean oil, sugarbeet sugar) often does not contain proteins, so there is no GM material and, therefore, no requirement for labelling under current regulations in Australia, New Zealand and Europe (although this is to change with the new European rules). Thus, in addition to the worldwide pattern of preferences creating GM-sensitive and GM-indifferent regions, there are also GM-sensitive and GM-indifferent uses. Trade impacts of GM crop production are therefore affected by production costs, consumer sensitivity and the uses to which the crop is put.

An illustration of the issues raised in relation to GM food is highlighted in the case of the mistaken release of StarLink GM feed maize into the food market (the StarLink GM maize was not approved for human consumption). This maize was mixed with food-grade maize in the USA, some of which was exported to Japan. This caused a significant negative market reaction (Lin *et al.* 2001) when the StarLink GM maize was detected.

StarLink-free maize initially had a premium of 7–12 cents (US$) per bushel. Following the detection of the GM maize, grain handlers moved the StarLink maize out of the food market into the appropriate feed market (resulting in the reduction of the premium on StarLink-free maize). The

USA and Japanese governments finally negotiated testing protocols for GM maize that reassured Japanese buyers.

The same trade effects are evident in other commodity markets. For example, the American Corn Growers Association reported that almost 20% of grain elevators surveyed reported offering a price premium for non-GM maize or soybeans (Anonymous 2002). Market sensitivity to GM food is affecting trade flows, with sensitive European and Asian markets increasing their purchases of non-GM Brazilian soybeans and soyameal and the European Commission effectively blocking bulk shipments of USA maize to Europe (USDA 2002). Governments are stepping in to affect the flow of GM commodities either in response to citizens' concerns or as 'green protectionism'. A final response of some food processors, not discussed above in relation to StarLink, is contracting for non-GM sources, an understandable internalisation in response to the increased cost of purchasing the required product on the open market. This anecdotal evidence suggests that the adoption of GMOs in production and concern about GM food among consumers are causing changes in international commodity trade. For broader understanding, one needs to turn to the trade modelling literature.

3.1 The trade modelling literature

The regional and global trade impacts of introducing GMOs have been estimated in a number of studies so far. Four different dimensions of the issue are discussed in these studies that might possibly cause shifts in international trade patterns. The first dimension is the increase in factor productivity and resulting increase in total production of the commodities in countries adopting GM technology. Many authors (Moschini *et al.* 2000; Nielsen and Anderson 2000a, 2000b; Nielsen *et al.* 2000; Anderson and Yao 2001; Barkley 2002) have attempted to quantify the effects on regional and global levels of production, price, trade and welfare of productivity increases in GM-adopting countries. To model the innovation at the production level, Moschini *et al.* (2000) quantify the per-hectare cost, profit and yield effects of GM soybean seed adoption, and calculate the price effects of quantity changes in the innovator country. In various studies performed by Nielsen and Anderson (2000a, 2000b), they base their policy analyses on the assumption that the GM-adopting sectors experience a one-off increase in total factor productivity (including all primary factors and intermediate inputs), thus lowering the supply price of the GM crop to that extent. In Barkley (2002), the supply curve of the GM-adopting product/nation shifts by the amount of research-induced cost reduction attributable to the technological change.

The second dimension of the discussions on effects of GM adoption is the possible changes in the consumer preferences towards GM-free products and away from GM-adopted ones. Nielsen and Anderson (2000b), Nielsen *et al.* (2000), Anderson and Yao (2001) and Barkley (2002) quantify the effects of shifts in consumer preferences, as well as the productivity changes resulting from GM adoption. In these studies (except in Nielsen *et al.* (2000)), the distinction between GM and GM-free products is based directly on the country of origin and labelling costs are ignored. In Nielsen *et al.* (2000), the products in each country are segregated into GM and GM-free and these are assumed to be substitutes both in production and consumption. The shifts in preferences are incorporated either through the use of exogenous shifts in intermediate and final demand or by changing the price elasticity of demand. The third dimension of the discussions about the global trade impact of GM production involves the demand-side shocks against GM products, such as implementing bans on imports of GM products (Nielsen and Anderson 2000b; Anderson and Yao 2001).

The fourth dimension arises through the implications of labelling policy and its harmonisation among trade partners. In the previous studies, the distinction between GM-inclusive and GM-free products is based directly on the country of origin and labelling costs are ignored. In Jackson (2002), the effects of product labelling are evaluated through explicit modelling of labelling costs. Labelling is assumed to affect both the production structure through the use of more labour, and consumption patterns because the consumers are assumed to care about the quality of the final good (GM inclusive products are assumed to have lower quality than GM-free products). Therefore, a price differential between GM and GM-free products arises at the market, which is calculated endogenously based on the new cost and utility functions, and which may or may not yield shifts in production and international trade patterns.

The general findings of these studies can be summarised as follows. The adoption of GM technology is found to create substantial efficiency and welfare gains, particularly to the producers of the innovator country and to the consumers due to the reduced prices for GM products (Moschini *et al.* 2000; Neilsen and Anderson 2000a, 2000b). However, the location of the GM production and the existence/availability of technological spillovers are also found to be important in determining the shifts in trade patterns and overall welfare gains/losses because international GM spillover can hamper the competitive position of the innovator country.

The product-specific demand elasticities are observed to also be important in determining the changes in foreign demand and in consumer welfare. For example, in Moschini *et al.* (2000) and Barkley (2002), it is shown that when GM adoption increases soybean production, farmers are negatively affected by the innovation because of the inelastic demand for soybeans and soybean products (lower price because of rising supply but inelastic demand). In these studies, consumer acceptance of GM products and governments' regulatory policies on the imports of GM products are found to have significant effects on producer and consumer welfare gains. In Nielsen and Anderson (2000a), for example, it is shown that an import ban on GM crops imposed by the European Union (EU) raises non-GM prices, and domestic production of non-GM components is forced to rise at the expense of other production. According to Barkley (2002), the impact of trade reductions in international feed markets, whether they are due to import bans or changing consumer preferences for non-GM food, have a significant impact on feed markets.

In Nielsen *et al*. (2000), it is shown that segregation of GM and GM-free markets may have substantial impacts on current trade patterns. Global markets are found to adjust to this segregation, in the sense that exports of non-GM products are diverted to the GM-critical regions, whereas GM exports are diverted to the indifferent regions. In addition, trade diversion is found to become significant when the GM-critical regions change their preferences towards GM-free products. However, the transfer of GM from the innovator country to the trade partners (widespread adoption of GM) would decrease the size of the effects on prices, production levels and international trade flows.

The price differentials between GM and GM-free products are found to be significant, but tempered by commodity arbitrage. Another important finding is that developing countries are also responsive to these GM preference changes and redirect their trade flows among partners accordingly. Furthermore, given the existing bilateral trade patterns for these particular crops, the price wedges that arise in the developing countries mainly reflect productivity differences, not preference changes, in the developed world (Nielsen *et al*. 2000).

According to Jackson (2002), the GM product policy dilemma stems from a fundamental conflict over how national policies categorise GM products. For example, whereas the EU justifies labelling because EU policies treat GM products as fundamentally different from traditional products, the USA policies treat GM products as if they are substantially equivalent to existing products and USA consumers consider these products to be interchangeable. Based on this, from the USA's frame of reference these labels act as non-tariff barriers, whereas from the EU's perspective these labels provide an appropriate classification for two different types of products. Therefore, simply categorising the label as a non-tariff barrier does not recognise the complexity of the GM trade issue.

General characteristics of the empirical models used in these studies to analyse the regional and global trade effects of GM products are presented in tables 1, 2.

In the present paper, the specific emphasis is on New Zealand, which is included as an explicit region, rather than within a group of countries, such as Austral–Asia, High Income South Asia, Other High Income Countries etc., as in other studies. Accordingly, the product focus shows differences with the other studies, which is composed of New Zealand's main export markets, such as raw milk, apples and kiwifruit, as opposed to cotton, rice and soybean, which are more common in the literature. However, in order to provide a comparison with the other studies, the impact on the New Zealand maize market is also analysed. The assumptions with regard to policy and non-policy induced shocks, such as a productivity change in GM-adopting products and a supply shift of, or changes in consumer preferences towards, GM products and a demand shift show similarities with the other studies in the published literature.

3.2 The empirical model

In this research, a partial equilibrium (PE) model, the LTEM, is used to quantify the price, supply, demand and net trade effects of various policy and non-policy induced shocks. The LTEM is an agricultural multicountry, multicommodity trade model, which does not consider the linkages of the agricultural sector with other industries, factor markets and macroeconomy. It is based on Vernon Oley Roningen Simulation (VORSIM),[3] which has evolved from Static World Policy Simulation (SWOPSIM) and associated trade databases used to conduct analyses during the Uruguay Round (Roningen 1986; Roningen *et al.* 1991). The LTEM is modified in the present study to quantify the global and regional effects of farmers adopting GM technology in production, consumers' preference changes in relation to GM products and policy induced shocks on imports of GM products.

Although a PE framework uses a 'standard approach' to model international trade policy, analysts tend to prefer PE frameworks in quantifying the effects of domestic agricultural and trade policy measures based on factors such as the level of commodity disaggregation, ease of traceability of the interactions, transparency of the results, relatively small size of the models, the number of behavioural parameters and the methods used to

[3] The policy simulation framework created by Vernon Oley Roningen. See http://members.aol.com/vorecon/vorsim.html

Table 1 General characteristics of the empirical models that focus on trade impacts of genetically modified products

Model	Modelling approach	Temporal properties	Solution type	Parameters	Commodity coverage	GM products included
Barkley (2002)	PE	Comparative static	Spatial, bilateral	Non-synthetic Econometric extimation	2	Maize Soybeans
Jackson (2002)	CGE	Comparative static	Spatial, bilateral	Mostly synthetic	7	Maize Soybeans
Saunders and Cagatay (2001)	PE	Comparative static	Non-spatial, net trade	Synthetic	14	Maize Kiwifruit
LTEM		Can also provide short-term dynamics				Apples Raw milk
Anderson and Yao (2001) GTAP	CGE	Comparative static	Spatial, bilateral	Mostly synthetic	17	Rice Cotton Maize Soyabeans
Moschini *et al.* (2000)	PE	Comparative static	Spatial, bilateral	Synthetic supply and demand Non-synthetic for the rest	3	Soybeans Soyoil Soimeal
Nielsen and Anderson (2000a) GTAP	CGE	Comparative static	Spatial, bilateral	Mostly synthetic	17	Rice Cotton
Nielsen and Anderson (2000b) GTAP	CGE	Comparative static	Spatial, bilateral	Mostly synthetic	17	Maize Soybeans
Nielsen *et al.* (2000)	CGE	Comparative static	Spatial, bilateral	Mostly synthetic	10	Maize Soybeans

PE, partial equilibrium; CGE, calibration problems, which arise as one of the main problems at this level of disaggregation in general equilibrium; GTAP, global trade analysis project.

Table 2 General characteristics of the empirical models that focus on trade impacts of genetically modified products

Model	Country coverage	Approach used to incorporate effects of GM technology	Induced shocks
Barkley (2002)	3	Increase in production via reduction in production costs	Unilateral adoption of GM technology Bilateral adoption of GM technology Consumer opposition to GM product
Jackson (2002)	3	Product differentiation in consumption with respect to quality (GM content)	Unilateral labelling Multilateral labelling Different labelling strategies
Saunders and Cagatay (2001)	9	Increase in production via reduction in production costs	Adoption of GM technology and changes in the adoption rate
LTEM		Substitutability among GM and GM-free components in consumption and production	Shifts in consumer preferences Import bans on GM products
Anderson and Yao (2001) GTAP	16	Increase in productivity via reduction in input use	Adoption of GM technology Shifts in consumer preferences Import bans on GM products
Moschini *et al.* (2000)	3	Increase in yield Decrease in production costs via the reduction in herbicide use	Changes in adoption rate of GM technology Technology spillover
Nielsen and Anderson (2000a)	16	Increase in productivity via reduction in input use	Adoption of GM technology
Nielsen and Anderson (2000b) GTAP	16	Increase in productivity via reduction in input use	Adoption of GM technology Shifts in consumer preferences Import bans on GM products
Nielsen *et al.* (2000)	7	Increase in productivity via reduction in input use Substitutability among GM and GM-free components in consumption and production	Adoption of GM technology Shifts in consumer preferences

GM, genetically modified; LTEM, Lincoln Trade and Environment Model; GTAP, global trade analysis project.

obtain those parameters (van Beers and van den Bergh 1996; Francois and Hall 1997; Roningen 1997; Gaisford and Kerr 2000).[4]

Therefore the LTEM is preferred in the present study because of the level of commodity disaggregation that the framework allows. The problem of data and parameter availability or calibration problems, which arise as one of the main problems at this level of disaggregation in general equilibrium (CGE) models, is also avoided in this way. Finally, explicit modelling of the dairy sector at a disaggregated level is another strength of the LTEM.

There are nine countries and 14 agricultural commodities included in the model (see Appendix table A1 for a list of these countries and commodities). The model has a non-spatial, price equilibrium structure and, therefore, can be used to calculate the net trade of each country for each commodity. It is a synthetic model in which the parameters are obtained from relevant studies in the published literature. The LTEM is used to derive the medium- to long-term (until 2010) policy impact in a comparative static fashion basing the beginning date to 1997. The model provides short-run solutions as well because it performs a sequential simulation procedure year by year in which the stock change is used to link two consecutive years. Basically, the model works by simulating the commodity based world market clearing price on the domestic quantities and prices, which may or may not be under the effect of policy changes in each country. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market by using a non-linear optimisation algorithm.

In general, there are six behavioural equations and one economic identity for each commodity under each country in the LTEM framework. The behavioural equations are domestic supply, demand, stocks, producer, consumer and trade prices, and the identity is the net trade equation. For some products, the aggregate domestic demand is separated into food, feed and processing demand.[5] Incorporation of GM in commodities to the LTEM is explained in the next section using grains as an example. Therefore, the additional variables/parameters used to incorporate GM product into the grains market in the LTEM applies for dairy and fruit markets also.

[4] In addition, the ability to include agricultural input markets endogenously and to treat commodities as imperfect substitutes (i.e. to include bilateral trade relationships) with some effort might make PE frameworks more attractive.

[5] The behavioural specifics of the LTEM, methodologies used to incorporate trade and domestic policy shocks and various parameters of the model are detailed in Cagatay and Saunders (2003).

3.3 Incorporation of GM Technology to the LTEM

In the LTEM, production in all countries is assumed to be segregated into GM and GM-free components. Therefore, effectively 28 products are modelled. The data for the segregated production are obtained from Campbell *et al.* (2000) and the percentage shares of GM production and GM feed consumption by meat and dairy sectors in total are given in table 3. The GM and GM-free components are assumed to be imperfect substitutes in production and consumption and identical supply, demand, stock and price functions are used for GM and GM-free varieties, which is the common method in the applied literature explained in the preceding text (Nielsen *et al.* 2000; Barkley 2002). The supply and demand equations used in the LTEM are extended to include new shifter variables in order to incorporate various shocks related to adoption of the GM technology and possible market responses. In these equations, cross-price effects of GM and GM-free components are also introduced (because they are assumed to be substitutes in consumption and production) in order to measure the cross-effects of a shock on one of the components.

Table 3 Share of GM Production and GM Feed Consumption in Total (%)

	AR	AU	CN	EU	JP	MX	NZ	USA	RW
GM production									
Wheat	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Coarse grains	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Maize	0.05	0.05	0.40	0.05	0.05	0.30	0.05	0.30	0.20
Oilseeds	0.50	0.05	0.50	0.05	0.05	0.50	0.05	0.50	0.30
Oilseed meals	0.50	0.05	0.50	0.05	0.05	0.50	0.05	0.50	0.30
Oils	0.50	0.05	0.50	0.05	0.05	0.50	0.05	0.50	0.30
Apples	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Kiwifruit	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Raw milk	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Liquid milk	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Butter	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Cheese	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Whole milk powder	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Skim milk powder	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
GM feed consumption									
Wheat	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Coarse grains	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.01
Maize	0.05	0.30	0.40	0.30	0.30	0.30	0.30	0.30	0.20
Oilseeds	0.30	0.30	0.50	0.30	0.30	0.30	0.30	0.30	0.20
Oilseed meals	0.30	0.30	0.50	0.30	0.30	0.30	0.30	0.30	0.20

Source: Campbell *et al.* (2000).
AR, Argentina; AU, Australia; CN, Canada; EU, European Union; JP, Japan; MX, Mexico; NZ, New Zealand; USA, United States of America; RW, rest of the World; GM, genetically modified.

In the LTEM, a uniform constant elasticity functional form is specified to reflect the aggregate domestic supply (demand) response of (for) each commodity in each country with respect to the own- and cross-prices (both for GM and GM-free products). The supply response of a GM product is specified as in equation 1. In this equation, the letter g is used to represent the GM component of the product i, which is maize in this case, and subscript j represents the substitute commodities, such as wheat and coarse grains. Therefore, supply of GM maize (qsg_i) is specified as a function of the supply side shifters (shf_{qsg}), producer price of the GM maize (ppg_i), of the other substitute GM products (ppg_j) and of the GM-free maize (pp_i). A similar functional form and behavioural relationship is also used to reflect the supply response in GM-free maize (qs_i) in which the producer price for GM maize (ppg_i) also appears as a substitute product to GM-free maize. The own-price elasticity (ppg_i) of GM maize supply is expected to be positive, but the cross-elasticities with respect to the prices of GM-free maize (pp_i) and other GM products (ppg_j) are expected to be negative.

A productivity change, such as an increase in the productivity of maize in a GM-adopting country, is reflected through the exogenous change in the shift variable (shf_{qsg}), which is equal to 1 initially. If, for example, a 10% increase in the production of maize is assumed as a result of a reduction in the use of factors of production, then the shifter becomes equal to 1.00 + 0.10 = 1.10 and causes a pivotal downward shift in the supply curve. As a result, a decrease in the price of GM maize is expected because of the excess supply created in the domestic market and this lower price feeds back into the supply function of GM-free maize, because GM and GM-free components are substitutes.

$$qsg_i = \alpha_0 shf_{qsg} ppg_i^{\alpha_1} pp_i^{\alpha_2} \prod_{j=1}^{2} ppg_j^{\alpha_j} \tag{1}$$

The demand for GM maize (grains) in the LTEM is disaggregated into feed and food demand. Equations 2 and 3 represent the feed and food demand for GM maize, respectively. The shifters shf_{qfg} and shf_{qcg} in equations 2 and 3 are used to reflect the impact of general feed and food demand shifters, respectively, such as consumers' preference change. The feed demand for GM maize (qfg_i) is specified as a function of own consumer price (pcg_i), consumer price of GM-free maize (pc_i), consumer prices of the other substitute GM feed products (pcg_i) and the supply amount of GM raw milk qsg_k ($_k$ is used to denote raw milk). While a negative sign is expected for the own-price elasticity (γ_1), a positive sign is expected for the coefficients of GM-free maize price (γ_2), other substitute prices (γ_j) and raw milk supply (γ_3; equation 2). The food demand for GM maize (qcg_i; equation 3) is specified as a function of own-consumer price (pcg_i), consumer price of the GM-free maize (pc_i), consumer prices of the other GM substitutes (pcg_j), per capita real income (pci) and population (pop). A negative own-price elasticity (β_1), a positive cross-price elasticity (β_2) and (β_j), and a positive coefficient on per capita income (β_3) and population (β_4) is expected. Similar functional forms and behavioural relationships are also used to reflect the feed and food demand response for GM-free maize (qf_i and qc_i), in which the consumer price for GM maize (pcg_i) also appears as a substitute product in consumption to GM-free maize.

Demand and supply equations in the LTEM model are assumed to have a constant elasticity functional form, and exogenous shocks to this model arising from GM technology are assumed to shift demand and supply by a constant percentage of price for all levels of production; in other words, pivotal shifts. Another widely used modelling approach, assumes that demand and supply curves are locally linear and shift in parallel (same change in price at all output levels) in response to exogenous shocks. Zhao *et al.* (1997) examined the errors in welfare measures associated with various combinations of assumptions about the nature of functional forms and exogenous shifts. Rose (1980) discussed the difficulties of anticipating the nature of supply shifts. We do not pursue this further in the present study except to note that GM technologies may have different effects on demand and supply.

The change in consumer preferences, for example against GM maize, is reflected through the use of the feed and food demand shifters (shf_{qfg} and shf_{qcg}). As in the case of supply, these shifters take the value 1 initially and are changed exogenously according to the direction and size of the change in consumer preferences by yielding pivotal up- or downward shifts in the demand curve. Through the changes in equilibrium quantity in the domestic market, the new consumer price for GM maize feeds back into the feed and food demand functions for GM-free maize.

$$qfg_i = \gamma_0 shf_{qfg} pcg_i^{\gamma_1} pc_i^{\gamma_2} qpg_k^{\gamma_3} \prod_{j=1}^{2} pcg_j^{\gamma_j} \tag{2}$$

$$qcg_i = \beta_0 shf_{qcg} pcg_i^{\beta_1} pc_i^{\beta_2} pci^{\beta_3} pop^{\beta_4} \prod_{j=1}^{2} pcg_j^{\beta_j} \tag{3}$$

Policy induced restrictions on market access for GM products in GM-critical regions, such as a possible ban on imports of GM products in the EU and Japan, are also simulated in the LTEM through the demand side shifter variables. A possible import ban in the EU and Japan against GM products is reflected as a large preference shift (80%) away from GM products, and therefore the value of the variables shf_{qfg} and shf_{qcg} in the feed and food demand equations changes from 1 to 0.20.

4. Empirical analysis

Given that there is no commercial release of GM products in New Zealand at present, it is impossible to currently assess the market performance of actual goods produced in New Zealand. Thus, it is assumed that GM technology is available for certain key commodities in New Zealand (i.e. milk, apples, kiwifruit and cereals) and various scenarios are constructed to assess the possible economic performance of these products. These scenarios, while attempting to reflect the predicted market impact of GM, given limited data, are largely experimental.

The scenarios relate to assumptions about production costs, consumer preferences and market access for GM/GM-free food that were then tested against various assumptions relating to the proportions of GM/GM-free food produced in the different countries in the model. These scenarios were developed to reflect current and potential developments (see section 2 and Campbell *et al.* 2000) and include the following:

1. No difference in preference for or against GM food
2. A 20% preference for GM-free food
3. A 20% preference for GM food
4. A large shift in preference in Japan and the EU away from GM food
5. A 10% reduction in producer costs of GM food.[6]

These five scenarios were then simulated against different assumptions regarding the proportion of GM/GM-free food produced in the countries modelled. These assumptions reflect current levels of GM/GM-free food production, predicted levels of GM/GM-free production estimated from various studies that have assessed the likely proportions of farmers who would convert to GM production (Campbell *et al.* 2000) and a 'high uptake of GM scenario'. These scenarios are applied to all products in the model and are outlined as follows:

1. GM/GM-free proportions similar to current proportions, based on estimates of the uptake of GM given in table 2
2. An increase in the predicted amount of GM food being produced to 75% in the USA and Canada, 20% in New Zealand and 26% in Australia

[6] Because research into production costs has shown little benefit from GM, most scenarios are consumer driven. However, recognising that GM may provide lower costs in the future, a scenario is included that assumes a lower cost of production, similar to the models referenced above.

3. GM/GM-free proportions as listed, but New Zealand producing zero GM food
4. A high uptake of GM food in New Zealand at 50% and a large shift in preferences away from GM food in Japan and the EU at 20%.

The results on overall producer returns in New Zealand are presented for the following commodity groups: maize, kiwifruit, apples and milk. Results relating to other cereals and oilseeds have not been presented in the present paper because the production of these crops is insignificant in New Zealand. The results for maize are presented in order to provide a comparison because maize is a common product included by other studies in the published literature. Finally, the impact of the various scenarios on total New Zealand producer returns across all commodity groups is analysed.

Figure 1 illustrates the impact on New Zealand producer returns by commodity across the different scenarios assuming the current proportions of GM/GM-free food in the countries in the model. Figure 1 illustrates that compared with the no-change scenario, which is current producer and consumer market conditions, a 20% preference shift for GM-free stimulates an increase in producer returns across all commodities, with a 15% increase in producer returns from milk, 20% from kiwifruit, 29% from apples and 23%

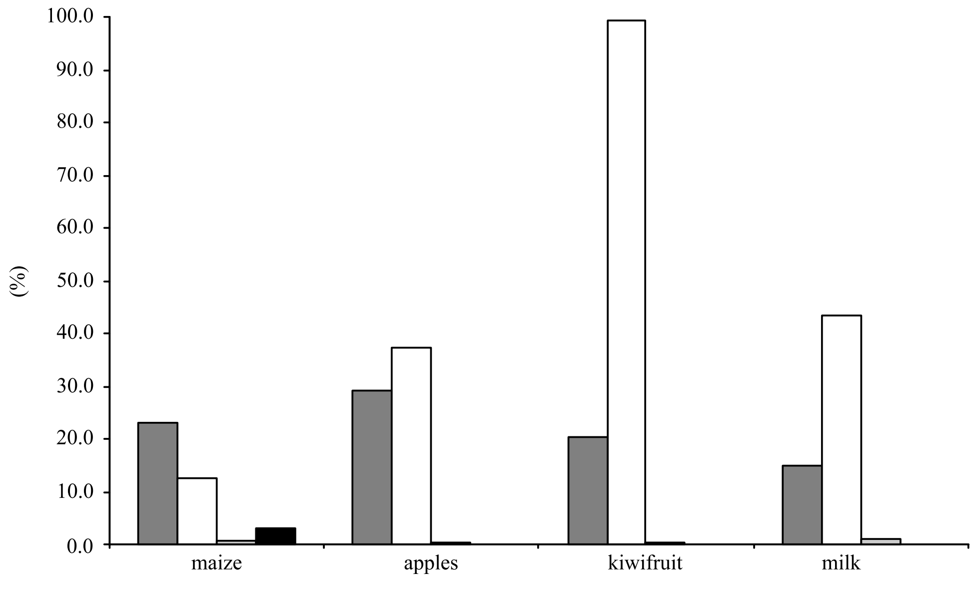

Figure 1 Producer returns by commodity assuming current proportions of genetically modified (GM)/GM-free production. (■), 20% preference shift towards GM-free; (□), Japan and European Union ban GM imports; (□), 10% fall in production costs of GM; (■), 20% preference shift towards GM.

from maize. A ban on access for GM food into the Japanese and European markets leads, in most commodities, to a greater increase in producer returns, with a 37% increase in returns from apples, 43% from milk, 12% from maize and almost double the returns from kiwifruit. A 10% reduction in costs of GM production and a 20% preference shift for GM have an insignificant impact on returns. These results are not surprising given the small proportions of GM products currently produced in New Zealand.

The direction of changes in New Zealand producer returns are similar, but lower values than the previous scenario, when the predicted proportions of GM/GM-free are assumed, as illustrated in figure 2. Assuming a 20% preference shift for GM-free food results in an increase in producer returns of 27% for apples, 18% for kiwifruit, 11% for milk and 26% for maize compared with the no change in consumer preference scenario. Again, the Japan and EU ban on GM food leads to the greatest increase in New Zealand producer returns, of 35% for apples, 41% for milk, 90% for kiwifruit and 13% for maize. Assuming a reduction in costs for GM products of 10%, given projected proportions of GM food, there is an increase in returns of 3% for apples, kiwifruit and, and 10% in the case of milk. However, assuming a 20% preference shift for GM products has a negligible impact on returns under this scenario.

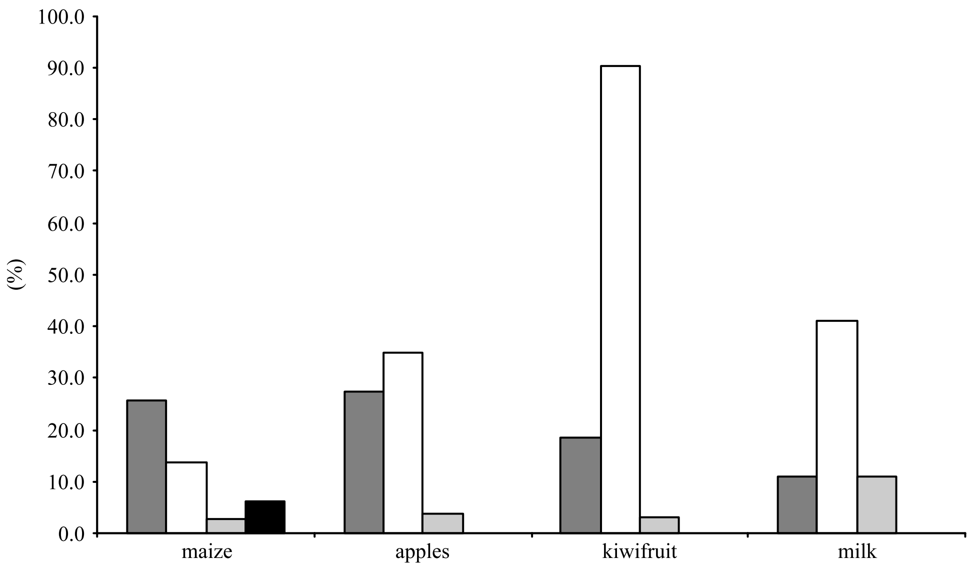

Figure 2 Producer returns by commodity assuming predicted proportions of genetically modified (GM)/GM-free production. (■), 20% preference shift towards GM-free; (□), Japan and European Union ban GM imports; (■), 10% fall in production costs of GM; (■), 20% preference shift towards GM.

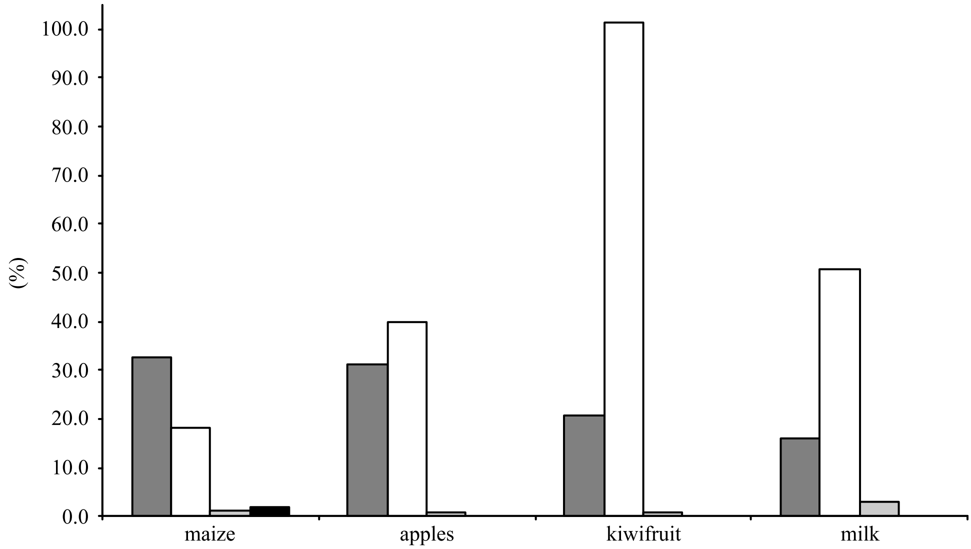

Figure 3 Producer returns by commodity assuming predicted proportions genetically modified (GM)/GM-free with New Zealand not producing GM products. (■), 20% preference shift towards GM-free; (□), Japan and European Union ban GM imports; (□), 10% fall in production costs of GM; (■), 20% preference shift towards GM.

Figure 3 shows the impact on New Zealand producer returns assuming other countries in the model have the same proportion of GM/GM-free as the above scenario, but New Zealand has no GM production. These results show that producer returns are greater than the previous scenario when a 20% preference shift is assumed for GM-free and when Japan and the EU are assumed to ban GM products. There is no significant change in producer returns between a 10% reduction in GM production costs or a 20% preference shift towards GM.

Figure 4 illustrates the impact on producer returns assuming New Zealand and other countries have relatively high proportions of GM production. Assuming a 20% preference shift for GM-free does lead to an increase in returns but, as expected, this increase is lower than the 20% preference shift, at 17% for apples, 14% for kiwifruit, 6% for milk and 3% for maize. Assuming a Japan and EU ban for GM products, New Zealand still experiences an increase in producer returns of 21% for apples, 68% for kiwifruit and 8% for milk, but a decrease of 2.5% in producer returns for maize. A 10% fall in production costs of GM leads to an increase in returns of under 10% for apples, kiwifruit and maize, but a rise of 22% for milk. A 20% preference for GM products only led to a 3–5% increase in producer returns for New Zealand in apples, kiwifruit and milk, but approximately 9% in maize.

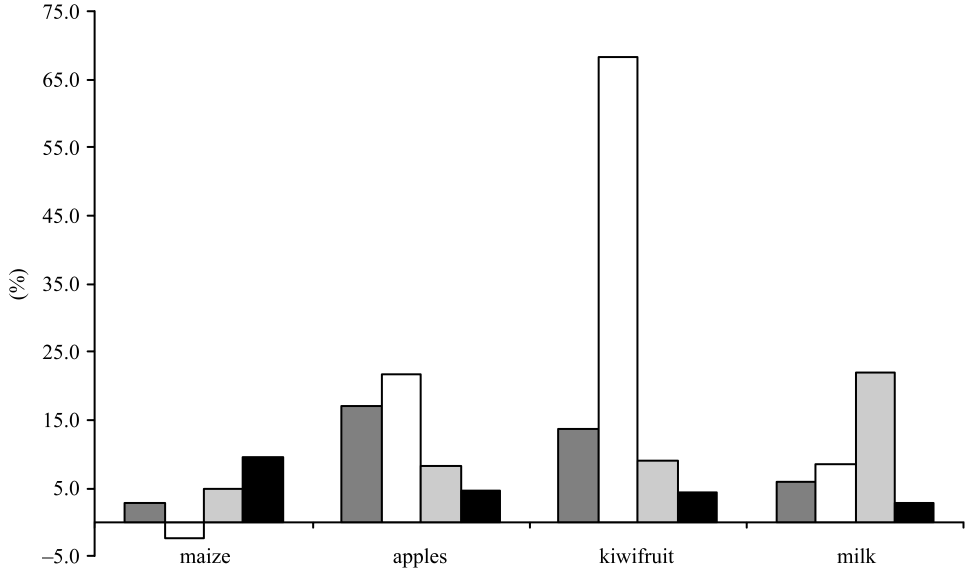

Figure 4 Producer returns assuming high proportions of genetically modified uptake. (■), 20% preference shift towards GM-free; (□), Japan and European Union ban GM imports; (■), 10% fall in production costs of GM; (■), 20% preference shift towards GM.

To assess the impact on total returns to New Zealand producers from the commodities modelled, the producer returns under each scenario were summed by commodity and results are presented in figure 5. Each cluster of bars represents a different scenario regarding consumer preferences or market access for GM/GM-free food. The direction of these results is consistent with expectations. The impact of a 20% preference towards GM-free products increases returns to New Zealand producers, especially when New Zealand is GM-free. The large shift in preferences away from GM products in Japan and the EU has the greatest effect on New Zealand. Perhaps the most unexpected result is when there is a 20% consumer preference shift for GM products: the effect on New Zealand returns is insignificant.

5. Conclusion

The commercial release of GM food is controversial. Current evidence of the impact of available GM technology on producer costs is mixed. However, there seems to be a definite shift away from GM food by consumers. There is trade diversion away from countries producing GM food to those that do not, illustrated by a rise in GM-free imports into Japan from the EU and Australia and a fall of imports from the USA. In addition, many

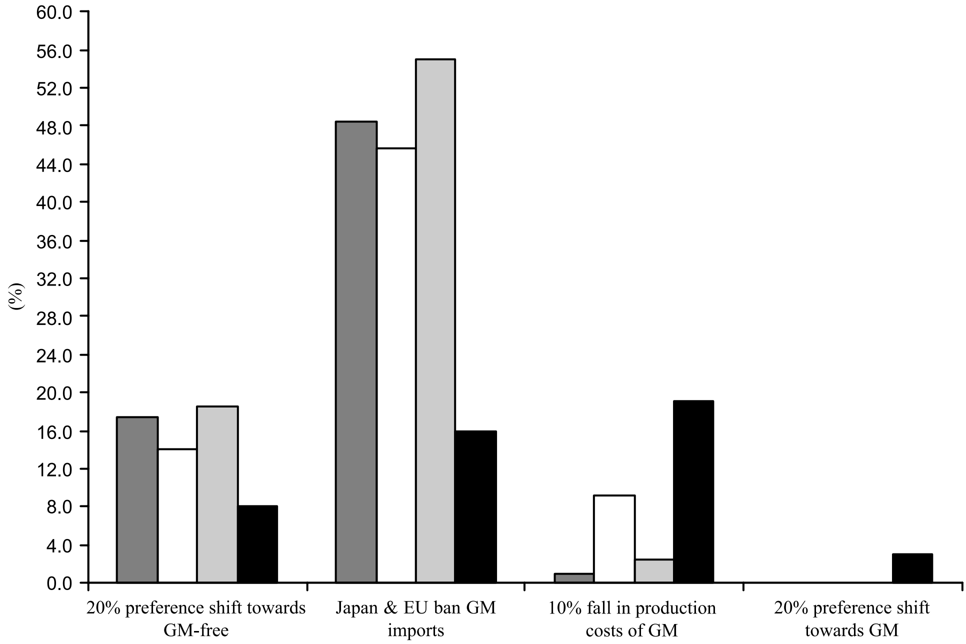

Figure 5 Total producer returns for commodities modelled in New Zealand. (■), 20% preference shift towards GM-free; (□), Japan and European Union ban GM imports; (□), 10% fall in production costs of GM; (■), 20% preference shift towards GM.

of the main markets for New Zealand products are stating that GM food, or even animal products produced using GM-feed, are not acceptable.

The results of these scenarios are consistent with theory and expectations. It is not surprising that markets such as Japan and the EU have such an influence on world and New Zealand trade; moreover, it is also to be expected that reductions in costs do not flow through to the same increase in producer returns. Of greater interest is the relatively small impact (simulated) increased preferences for GM have on returns. However, this may reflect the fact that, in each scenario, New Zealand still produced relatively lower proportions of GM than some other countries.

The results of the scenarios run through the LTEM on New Zealand producer returns seem to indicate that, given current technology and predictions about consumer preferences, New Zealand has higher returns with low or zero GM food production. Clearly, these results are dependant on the assumptions behind these scenarios. Different technologies could change the results as second-generation GM products become available.

New Zealand has a unique position in being an island nation that does not have the potential for cross-pollination from GM crops and, therefore, can maintain a GM-free status, unlike many other continental countries. Even countries like the UK have problems with the cross-pollination of canola and other crops. Thus, New Zealand is uniquely placed to take advantage of any consumer preference shifting towards GM-free food.

References

Anderson, K. and Yao, S. 2001, *China, GMOs, and World Trade in Agricultural and Textile Products*, Discussion Paper No. 0126, Centre for International Economic Research, Adelaide.

Anonymous 2002, 'More elevators are requiring GMO segregation', *Countryside and Small Stock Journal*, vol. 86, p. 82.

Barkley, A.P. 2002, 'The economic impacts of agricultural biotechnology on international trade, consumers, and producers: The case of corn and soybeans in the USA', paper presented at the 6th International Consortium on Agricultural Biotechnology Conference, Ravello, Italy, 11–14 July.

Burton, M., Rigby, D., Young, T. and James, S. 2001, 'Consumer attitudes to genetically modified organisms in food in the UK', *European Review of Agricultural Economics*, vol. 28, pp. 479–498.

Cagatay, S. and Saunders, C.M. 2003, 'Lincoln trade and environment model: an agricultural multi-country multi-commodity partial equilibrium framework', research report Agribusiness and Economics Research Unit, Lincoln University, Canterbury, NZ.

Campbell, H., Fitzgerald, R. and Saunders, C. 2000, *Strategic Issues for GMOs in Primary Production*, Centre for the Study of Agriculture, Food and Environment Discussion Paper no. 1, Otago University, Dunedin.

Chapple, I. 2001, 'Stores strike early with GM ban', *The New Zealand Herald*, 21 November.

CEC (Commission of the European Communities) 2000, *Economic Impacts of Genetically Modified Crops on the Agri-Food Sector: A First Review*, Commission of the European Communities. [Online]. Available: http://www.europa.eu.int/comm/dg06/publi/gmo/full_en.pdf

Duffy, M. 1999, 'Does planting GMO seed boost farmers' profit?', Leopold Centre for Sustainable Agriculture, Iowa State University. [Online]. Available: http://www.leopold.iastate.edu/99-3gmoduffy.html

European Commission 2001, *Commission Improves Rules on Labelling and Tracing of GMOs in Europe to Enable Freedom of Choice and Ensure Environmental Safety*, Press release, available on-line: http://europa.eu.int/comm/dgs/health_consumer/library/press/press172_en.pdf

Fair, R.C. 1984, *Specification, Estimation and Analysis of Macroeconometric Models*. Harvard University Press, Cambridge, MA.

Fernandez-Cornejo, J. and McBride, W.D. 2000, *Genetically Engineered Crops for Pest Management in US Agriculture: Farm Level Effects*, Report No. 786. Resource Economics Division, USDA, Washington.

Francois, J.F. and Hall, H.K. 1997, 'Partial equilibrium modeling', in J.F. Francois and K.A. Reinert (eds), *Applied Methods for Trade Policy Analysis: A Handbook*, Cambridge University Press, Cambridge.

Furman Seltz, L.L.C. 1998, 'The agbiotech and seed industry', Investment report, Furman Seltz, New York.

Fulton, M. and Keyowski, L. 1999, 'The producer benefits of herbicide-resistant canola', *Ag Bio Forum*, vol. 2, pp. 85–93.

Gaisford, J.D. and Kerr, W.A. 2000, *Economic Analysis for International Trade Negotiations: The WTO and Agricultural Trade*, Edward Elgar, Cheltenham.

Gianessi, L. and Carpenter, J. 1999, *Agricultural Biotechnology: Insect Control Benefits*. National Center for Food and Agricultural Policy, Washington D.C.

Jackson, L.A. 2002, *Is Regulatory Harmonization Efficient? The Case of Agricultural Biotechnology Labelling*, Discussion Paper No. 206, Centre for International Economic Research, Adelaide.

James, S. and Burton, M. 2001, 'Consumer attitudes to GM foods: Some preliminary results from Western Australia', in R. Fraser and J. Taylor (eds), *Research Profile: Agricultural and Resource Economics at the University of Western Australia in 2001*, University of Western Australia, Perth.

Kehoe, T.J. 1991, 'Computation and multiplicity of equilibria', in W. Hildenbrand and H. Sonnensschein (eds), *Handbook of Mathematical Economics*, Vol. IV, North-Holland, Amsterdam.

Lin, W., Price, G.K. and Allen, E. 2001, 'StarLink: Where no Cry9C corn should have gone before', *Choices*, second quarter, pp. 31–34.

Moschini, G., Lapan, H. and Sobolevsky, A. 2000, 'Roundup ready soybeans and welfare effects in the soybean complex', *Agribusiness*, vol. 16, pp. 33–55.

Nielsen, C.P. and Anderson, K. 2000a, *Global Market Effects of Adopting Transgenic Rice and Cotton*, Centre for International Economic Research, Adelaide.

Nielsen, C.P. and Anderson, K. 2000b, *Global Market Effects of Alternative European Responses to GMOs*, Centre for International Economic Research, Adelaide.

Nielsen, C.P., Robinson, S. and Thierfelder, K. 2000, 'Genetic engineering and trade: Panacea or dilemma for developing countries', paper presented at Third Annual Conference on Global Economic Analysis, Melbourne, 27–30 June.

Phillips, P.W.B. and McNeill, H. 2000, 'A Survey of national labeling policies for GM foods', *Agbioforum*, vol. 3, pp. 219–224.

Roningen, V.O. 1986, *A Static Policy Simulation Modeling (SWOPSIM) Framework*, Staff Report AGES 860625, Economic Research Service, Washington.

Roningen, V.O. 1997, 'Multi-market, multi-region partial equilibrium modeling', in J.F. Francois and K.A. Reinert (eds), *Applied Methods for Trade Policy Analysis: A Handbook*, Cambridge University Press, Cambridge.

Roningen, V.O., Dixit, P., Sullivan, J. and Hart, T. 1991, *Overview of the Static World Policy Simulation (SWOPSIM) Modelling Framework*, Staff Report AGES 9114, Economic Research Service, Washington.

Rose, R. 1980, 'Supply shifts and research benefits: Comment', *American Journal of Agricultural Economics*, vol. 62, pp. 834–844.

Royal Commission on Genetic Modification 2001, 'Report of the Royal Commission on Genetic Modification', [Online]. Available: http://www.gmcommision.govt.nz/RCGM/index/html

Saunders, C. and Cagatay, S. 2001, 'Economic analysis of issues surrounding commercial release of GM food products in New Zealand', Commerce Division discussion papers, no. 94, Lincoln University, Canterbury, NZ.

United States Department of Agriculture (USDA) 2002, *Genetically Modified Foods/Novel Foods*, USDA, [Online]. Available: http://www.useu.be/agri/GMOs.html

van Beers, C. and van den Bergh J.C.J.M. 1996, 'An overview of methodological approaches in the analysis of trade and environment', *Journal of World Trade*, vol. 30, pp. 143–167.

Wooldridge, J.M. 2002, *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, MA.

Zhao, X., Mullen, J.D. and Griffith, G.R. 1997, 'Functional forms and economic surplus changes', *American Journal of Agricultural Economics*, vol. 79, pp. 1243–1251.

Appendix

General features of the Lincoln Trade and Environment Model

In the main Lincoln Trade and Environment Model (LTEM) framework, 19 agricultural commodities (seven crop and 12 livestock products) and 17 countries are included, which are modified and aggregated here into 14 agricultural commodities (eight crop and six livestock products) and nine countries, for the purposes of the present study. The commodities included in the model are treated as homogeneous with respect to country of origin and destination. Therefore, commodities are perfect substitutes in consumption in international markets, and importers and exporters are assumed to be indifferent about their trade partners. Based on these data, the model is built as a non-spatial type that emphasises the net trade of commodities in each region. However, the supply and demand shares of countries in trade can be traced down.

The LTEM is a synthetic model because the parameters are adopted from the published literature. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities. The policy parameters and/or variables are listed in Appendix table A2. The economic welfare implications of policy changes are also calculated in the LTEM using the producer and consumer surplus measures. The model is used to derive the medium- to long-term (until 2010) policy impact in a comparative static fashion, basing the beginning date to 1997. The model also provides short-run solutions because it applies a sequential simulation procedure year by year in which the stock change is used to link 2 consecutive years.

In general there are six behavioural equations and one economic identity for each commodity under each country in the LTEM framework. Therefore, there are seven endogenous variables in the structural form of the equation set for a commodity under each country.[7] There are four exogenously determined variables,[8] but the number of exogenous variables in the structural form equation set for a commodity vary based on the cross-price, cross-commodity relationships. The behavioural equations are domestic supply, demand, stocks, domestic producer and consumer price functions and the trade price equation. The economic identity is the net trade equation, which is equal to excess supply or demand in the domestic economy. For some products, the number of behavioural equations may change as the total demand is disaggregated into food, feed and processing industry demand, and these are determined endogenously.

[7] There are 126 equations for each country and, in total, there are 2142 equations.

[8] The list of non-agricultural exogenous variables is given in Appendix table A2.

Table A1 Country and commodity* coverage

Countries	Commodities	
Argentina	Wheat	Raw milk
Australia	Coarse grains	Liquid milk
Canada	Maize	Butter
European Union (15)	Oilseeds	Cheese
Japan	Oilseed meals	Whole milk powder
Mexico	Oils	Skim milk powder
New Zealand	Apples	
United States of America	Kiwifruit	
Rest of World		

*Each commodity is included as genetically modified (GM) and GM-free components.

Table A2 Policy variables/parameters and non-agricultural exogenous variables in the main Lincoln Trade and Environment Model framework

Policy Variables Domestic market	Border	Non-agricultural exogenous variables
Land set aside	Import tariff	Gross domestic product
Production quota	Export subsidy	Country price index
Support/minimum price	Trade quota	Population
Producer market subsidy	In-quota tariff	Exchange rate
Producer input subsidies	Out-quota tariff	
Producer direct payments		
Producer general services		
Consumer market subsidy		

Basically, the model works by simulating the commodity based world market clearing price on the domestic quantities and prices, which may or may not be under the effect of policy changes, in each country. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market using a non-linear optimisation algorithm (Newton's global or search algorithm[9]).

For the purposes of the present study, various components of the LTEM framework were modified. The regional and commodity coverage was specified as nine countries (including rest of the world) and 14 agricultural products (see table A1). Each commodity is segregated into GM and GM-free components and each is dealt with as a different product, effectively meaning 28 different products are modelled. The present study focuses mainly on four sectors (maize, kiwifruit, apples and raw milk) and the main emphasis

[9] See Fair (1984) p. 29, Kehoe (1991) p. 2058 and Wooldridge (2002) for more explanation on Newton's global algorithm.

Table A3 Supply side parameters: own- and cross-price elasticities

Commodity/ country	Producer price GM-free maize	GM-free wheat	GM-free coarse grains	GM-free oil seeds	GM maize
GM-free maize					
Australia	0.86	–0.18	–0.14	–0.01	
EU (15)	0.68	–0.10	–0.20	–0.05	
Japan	0.45				
New Zealand	0.90	–0.14	–0.33		
USA	0.60	–0.04	–0.02	–0.05	–0.04

Commodity/ country	Producer price GM maize	GM wheat	GM coarse grains	GM oil seeds	GM-free maize
GM maize					
Australia	1.03	–0.22	–0.16	–0.01	–0.09
EU (15)	0.85	–0.13	–0.25	–0.06	–0.09
Japan	0.54				–0.05
New Zealand	1.08	–0.17	–0.39		–0.09
USA	0.60	–0.01		–0.06	–0.10

Commodity/ country	Consumer price GM-free maize	GM-free wheat	GM-free coarse grains	GM-free oil seeds	GM-free oil meals	Producer price GM-free raw milk
GM-free raw milk						
Australia	–0.02	–0.09	–0.10		–0.02	0.50
EU (15)	–0.10	–0.11	–0.10		–0.10	0.51
Japan	–0.12		–0.20	–0.01	–0.08	0.61
New Zealand	–0.13	–0.04	–0.04	–0.01	–0.09	0.87
USA	–0.10	–0.02	–0.10	–0.01	–0.04	0.40

Commodity/ country	Consumer price GM maize	GM wheat	GM coarse grains	GM oil seeds	GM oil meals	GM raw milk	Producer price GM-free raw milk
GM raw milk							
Australia	–0.03	–0.12	–0.14		–0.03	0.68	–0.09
EU (15)	–0.19	–0.21	–0.19		–0.19	0.97	–0.10
Japan	–0.17		–0.29	–0.01	–0.12	0.88	–0.09
New Zealand	–0.19	–0.06	–0.58	–0.01	–0.13	1.26	–0.09
USA	–0.17	–0.03	–0.17	–0.02	–0.07	0.68	–0.09

Commodity/ country	Producer price GM-free apples	Commodity/ country	GM apples	Producer price GM-free apples
GM-free apples		GM Apples		
Australia	0.30	Australia	0.36	–0.09
EU (15)	0.40	EU (15)	0.50	–0.10
Japan	0.40	Japan	0.48	–0.09
New Zealand	0.40	New Zealand	0.48	–0.09
USA	0.40	US	0.48	–0.09

Table A3 *Continued*

Commodity/ country	Producer price GM-free Kiwifruit	Commodity/ country	GM Kiwifruit	Producer price GM-free kiwifruit
GM-free kiwifruit		GM kiwifruit		
Australia	0.30	Australia	0.36	–0.08
EU (15)	0.40	EU (15)	0.50	–0.10
Japan	0.40	Japan	0.48	–0.09
New Zealand	0.50	New Zealand	0.60	–0.09
USA	0.40	US	0.48	–0.09

GM, genetically modified; EU, European Union.

regarding the impact of policy/non-policy induced shocks is on New Zealand. The behavioural equations and parameters related to these commodities and quantification of domestic agricultural and trade policies are described in more detail in Cagatay and Saunders (2003).

In Appendix table A3, supply side own- and cross-price elasticities for GM and GM-free components of maize, raw milk, apples and kiwifruit are given for the main markets in the LTEM. In general, it can be noticed that the own-price elasticity of the GM components of the products are higher than the own-price elasticity of the GM-free components. Therefore, own-prices of the GM components are more influential on the variation in the GM supply compared with the effect of the own-prices of the GM-free components on their supply level. In the maize market, price response of supply is higher in Australia and New Zealand in both components compared with the EU and USA. Raw milk supply is more sensitive to its own price in New Zealand and the EU compared with the rest of the markets. In both fruit markets, the elasticities are quite close to each other.