**Economic Impacts on New Zealand of GM Crops:
Result from Partial Equilibrium Modelling**

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Abstract

This paper reports findings from economic modelling of the impacts on New Zealand agricultural producer returns from the commercial use of genetically modified (GM) food crops. Several possibilities are considered in the modelling, including different rates of GM crop adoption, positive and negative consumer responses, increases in productivity, first- and second-generation GM crops, and control of the intellectual property.

The results are consistent with theory, other studies and expectations. Thus, it is not surprising that New Zealand producers increase their revenue the most when they concentrate on products that have a premium in the market because consumers prefer them. If consumers prefer non-GM products, New Zealand producers gain by focusing on those crops. If consumers prefer second-generation GM products, producers increase their returns by growing those crops. Secondly, it is also consistent with theory, experience and expectations that an increase in productivity does not necessarily lead to increased returns. This is dependent upon whether NZ has sole access to the technology or whether it is or becomes available overseas. Thus, even where a product has a consumer preference, producer returns can fall when productivity increases. Thirdly, controlling access to preferred products or to productive technology has beneficial effects for New Zealand commodity producers.

Chapter 1
Introduction

This paper reports findings from economic modelling of the impacts on New Zealand agricultural producers' gross income from the commercial use of genetically modified (GM) food crops both in NZ and in key overseas markets. Several possibilities are considered in the modelling, including different rates of GM crop adoption, positive and negative consumer responses, increases in productivity, first- and second-generation GM crops, and control of the intellectual property again both within NZ and overseas.

In order to inform the economic modelling, a large amount of literature on GM food crops was reviewed. This paper begins by discussing existing studies that have evaluated the impacts of GM food crops on farm production, then turns to a discussion of consumer reactions to GM food. The subsequent section reviews research on the impacts of GM crops on international trade.

The paper then turns to the economic modelling. The Lincoln Trade and Environment Model (LTEM), a model of international trade, is presented. Next, the specific scenarios to be modelled and compared are described. Finally, results of modelling producer and consumer impacts of GM food crops with the LTEM are presented, with a discussion of overall conclusions from the findings.

Chapter 2
Impact of GM Food Crops on Producers and Consumers

2.1   Producer Impacts of GM Crops

The current commercial release of first generation GM food affects the production system. The main commercially released GM food crops are herbicide-tolerant (Ht) soybeans and insect-resistant maize, with insect-resistant canola of somewhat less importance (ISAAA, 2003; James, 2000 and 2001). Thus, nearly all of the current benefits of GM come from the supply side and relate to potential increases in yield and/or reductions in costs. (Caswell, et al., 1998; OECD, 2000; USDA, 2000 and 2002).

Various studies show that the impact of GM production on yield varies according to the crop type. For herbicide-tolerant (Ht) soybeans, university varietal trials (Benbrook, July 1999), USDA field-level data (Fernandez-Cornejo & Klotz-Ingram, 1998, in USDA, 2000), and farmer surveys (Marra, et al., 2002) indicate lower yields. Research using later data largely confirms these earlier findings (Duffy, 2001), although the USDA (2002) calculates small increases in yields. Ht corn and canola also show evidence of lower yields (CEC, 2000). By contrast, maize genetically modified to express an insect toxin from the bacterium *Bt* generally shows yield improvement (Marra, et al., 1998, in USDA, 2000; Duffy, 2001; CEC, 2000). Finally, the use of rbST, recombinant bovine somatotropin, has increased actual dairy herd productivity, although by less than projected increases (Stefanides & Tauer, 1999; Caswell, et al., 1998)

Several inputs are affected by the adoption of GM crops, including pesticide use, seed costs, and labour and management effort. For pesticides, changes are crop specific. Herbicide-tolerant crops, for example, are generally associated with higher use of glyphosate herbicide (Roundup), but lower use of other herbicides (USDA; 2000; Shoemaker, et al., 2001; Duffy; 2001; CEC. 2000). Whether there is an overall decrease in herbicide use is uncertain, and also depends on how use is measured (USDA, 2002; CEC, 2000; Benbrook, 2001a; Marra, et al., 2002). A different pesticide issue is the effect of *Bt* corn on the use of insecticides, particularly against the European corn borer. Some research suggests that *Bt* corn has led to savings in insecticide costs (Marra, et al., 1998, in USDA, 2000). Other research has found little is any changes in insecticide use in corn (Benbrook, 2001a), and suggests that *Bt* corn is valuable not for savings in insecticide costs, but for protecting farmers' yields (Duffy, 1999 and Furman Selz, 1998, both in CEC, 2000)

Seed costs are higher for GM crops because they require a technology fee. This is largely either found or assumed to be constant across the U.S. (Falck-Zepeda, et al., 2000; Gianessi, et al., 2002; Marra, et al, 2002; Marra, et al., 1998, in Shoemaker, et al., 2001; Gianessi & Carpenter, 2001, in Benbrook, 2001b; Duffy, 2001; CEC, 2000), and to run about $8-$10 per acre for *Bt* corn, for example. However, research by Benbrook (2001b) indicates that the technology fee varies regionally and by corn variety, from a few dollars an acre to as much as US$30 per acre.

Management and labour effort are considered lower for Ht crops, because they make the job of weed management easier. Farmers can use fewer pesticides and have a wider window for their use than with other weed management programmes (USDA, 2002; CEC, 2000; Gianessi, et al., 2002; Benbrook, 2001a; Duffy, 2001). Several studies note this benefit of Ht varieties, but do not try to calculate a value for it. Econometric analysis such as done by the USDA (2000 and 2002) does attempt to control for factors that would be affected by ease of

management, such as farm size, other management practices such as rotation and tillage, off-farm employment, and the like. The CEC (2000) reports on research done on GM canola and considers that ease-of-use has been included in the analysis in labour and fuel savings for the GM canola.

The bottom line is the impact of yield and costs changes on net returns. A review of profitability estimates shows that findings are mixed. Ht soybeans have been found to decrease net returns, (Duffy et al. 1999, in CEC 2000), increase net returns (Marra, et al., 1998, in Shoemaker, et al., 2001), or have no effect (Fernandez-Cornejo, et al., 1999, in Shoemaker, et al., 2001; Duffy, 2001; USDA, 2002). It is more difficult to assess the impact on gross margins for *Bt* corn given that it is highly dependent on the level of insect infestation. Again, there are reports of net gains from *Bt* corn (Furman Seltz, 1998, in CEC, 2000; Marra, et al., 1998, in Shoemaker, et al., 2001), net losses (USDA, 2002), and no effect (Duffy, 2001). Net results have also been shown to vary by year, with gains in 1997 and losses in 1998 (Gianessi & Carpenter, in CEC, 2000; Benbrook, 2001b). For Ht corn, the USDA (2002) found improved net farm returns for specialised corn farms. In the case of Ht canola, results are mixed with Fulton & 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 a higher returns on another (CEC 2000). Marra, et al. (2002) reported findings of increased profitability from Roundup-Ready canola. Finally, research on the use of rbST has found that profits did not increase (OECD, 2000; Stefanides & Tauer, 1999; Foltz & Chang, 2002).

One important issue with these estimates of profitability is that the effect of differential prices for GM and non-GM crops is generally not factored into the analyses (e.g., Gianessi, et al., 2002; Duffy, 2001). Much of the research relies on figures from 1997 and 1998 (USDA, 2000 and 2002; Shoemaker, et al., 2001; CEC, 2000; Marra, et al., 2002), and price differentials did not appear until 1999 (CEC, 2000). In that year, premiums of 2% to 6% were reported for non-GM soybeans and maize/corn (Golan, et al., 2000). The assumption of equal prices for both crops may be an accurate portrayal of commodities with supported prices (CEC, 2000; Duffy, 2001), but may not apply to other crops. Thus, these assessments of farm-level profitability do not take into account possible negative consumer reactions to GM food.

2.2   Consumer Impacts of GM Food

Consumer responses to GM food are important and have not always been positive. As the first wave of commercially released GM crops has only affected production inputs and not enhanced products in ways valuable to consumers, this reaction may not be surprising (CEC, 2000). Moreover, to evaluate GM food ordinary citizens use knowledge of everyday human fallibility and of past behaviour of institutions responsible for the development and regulation of technological innovations and risks (Marris, et al., 2001). These reactions have led to various regulatory and labelling frameworks for GM food, as well as clear positioning by European retailers as providing non-GM food (ANZFA, 2001; CEC, 2000; Phillips & McNeill, 2000).

Studies of consumer attitudes towards GM have been considerable and show that these attitudes vary regionally with, for example, GM being more acceptable in North America than Europe. Studies also conclude that information provision is important in increasing the acceptability of GM, as is the source of that information. However, transgenics and the manipulation of genes in humans and animals have lower acceptability than gene manipulation in plants (Campbell, et al., 2000).

Economic estimates of willingness to pay for non-GM food bear out the results of more general opinion surveys. Contingent valuation surveys have shown that consumers are willing to pay a premium to avoid GM food. Moon & Balasubramanian (2001) found, for example, that U.S. consumers were willing to pay 37% more and U.K. consumers 56% more to avoid GM foods. Choice modelling has found similar results, with sometimes large price differentials between GM and non-GM food that varied by gender and other factors (James & Burton, 2001; Burton & Pearse, 2002; Burton et al. 2001). Thus, James & Burton (2001) found that GM food would have to sell at an average discount of 20% to 47% in Western Australia. Burton, et al. (2001) reported that the group of U.K. respondents most favourably disposed towards GM food would nevertheless be willing to pay a 26% premium to have non-GM products, and other groups were willing to pay much more. Additional evidence of non-GM price premiums comes from auction experiments, which have assessed the willingness to pay for non-GM food, the reaction to different levels of adventitious presence (i.e., co-mingling), and the effects of information provision (Tegene, et al., 2003; Huffman et al. 2001; Rousu et al. 2002). Tegene, et al. (2003), for example, found that U.S. Midwestern consumers discounted 'GM'-labelled products by 14 percent, and reported that their results suggest that mandatory labelling (such as exists in Australia, New Zealand, the European Union, Japan, and South Korea, but not the U.S.) likely reduces demand for GM food products.

Price premiums for non-GM products in international markets began to appear in 1999 (CEC, 2000) with two-tiered pricing structures developing in some markets, such as Japan, Korea, and Europe. The introduction of labelling laws has also encouraged market to source non-GM food, as with the ANZFA laws in Australia and New Zealand (Robertson, 2002). The Tokyo Grain Exchange instituted futures trading in non-GM soybeans in 2000, and these contracts generally trade at a US$0.30 per bushel premium over generic soybean contracts (Parcell, 2002 and 2001).

The results of the market changes outlined above are that any potential benefits from planting the current commercially released GM crops are further reduced when differential prices are included in the analysis. Even a ten-percent premium for Non-GM products reduces further the incentives to produce GM food. Moreover, if substantial markets begin to ban the use of GM, the negative impacts would be much larger. Of course, it is uncertain how these preferences will develop into the future and whether consumer acceptance will change.

Chapter 3
Trade Impacts of GM Production

3.1   The Literature

The trade impact of introducing GM has been estimated by several studies. Moschini, et al. (2000) attempt to quantify the effects on production, price and welfare of adoption of roundup ready (RR) soybeans. This study uses a three-region, US, South America and the Rest of the World (ROW), bilateral partial equilibrium trade model and they focus only on soybean and soybean products (meal and oil). To model the innovation at the production level, Moschini, et al. (2000) first quantify the per hectare cost, profit and yield effects of RR soybean seed adoption. They then calculate the price effects of quantity changes in the innovator country. The effect of trade polices in their model are assumed to be captured by price differentials between the regions. Finally, Moschini, et al. (2000) quantify the consumer and producer surplus measures of welfare effects of RR adoption in the innovator country and in the other regions. They also provide the welfare effects under the assumption of international technology spill-over from innovator country to other regions. They find that U.S. farmers are better off in the base scenario. However, they are worse off if the technology increases their yields, and they do not gain nearly as much if other countries also adopt the technology.

Nielsen, et al. (2000) analyse the impact of consumers' changing attitude toward genetically modified organisms (GMOs) on world trade patterns, with emphasis on the developing countries. They use a multi-regional computable general equilibrium (CGE) framework that models the bilateral trade among 7 regions that are High-Income Austral-Asia, Low-Income Asia, North America, South America, Western Europe, Sub-Saharan Africa and the ROW. Production is aggregated into 10 sectors in each region including 5 primary agricultural products (cereal grains, oilseeds, wheat, other crops, and livestock), 3 food processing industries and a manufacturing and services industry at aggregate level. The goods are assumed to be imperfect substitutes in the international market. Regional production is achieved by using 5 factors of production: skilled and unskilled labour, capital, land and natural resources.

Nielsen, et al. (2000) allow the GM and non-GM production of maize and soybeans sectors in their model. Initially, they assume an identical production structure in terms of the composition of intermediate input and factor use in the GM and non-GM varieties and also the same structure of exports in terms of destinations for both varieties. The producers and consumers' decision to use GM versus non-GM varieties in their production and final demand respectively is endogenised for maize and soybeans sector. For the other crops, intermediate demand is held fixed as proportions of output and final consumption of each composite good is also fixed as a share of total demand.

The policy scenarios are based on the assumption that the GM-adopting sectors do make a more productive use of the primary factors of production as compared with the non-GM sectors. Therefore, they introduce a 10 % higher level of factor productivity in GM-adopting maize and soybean sectors in all regions as compared with their non-GM counterparts. The factor productivity shocks are introduced in alternative scenarios which differ in terms of the degree to which consumers and producers in high-income regions find GM and non-GM products substitutable. Starting from the perfect substitution case they lower the degree of substitution among GM and non-GM maize and soybeans in production and consumption as the citizens of high-income, Western Europe and High-Income Austral-Asia, regions become

more sceptical of the new GM varieties. In the other regions, the citizens are assumed to be indifferent, and hence the two crops remain highly substitutable in those production systems.

Nielsen, et al. (2000) include NZ implicitly in High Income Asia group. The main findings of their study, related to GM-critical High Income countries, can be summarized as follows. They find out that trade diversion becomes significant when the GM-critical regions change their preferences towards Non-GM products. The trade of GM-varieties is found to divert towards GM-indifferent markets and Non-GM varieties divert towards GM-critical regions. This is explained as a result of the price differential between GM and Non-GM varieties, which is a consequence of factor productivity differences in the production of these varieties. However, the degree of the price differential and its impact on the supply show differences between the GM-critical and GM-favourable regions. In particular, in GM-favourable regions the prices of the Non-GM varieties declines as well as the price of GM-varieties, due to the high degree of substitution between the two varieties in consumption and to the increased production to supply to GM-critical regions. In the GM-critical regions on the other hand, the price differential impact on the supply of Non-GM goods is minor. Moreover, as there is not perfect substitutability between GM and Non-GM products in these regions, there is still possibility for both varieties to access the GM-critical markets.

In a similar work that focuses on production of GM maize and soybean crops, Anderson & Nielsen (2000a) uses a CGE model, GTAP (Global Trade Analysis Project), to quantify the effects on production, prices, trade patterns and welfare of certain countries adopting GM maize and soybean crops[1]. They analyse the policy impacts in various scenarios with and without considering the trade policy and/or consumer reactions to GMOs. GTAP is a static CGE model that provides the bilateral trade relations among countries by using the Armington (1969) approach to differentiate the products. Anderson & Nielsen focus on 17 industries of which agricultural production is disaggregated into coarse grains, oilseeds, livestock, meat and dairy products, vegetable oils and fats, and other foods. The world is aggregated into 16 regions in which North America, Southern Cone, China, India, Western Europe, Sub-Saharan Africa, Other High-Incomes and Other Developing and Transition Economies are specified explicitly.

The policy scenarios are based on the assumption that the GM-adopting sectors experience a one-off increase in total factor productivity (including all primary factors and intermediate inputs) of 5%, thus lowering the supply price of the GM crop to that extent. Anderson & Nielsen first analyse the impacts GM-driven productivity growth of 5% in the related countries when others such as Western Europe, Japan, Other Sub-Saharan Africa are assumed to refrain from using or be unable to adopt GM crops in their production systems. In another scenario, the case of a policy and/or consumer response in Western Europe is introduced by banning the imports of maize and soybean products from GM-adopting regions. This scenario is based on the implicit assumption that labelling enables Western European importers to identify such shipments. The distinction between GM-inclusive and Non-GM products is based directly on the country of origin, and labelling costs are ignored. In a subsequent scenario, consumers in Western Europe are assumed to shift their preferences away from imported coarse grain and oilseeds and in favour of domestically produced crops. This scenario involves an exogenous 25% reduction in final consumer and intermediate demand for all imported maize and soybeans. Incomplete information about the imported products in terms of whether they are Non-GM or not is the implicit assumption behind this scenario.

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[1] Nielsen & Anderson (2000) also tries to quantify the effects on production, prices, trade patterns and national economic welfare of certain countries adopting GM cotton and rice in another study by employing the same approach used in Anderson & Nielsen (2000a).

Anderson & Nielsen (2000a) include NZ implicitly in Other High Income countries. They analyse the impact of policy scenarios on Other High Income economies by showing the change in economic welfare. In the case of GM adoption by other regions (except Western Europe), their findings show that the increase in economic welfare (equivalent variation) of Other High Income group is higher when Western Europe bans the GM imports, compared to 'no policy response' case. The same result also applies when consumer preferences in Western Europe shift towards non-GM varieties and away from GM products. The same results are reported in Anderson & Nielsen (2000b). In addition, they note that the analysis does not account for any increase in welfare European might derive from having access to non-GM products. Furthermore, they note that 'the cost of banning GMO imports in Western Europe amounts to barely US$15 per capita per year – hardly a major impediment to imposing an import ban' (p. 14).
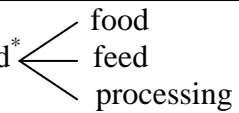
Jackson & Anderson (2003) use a similar GTAP model to estimate intra-national distributive impacts. They model several scenarios, including: increases in productivity enhancements alone and productivity increases with different regulatory and labelling policies. They find that aggregate welfare in North America increases in all model scenarios, but that Australasia gains when other countries ban GM products and lose welfare otherwise. Importantly, they link bans on GM products with the welfare of European producers, finding that they tend to gain from the ban, too.

Another example of GTAP modelling is a report by the Productivity Commission in Australia (Stone, et al., 2003). The paper models three main scenarios regarding GM crops and assesses the impacts on Australian trade: a) an improvement in productivity from GM crops, b) an improvement in productivity plus some consumer resistance to GM and some regulatory costs, and c) a steady-state future with low productivity gains, little consumer resistance, and no regulation. The overall conclusion is that adoption of GM crops will not have a large impact on Australia's trade. The report does however suggest that the long-term implication is that Australia could lose market share and therefore export earnings if it does not expand its GM sector.

3.2 The Empirical Model

In this research, a partial equilibrium model, the LTEM, was used to quantify the price, supply, demand and net trade effects of various policy and non-policy induced shocks. The LTEM is an agricultural multi-country, multi-commodity trade model, which does not consider the linkages of the agricultural sector with other industries, factor markets and the macroeconomy. The behavioural specifics, methodologies used to incorporate trade and domestic policy shocks and various parameters of the LTEM and its modified version that was used to simulate various impacts regarding GM production were previously introduced in Saunders and Cagatay (2001; 2003), and Cagatay and Saunders (2003) and a brief description of the model is provided here in Table 1. The LTEM was modified in the present study to quantify the effects of price differential between GM and non-GM varieties of products on agricultural earnings and trade.

Table 1
General Characteristics of the LTEM

Model	LTEM
Modelling Approach	Partial equilibrium
Temporal Properties	Comparative static & can also provide Short term dynamics (via sequential simulation)
Solution Type	Non-spatial, net trade
Solution Algorithm	Newton's global algorithm
Parameters	Synthetic
Commodity Coverage	16 (see Appendix B)
Country Coverage	9 (see Appendix B)
Behavioural Equations (per commodity, country)	Domestic supply — food Domestic demand[*] — feed Stocks — processing Producer price Consumer price Trade price
Economic Identity	Net trade
Approach Used to Incorporate Price Differential	Preference changes
Induced Shocks	Productivity increase in GM products Preference for non-GM varieties Preference for GM varieties Differential access to technology by countries other than NZ
Sources	Saunders and Cagatay, (2003; 2001); Cagatay and Saunders (2003)

[*]: Type of demand is dependent on the type of product.

A partial framework was preferred in this study because of the level of commodity disaggregation that the framework allows and because it avoids the problem of data and parameter availability or calibration problems. In addition ease of tracebility of the interactions and transparency of the results appear as other advantages that could be made use of during simulations. Finally, explicit modelling of the dairy sector at a disaggregated level is another strength of the LTEM.

There are nine countries and 16 agricultural commodities included in the model (see Appendix Table B1 for a list of these countries and commodities). 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 the LTEM, production in all countries is assumed to be segregated into GM and non-GM components (effectively 32 products are modelled). The GM and non-GM components of a product were assumed to be imperfect substitutes in production and consumption and

identical supply, demand, stock and price functions were used for GM and non-GM varieties (similar to the approach used in Nielsen, et al. 2000; Barkley 2002).

The supply response of a GM product was specified as in equation 1. In this equation, the letter *g* is used to represent the GM component of the product *i* and subscript *j* represents substitute commodities. Therefore, supply of a GM product (qsg_i) was specified as a function of the supply side shifters (shf_{qsg}), and producer prices of the GM product (ppg_i), of the other substitute GM products (ppg_j) and of the non-GM component (pp_i). A similar functional form and behavioural relationship was also used to reflect the supply response in non-GM product (qs_i), equation 2, in which the producer price for GM component (ppg_i) also appeared as a substitute product to non-GM component. The own-price elasticity (ppg_i) of GM supply was expected to be positive, but the cross-elasticities with respect to the prices of non-GM component (pp_i) and other GM products (ppg_j) are expected to be negative.

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

$$qs_i = \varphi_0 shf_{qs} pp_i^{\varphi_1} ppg_i^{\varphi_2} \prod_{j=1}^{2} pp_j^{\varphi_j} \qquad\qquad 2$$

The demand in the LTEM was disaggregated into feed, food and processing demand (only food demand is presented below) and the food demand for GM and non-GM varieties are presented in equations 3 and 4. The shifters shf_{qcg} and shf_{qc} in these equations were used to reflect the impact of food demand shifters, such as the changes in consumers' preferences. The food demand for the GM component (qcg_i; equation 3) was specified as a function of own-consumer price (pcg_i), consumer price of the Non-GM component (pc_i), consumer prices of the other GM substitutes (pcg_i), per capita real income (pci) and population (pop). A negative own-price elasticity ($^{\beta 1}$), a positive cross-price elasticity ($^{\beta 2}$) and ($^{\beta j}$), and a positive coefficient on per capita income ($^{\beta 3}$) and population ($^{\beta 4}$) was expected. Similar functional forms and behavioural relationships were also used to reflect the food demand response for non-GM component (qc_i), equation 4, in which the consumer price for GM component (pcg_i) also appeared as a substitute product in consumption to Non-GM component.

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

$$qc_i = \gamma_0 shf_{qc} pc_i^{\gamma_1} pcg_i^{\gamma_2} pci^{\gamma_3} pop^{\gamma_4} \prod_{j=1}^{2} pc_j^{\gamma_j} \qquad\qquad 4$$

3.3 Review of Assumptions

Uptake of GM Crops

In the LTEM, production of all commodities in all countries is assumed to be segregated into GM and non-GM varieties. The data for the GM adoption rate were obtained from several sources (Dargie, 2002; ISAAA, 2003; Miles, 2002; Schnepf, et al. 2001; Stone, et al., 2002), and the GM production and GM feed consumption by meat and dairy sectors in total were provided in Saunders and Cagatay (2003). The rate of uptake of GM crops in New Zealand, where a moratorium currently prevents commercial GM crop farming, was modelled at both 10% and 50% to observe the impacts of low and high rates of adoption.

Productivity Increase

The effects of GM adoption were simulated with two alternative scenarios on the supply side. In the first one, the adoption was assumed to yield no productivity increase. In the second one, a 20 percent increase in the productivity of GM crops in specific countries was assumed. Demand and supply equations in the LTEM were assumed to have constant elasticity functional form and exogenous shocks to this model arising from GM technology were assumed to shift demand and supply by a constant percentage of price for all levels of production; in other words, pivotal shifts were assumed.

Therefore, while the shift variable was equal to its initial value ($shf_{qsg}= 1$) for all products in the first scenario, in the second scenario the exogenous productivity shock of 20 percent was reflected via a 20 percent exogenous increase in shift variable for all products, $shf_{qsg}= 1.20$, by yielding a pivotal downward shift in supply curve. The feedback effect of the productivity increase in GM variety was reflected on both GM and non-GM output level by cross-price elasticities.

Shifts in Preferences for GM and Non-GM Varieties

Three alternative demand responses were simulated to analyse the effects of price differential on GM and non-GM varieties. In the first one, the differential was assumed to have caused no change in consumers' preferences towards GM and Non-GM varieties. Hence, the shifter variables in equations 3 and 4 stayed at their initial value for all products, $shf_{qcg}= shf_{qc}= 1$. Subsequent scenarios considered various consumer preferences. In the literature, and from observation of the market, it is not clear whether a change in consumer preference applies as a discount for one type of produce or as a premium for the other. Therefore in the scenarios below it was assumed that this effect was a split differential with half any change in preference falling as a discount and the other half as a premium (further explanation can be found in Appendix C). In the second scenario, a 5 percent decrease in demand for the GM variety and a 5 percent increase in demand for the non-GM variety were assumed, for a total 10% preference for non-GM. This approach simulated a shift in preferences away from GM but towards the non-GM variety. Therefore, while the shifter was reduced 5 percent in the demand equation for the GM variety ($shf_{qcg}= 0.95$), it was increased 5 percent in the equation for Non-GM variety ($shf_{qc}= 1.05$). These shifts represent a pivotal downward and upward shift in the demand curve respectively. In the third scenario, demand for GM products was decreased by 10 percent and the demand for non-GM products was increased 10 percent, for a total 20% preference for non-GM. In the fourth scenario, the impact of a preference for GM products is analysed by increasing demand for GM products by 10 percent and reducing demand for non-GM products by a similar 10 percent, so that the preference for GM products totalled 20%. This fourth scenario is modelling the case of a second-generation GM food product, whose modification enhances the product with a discernable consumer benefit.

Access to GM Technology

The possibility that New Zealand could have preferential access to GM technology was also modelled, using three different scenarios. In the first scenario, GM crops are more productive than their non-GM counterparts only in New Zealand; GM crops in other counties are not more productive. In the second scenario, New Zealand has a five-year head start on other countries in the use of more-productive GM crops. After 5 years, the other countries in the model also start using the more-productive GM crops. The final scenario models the impact of simultaneous adoption in all countries of productivity-enhancing GM technology.

Chapter 4
Results of Empirical Analysis

The results of the different modelling scenarios are presented below, broken down into specific topics: productivity and preference effects, effects of different rates of adoption, control of intellectual property rights, and second-generation GM products. In the actual modelling, the specified changes are modelled over 10 years. For each year, data on consumer, producer, and trade prices and volumes are generated. To summarise these data, total New Zealand producer returns are calculated for the final model year. By comparing the final total producer returns of a specific scenario with the base situation of no consumer and no producer changes, a percentage change in producer returns is calculated. This percentage change allows the net effect of different changes to be compared with one another.

4.1   Productivity and Preference Effects

The first set of scenarios to be considered simulates the impacts of three different preferences for non-GM commodities against two different productivity effects. For these scenarios, New Zealand has 50% of its agricultural production in GM crops.

Table 2
Changes in Producer Returns from Demand Preferences and Productivity Shifts

	No supply shift	20% supply shift
No demand effect	Base	-15%
10% non-GM preference	-3%	-15%
20% non-GM preference	-4%	-13%

Table 2 presents the changes in producer returns for different changes in consumers' preferences and agricultural productivity. Each row represents a different level of preference for non-GM products – no preference, 10% preference, or 20% preference. The two columns represent either no change in productivity in GM crops, or a 20% increase in productivity. The case with no shift in either preferences or productivity represents the base case, and the results of the shifts are given as the percentage change from the base case. If GM crops are not more productive and New Zealand uses them for 50% of its production, then a 10% consumer preference for non-GM crops (which New Zealand produces and sells as non-GM) reduces producer returns by 3%. If there is a 20% preference for non-GM products, then producer returns are 4% lower. In the case where GM crops used in New Zealand are 20% more productive, without an increased demand for non-GM products producer returns fall by 15%. When demand for non-GM products is 10% higher than for GM products, the loss in producer returns is also 15%, but the loss is a bit less at 13% should the preference for non-GM products be 20 %.

These results may at first sight be counterintuitive. However they do reflect basic economic theory and experience relating to increases in productivity especially for agricultural products. Agricultural commodities tend to have an inelastic demand so that the price fall required for the extra supply to be sold is proportionally greater than revenue from the extra supply itself. Moreover, the situation is made worse in NZ case due the restriction on access to high value markets, so that extra supply has to be sold on the lower value other markets.

There are therefore two key messages from this table, ones that are also clear in other similar research (Moschini, et al., 2000; Saunders & Cagatay, 2001; Sanderson, et al., 2003). The first message is: producing more agricultural commodities does not increase producer returns. In all scenarios in which GM crops increase productivity, New Zealand loses producer returns. The second message concerns consumer preferences: a shift away from products, even if it only affects half of the products that are produced in NZ, reduces net returns. Thus in New Zealand, the rise in non-GM products' prices does not fully offset the fall in GM products' prices. The net effect is a loss for producers.

4.2   Effects of Different Rates of Adoption

The next set of scenarios examines the impact of different levels of GM crop uptake in New Zealand. Two uptake percentages are modelled against different consumer preferences and productivity effects.

Table 3
Changes in Producer Returns Under Different Adoption Rates,
Preferences, and Productivity Impacts

	No supply shift		20% supply shift	
	NZ 50% GM adoption	NZ 10% adoption	NZ 50% adoption	NZ 10% adoption
No demand effect	Base	Base	-15%	-3%
10% non-GM preference	-3%	8%	-15%	6%
20% non-GM preference	-4%	18%	-13%	16%

Table 3 compares the results presented in Table 2, which used a 50% adoption rate, with the results from the scenarios modelling only a 10% uptake of GM production in New Zealand. Again, three different levels of consumer preferences and two different productivity effects are used. With a 10% adoption rate and no productivity increase, a 10% preference for non-GM products leads to an 8% increase in producer returns. Under similar conditions, a 20% preference for non-GM products creates an 18% increase in producer returns. If GM crops are more productive than their non-GM counterparts, then New Zealand producers lose 3% of their income without any change in consumer preferences. With a 10% consumer preference for non-GM, producer returns rise 6%, and a 20% preference leads to a 16% increase in producer returns.

The same conclusions about the effects of productivity increases and consumer preferences apply, regardless of the uptake of GM technology. In addition, these results indicate that if

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NZ can produce what overseas consumers prefer – which is the case where there is only a little GM adoption and a preference for non-GM products – then producers can increase their returns. Even if GM crops are more productive, the premium from non-GM production still allows NZ farmers to increase net returns. This again is consistent with theory in that an increased demand will always lead to an increase in producer returns.

4.3   Control of Intellectual Property Rights

The situation in which New Zealand controls access to GM technology is considered in the following scenarios. Three different assumptions about access to GM crops are modelled against demand preferences and productivity impacts.

Table 4
Changes in Producer Returns from Differential Access to
GM Technology

	NZ only for all years	NZ only for 5 years, then all countries	All countries simultaneously
No demand effect	3%	-7%	-15%
10% non-GM preference	0%	-9%	-15%
20% non-GM preference	-1%	-8%	-13%

Table 4 shows results from different assumptions regarding the dissemination of GM technology. The results are based on an adoption rate in New Zealand of 50%, a productivity increase of 20%, and three different levels of consumer preferences. Three different scenarios regarding the productivity-enhancing GM technology are modelled: a) New Zealand alone increases productivity, either because it limits access via intellectual property rights or because the technology is only relevant in New Zealand; b) New Zealand alone benefits from the technology for 5 years and then international producers start to use it or some other productivity-enhancing GM technology; and c) all countries increase GM productivity at the same times and same rates. In the case where New Zealand alone uses such technology, producer returns increase 3% if there is no difference in consumer preference, returns remain constant if there is a 10% consumer preference, and returns fall by 1% with a 20% preference. If this technology becomes available to the rest of the world after five years, at the end of ten years New Zealand producer returns will have fallen 7%. If a consumer preference is also factored in, a 10% preference level results in a 9% reduction in producer returns, and a 20% preference level in an 8% fall in returns.

These results suggest that if NZ can increase productivity with a technology it controls or that no-one else can use, then it can at least maintain and even in some cases increase producers' incomes. In this case, producers benefit from being able to produce commodities more cheaply than competitors, but the change in quantities does not lower international prices enough to negate the productivity gains. If the technology (or some other GM technology affecting products in the same markets) is released overseas, then NZ agricultural producers lose revenue. This is a similar result to that obtained by Moschini, et al. (2000). They found

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that using Roundup-Ready soybeans increased producer welfare in the U.S., but the increase was sensitive to how widely the technology was used. U.S. soybean producers lost most of their increased welfare when use of the GM technology was extended worldwide. Not included in these results for New Zealand is a calculation of returns from intellectual property rights that might accrue to a New Zealand-owned innovation.

4.4 Second-Generation GM Products

Second-generation GM food crops offer the possibility of consumer-oriented enhancements, products that consumers will prefer to their non-GM counterparts. This possibility is modelled in the following set of scenarios.

Table 5
Changes in Producer Returns with Second-Generation GM Products

	No supply shift		20% supply shift		NZ only for 5 years, then all countries	NZ only for all years
	NZ 50% GM adoption	NZ 10% adoption	NZ 50% GM adoption	NZ 10% adoption	NZ 50% GM adoption	NZ 50% GM adoption
No demand effect	Base	Base	-15%	-3%	-7%	3%
20% non-GM preference	-4%	18%	-13%	16%	-8%	-1%
20% GM preference	17%	-13%	-10%	-19%	3%	21%

Table 5 presents results from scenarios designed to simulate second-generation or output-oriented products. Because of their enhanced attributes, these products would be preferred over their non-GM counterparts by consumers. As before, two different adoption rates are included, as are two different productivity levels. Consumer preferences are simulated three ways: as no preferences, as a 20% preference for non-GM products, and as a 20% preference for GM products. It is the bottom row of this table, the preference for GM products, that presents new data; the other results in the table are as described above. If New Zealand has a 50% uptake in GM technology and produces preferred second-generation GM products, then producer returns increase by 17%. If only 10% of New Zealand production is in production of such GM products, then returns fall by 13%. When an increase in production is included, such that GM technology both increases productivity and creates more-desirable crops, New Zealand producers lose 10% of their returns under a 50% uptake rate and 19% of their returns under a 10% uptake rate. However, if New Zealand is able to control access to the technology such that it alone produces the preferred, more-productive GM commodity, producer returns increase. If the lock-out period is five years, producer returns are 3% higher; if the period is 10 years, producer returns are 21% higher.

The results present the same messages as before. First, New Zealand producers gain revenue when they produce crops that consumers prefer. If consumers prefer non-GM products, New Zealand producers gain by focusing on those crops. If consumers prefer second-generation GM products, producers increase their returns by growing those crops. Secondly, increasing the production of commodities does not lead to increased returns. Thus, even where a product has a consumer preference, producer returns fall when productivity increases. Thirdly, controlling access to preferred products or to productive technology has beneficial effects for New Zealand commodity producers.

4.5   Discussion of Modelling Results

The results present several patterns. First, consumer preferences are by far the most important factor affecting producer returns in NZ. This should be of no surprise to those in the industry as the sectors which have grown have been those targeting high value and/or niche type markets with relatively high premiums. This finding is also totally consistent with overseas experience and theory. Secondly, increasing productivity is not necessary to increase producer returns, and may even be counter-productive for commodity crops. Demand for commodities is not sensitive to price changes, so producing more of them is only of value if no-one else does the same. Even then, the gains are not very great and easily overwhelmed by changes in consumer preferences. It is possible that differential impacts of the technology could lead to gains for some producers and losses for others; the LTEM results relate to the sector as a whole. Thirdly, control of intellectual property rights is important. If only one country has a more-productive GM technology, or if only one country produces a product that consumers prefer, that country has an increase in its producer returns.

The results of the modelling are consistent with both experience and theory. The results show clearly the different impacts of supply and demand shifts on producer returns to New Zealand. This is illustrated below by figures A and B. Figure A shows a demand shift for a product with the demand curve moving from Demand A to Demand B, the case of a discount on NZ products.

Figure A
Effect of Demand Shift
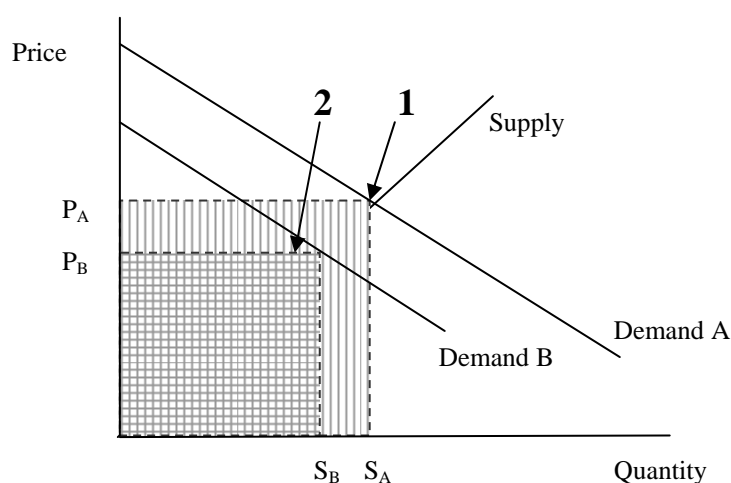
A movement from Demand B to Demand A would be a premium for NZ products. What is clear from Figure A is that the demand shift has an unequivocal effect on producer returns. If we assume a decrease in demand then producer returns decrease from the larger area 1 to the smaller area 2. Whilst the size of this impact will be influenced by the relative elasticities of supply and demand, there will always be a decrease in producer returns.

In the case of shift in supply the result is uncertain. This is illustrated by figure B. This figure illustrates a shift in supply, representing an increase in productivity, from Supply A to Supply B. Producer returns change therefore from the areas in boxes 1 and 2 to the areas in boxes 1 and 3. Thus whether there is an overall gain in producer revenue or not depends upon whether the loss of area 2 is less than the gain in area 3. This is dependent on the relative elasticities of supply and demand. If demand is considered more responsive than supply then producer returns will increase. However if demand is less responsive than supply then producer returns will actually fall. The evidence from agricultural markets is that the latter holds true and an increase in supply does lead to a fall in producer returns. In the case of the adoption of rbST, for example, there was a significant increase in productivity but no effect on profits (Foltz & Chang 2002; Stefanides & Tauer, 1999).

Figure B
<u>Effect of Supply Shift</u>
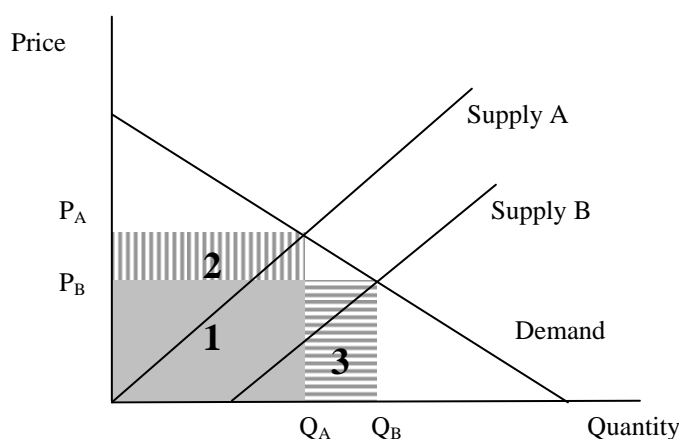
Therefore demand shifts have clear and unambiguous effects on producer returns. If we assume a decrease in demand – a discount because NZ releases GMOs – then we must expect producer returns to decrease. Supply increases can result either in gains or losses, because the larger volumes are offset by lower prices. Which effect prevails is an empirical question. In the case of agriculture, the tendency is for markets to need a proportionally greater fall in producer returns in order to clear an increase in supply. This particularly true for NZ as it has a significant share of the world market in pastoral products and therefore is not a price taker. Moreover, this effect is made worse by access into high value markets being restricted and thus the only alternative markets are frequently the lower value ones in any case.

Chapter 5
Conclusion

This paper examined GM food from several perspectives. From the perspective of individual producers, it examined research on the impact of GM technology on agricultural production. GM crops were generally found to have had little impact on producers' net returns, and impacts on agricultural productivity as measured by changes in yields or production costs were sometimes negative and sometimes positive. From consumers' perspective, non-GM foods were preferred in consumer research and economic surveys and experiments, thus it is not surprising that a price differential has developed between GM and non-GM commodities. Finally, from the perspective of international trade, the patterns of GM crops adoption and GM food sensitivity have been shown to create price differentials, welfare changes, and shifts in trading patterns.

The economic modelling in this paper considered many alternatives. Productivity was either constant or increased. Consumer preferences were assumed to lead to no changes in demand for commodities, to lead to a 10% or 20% preference for non-GM commodities, or to lead to a 20% preference for GM commodities. The possibility of controlling access to more-productive GM technology was also analysed, with three different timeframes for international dissemination of these GM crops. The results show that consumer preferences are by far the most important factor affecting producer returns in NZ, and that increasing productivity is not necessary to increase producer returns and may even be counter-productive. However, this is influenced by whether NZ is the sole producer of the product or not.

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Appendices

Appendix A: Complete Modelling Results

Table A1
Complete Tabulation of Results Presented in Paper

		No supply shift	**20% supply shift**		
			All countries	**NZ only for 5 years, then all countries**	**NZ only for all years**
NZ 50% GM adoption	No demand effect	Base	-15%	-7%	3%
	10% non-GM preference	-3%	-15%	-9%	0%
	20% non-GM preference	-4%	-13%	-8%	-1%
	20% GM preference	17%	-10%	3%	21%
NZ 10% GM adoption	No demand effect	Base	-3%	N/a	1%
	10% non-GM preference	8%	6%	N/a	9%
	20% non-GM preference	18%	16%	N/a	19%
	20% GM preference	-13%	-19%	N/a	-11%

Appendix B: Countries and Commodities in LTEM

Table B1
Country and Commodity[*] Coverage

Countries	Commodities	
Argentina-AR	Wheat	Raw milk
Australia-AU	Coarse grains	Liquid milk
Canada-CA	Maize	Butter
European Union (15)-EU	Beef and veal	Cheese
Japan-JP	Sheepmeat	Whole milk powder
Mexico-MX	Oilseeds	Skim milk powder
New Zealand-NZ	Oilseed meals	
United States of America-USA	Oils	
Rest of World-RW	Apples	
	Kiwifruit	

[*]: Each commodity is included as GM and non-GM components.

Appendix C: Modelling Demand Preferences

Economic research suggests that genetically modified (GM) food would trade for less than non-GM food. It is not clear whether this price differential represents a discount on GM food or a premium attached to non-GM food. When comparing alternative model scenarios with a base scenario, how the price differential is modelled might affect the results obtained and the policy conclusions drawn from those results. A separate paper (Saunders, et al., 2003) explored the price differential three different ways and assessed the impact on agricultural earnings and trade. The method of modelling the differential was found to have a significant impact on comparative results. A summary of those findings are presented here.

The Empirical Analysis

LTEM was used to model different assumptions regarding the how the price differential fell on GM and non-GM crops, as well as different productivity effects from adopting GM crops. On the demand side, four different reactions were modelled: no price differential, a 20% discount on GM crops, a 20% premium on non-GM crops, and a split price differential of 10% discount for GM and 10% premium for non-GM. These demand effects were applied to all countries and commodities. On the productivity side, two levels were considered: either adoption of GMOs had no effect on productivity, or it increased output by 20%. Altogether, eight different scenarios (4 demand x 2 productivity) were modelled.

An important model input is the adoption rates of GM crops. The adoption rates (or uptake proportions) are specified individually for each crop and country, and have been taken from the literature (Dargie, 2002; ISAAA, 2003; Miles, 2002; Schnepf, et al. 2001; Stone, et al., 2002). New Zealand agriculture was assumed to start with 50% of its production in GM crops. The adoption rate for Australia was only 10%, as suggested by the Productivity Commission (Stone, et al., 2002), as was the rate for the EU. Uptake rates for the US varied by crop, and were set at 65% for the oilseed complex and 40% for all other crops.

To summarise and compare the results of different modelling runs, we sum producer returns for each country. The results for each model run are compared with the base scenario and the

percentage increase or decrease calculated. This procedure allows us to indicate whether possible productivity increases or price premiums lead to gains or losses for the agricultural sector.

The table C1 summarises the modelling results for New Zealand as total producer returns for the crops modelled, mainly cereals, dairy, meat, kiwi fruit and apples.

Table C1
Changes in NZ Producer Returns from GM Productivity
Changes and GM/Non-GM Price Differentials

Price differential modelling method	Productivity effect	
	None	20% increase
No differential	base	-15.1%
20% discount for GM products	-23.3%	-30.6%
20% premium for non-GM products	18.6%	7.0%
10% non-GM premium and 10% GM discount	-3.7%	-13.0%

There are clear patterns to the results illustrated in table C1. First, for each level of demand, a 20% increase in productivity leads to a decrease in total producer returns. Secondly, for each level of productivity, a premium raises total returns, and a discount lowers returns. These productivity and demand effects are consistent with theory and expectations. Interestingly, the results indicate that the split price differential leads to lower returns for NZ farmers.

The interactions between productivity and price differential also yield clear results. Without a demand effect, a general productivity increase from adopting GM in agriculture would lead to an overall loss to agriculture of 15%. If adoption of GM technology leads to across-the-board discounts on NZ agricultural products, then the demand shift exacerbates this loss in producer returns. If adopting GM leads to a general premium for non-GM products and New Zealand is able to capture that premium, then producer returns increase. However, that increase is reduced if GM crops create productivity increases. Overall, it is those scenarios with a premium for non-GM products that show higher producer returns.

As would be expected from economic theory, an inward shift of the demand curve results in both lower quantities produced and lower prices for NZ products. Because LTEM is a model of international trade, it models both the price and quantity shifts simultaneously, thus giving a picture of the full impact of a discount on NZ products from our overseas markets. This capability of the model is particularly important for NZ's main exports. For example, NZ produces a small portion of total world dairy products, but accounts for 23% of world milk powder exports, 36% of world butter exports, and 19% of world cheese exports (1997 figures). An increase in the quantity of NZ exports will therefore decrease their world prices. Because NZ is an open economy, lower world prices result in lower farm gate prices.

Conclusion

The above results demonstrate that the method of modelling a price differential between GM and non-GM affects the results obtained. For the scenarios in this paper, four different demand levels were modelled, including one base level (no change) and three methods of modelling 20% higher demand for non-GM over GM food. Whilst the three methods of modelling a demand shift all behaved similarly vis-à-vis a productivity shift, they gave different results when compared with the base model. How much producer returns would change as a result of adopting GM crops will depend in part on how the price differential falls. Models that attempt to show possible future returns for agriculture should take this finding into account.

The importance of this finding stems from the ways results are interpreted. The results of a policy change – in this case, adopting GM in agriculture – are usually compared to a base case. If it is assumed that consumers will pay a premium to obtain non-GM food, then the price of GM products does not change from the base case. Thus, there can be no negative demand effect from such a policy. If it is assumed that GM products will bear the full price differential – that non-GM products will not change in price – then the result is negative. When the price differential is split across the two types of commodities, total returns for agricultural commodities change less than in the other two cases. The changes in producer returns are therefore more reflective of changes in relative demand between the two types of products, rather than being the result of an overall increase or decrease in consumption of agricultural goods.

Additional Reference

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