Modelling the Trade Impacts Of Willingness to Pay for Genetically Modified Food

William Kaye-Blake
Caroline Saunders
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Agribusiness and Economics Research Unit
PO Box 84
Lincoln University
Canterbury
New Zealand

Ph: (64)(3) 325 3627
Fax: (64)(3) 325 3847
http://www.lincoln.ac.nz/AERU/

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Preface

This report is part of ongoing work of the Agribusiness and Economics Research Unit on the issues surrounding the commercial impacts of genetically modified food. It combines research funded by the Foundation for Research, Science and Technology (FoRST) into public perceptions of biotechnology with the ongoing Trade and Environment programmes using the Lincoln Trade and Environment Model (LTEM). The results of a nationwide survey into attitudes towards different types of biotechnology were incorporated into model scenarios for the LTEM, thus using new data to assess potential impacts on New Zealand's agricultural sector. This combination of the two projects has enhanced the research output from both programmes.

Acknowledgements

We would like to acknowledge the contributions of Selim Cagatay, Ann Christie, and Andrew Cook in the research and preparation of this report. Their work has been most helpful. We wish also to thank the Foundation for Research, Science and Technology (FoRST), for the funds to conduct the survey and its analysis.

Summary

The present research had two objectives: first, to examine New Zealanders' intentions to purchase and willingness to pay for several specific genetically modified (GM) food products; and second, to use these results as input for a model of international trade to estimate potential impacts from trade on New Zealand. For the first part, a nationwide survey was administered and the resultant data analysed. The second part required using the results of the data analysis to estimate consumer and producer impacts of GM crops and the best adoption rate of GM crops for New Zealand agriculture, all of which became inputs for the trade model.

From the survey results, it is clear that different New Zealanders have different willingness to pay for GM food. For all six GM products in the survey, about 30 per cent to 45 per cent of respondents were indifferent to the GM products. These respondents would pay the same price for the GM as for non-GM food. For four or the six GM food products, there were respondents willing to pay a 40 per cent premium for GM food. On the other hand, seven per cent to 27 per cent of respondents, depending on the product, were willing to pay for the GM food but at a discounted price. The proportion of respondents who rejected each product was fairly consistent at about 40 per cent. However, the proportion of respondents who rejected all GM products was lower at 31.4 per cent.

This willingness to pay data was transformed into a demand curve. The raw data and the estimated demand curve were S-shaped (sigmoid) – steeply sloped at both high and low prices and fairly flat in the middle. A sigmoid regression was estimated and fit the data very well. It showed that, with one exception, the type of GM product offered had little effect on the prices people were willing to pay. This estimated demand curve was used to calculate the optimal uptake of GM crops, which is the percentage of total output that should be GM in order to have the highest industry revenues. This calculation led to the finding that the agricultural sector could maximise its revenue from most products by having 15 per cent of its production in GM products and charging an 11 per cent premium for the products. This would raise sector revenues by 1.6 per cent. If the percentage of consumers willing to pay for GM food increased from the 62 per cent in the survey data to 90 percent of consumers, then the optimal uptake would be 22 per cent, the premium would be 11 per cent, and the increase in agricultural revenues would be 2.4 per cent.

These findings were incorporated into the model of international agricultural commodity trade. Using the optimal uptake rate, a universal willingness to pay a premium for certain GM crops, and increased productivity of some GM products, the modelling found that New Zealand could increase its agricultural revenues by up to six percent by adopting GM crops. It is further shown that increased productivity not accompanied by consumer premia leads to reduced revenues.

This report goes beyond a polarised either-or approach to GM crops and, for the first time, attempts to estimate how much of production would optimally be GM. Using this optimal uptake, the research estimates potential impacts on New Zealand agriculture. Because the analysis attempts to incorporate reactions to GM food from all consumers, it is able to show the importance of the large number of consumers who are either indifferent to GM or who wish to reject GM food. The existence of such consumers places limits on the profitability of GM food crops. Nevertheless, at the appropriate levels of production, GM food could be sold at a premium and could increase total agricultural sector revenues.

Chapter 1
Introduction

This AERU research report uses consumer data to estimate (1) the relationship between production of genetically modified (GM) food and its price, and (2) economic impacts of various scenarios regarding adoption of GM crops on the New Zealand agricultural sector. The consumer data was generated from a New Zealand survey on public perceptions of biotechnology. This survey asked respondents about their intentions to purchase and willingness to pay for specific GM products with production and consumer-oriented benefits. These findings were then used to estimate the optimal adoption rate of GM crops – the uptake percentage that would maximise industry revenues. The results were then incorporated into a partial equilibrium model of world agricultural trade, the Lincoln Trade and Environment Model (LTEM). The model simulated the economic impact on New Zealand's agricultural sector of domestic and international demand for the specific products in the survey.

This research extends prior research in several ways. First, it considers specific genetically modified food products with defined productivity benefits and/or defined consumer benefits. Respondents were presented with plausible products that offered specific benefits, such as butter with 50 per cent less cholesterol. The survey therefore represented an improvement over research concerned with undefined 'genetically modified food'. Secondly, the survey was designed to allow a respondent to express acceptance or rejection of each GM food product, and to consider a range of possible prices for the products. The entire range of demand for GM food was therefore present in the data. Finally, the data were incorporated into a model of the international agricultural commodity market. Modelling the data allowed both the productivity impacts and the consumer reactions to specific products to be brought together to estimate the impacts on the whole market.

This report has two substantive chapters. Chapter 2 discusses consumer reactions to GM food. It begins with a brief review of the literature on consumer reactions, presents results from the New Zealand survey on public perceptions of biotechnology, and then discusses those results. An analysis of the survey data is included and the results are used to estimate the demand curve and the optimal uptake of GM crops. Chapter 3 focuses on modelling. It starts with an overview of the literature on trade impacts of GM crops, then presents the trade model. The data from the survey are incorporated into the model and the results are analysed. The report concludes with a discussion of the results.

Chapter 2
Consumer Reactions to GM

The goal of this chapter is to estimate the relative demand curve for GM and non-GM food, which is then used to estimate the optimal uptake of GM crops. It starts by reviewing the relevant literature, then presents results of the survey, and finally analyses the survey results.

2.1 Literature on Consumer Reactions to GM Food

Economic research on consumer reactions to GM food has consistently found, on average, either a willingness to pay for non-GM food or a willingness to avoid GM food (Kaye-Blake et al., 2003; Saunders, Kaye-Blake, & Cagatay, 2003). However, using an average willingness to pay obscures this variation in consumer responses. Consumer and public perception research has found that reactions to GM food and biotechnology can be categorised into several different groups (Gaskell et al., 2003). From an economic perspective, there are four different consumer responses to consider: willingness to pay a premium in order to have quality-enhanced GM food, indifference to the issue of genetic modification, willingness to buy GM food at a discount, and refusal of GM food (Noussair, Robin & Ruffieux, 2004). Each response is considered in turn.

Economic research has found that some consumers are willing to pay more for GM food that offers specific benefits. A contingent valuation survey in Beijing, China found that 43.9 per cent of respondents would pay a premium for GM rice with extra vitamins (Li, Curtis, McCluskey, & Wahl, 2002). In a choice experiment survey, respondents who were concerned about their cholesterol levels were prepared to pay $0.83 on average for a GM beer that reduced their cholesterol levels by 20 per cent (Burton & Pearse, 2002). For these consumers, GM technology offers a way to increase the value of food.

Other research has indicated that some consumers are indifferent to the use of gene technology. In an auction experiment at a US university, most students were not willing to pay a premium in order to have non-GM food (Lusk, Daniel, Mark, & Lusk, 2001). Choice experiment surveys in the U.K. and Australia have found that GM food produced with plant-only gene technology has approximately the same value as non-GM food for most consumers (Burton, Rigby, Young, & James, 2001; James & Burton, 2003). A conjoint analysis survey for pST-treated pork (Halbrendt, Pesek, Parsons, & Lindner, 1994) determined that respondents who were unconcern about the use of pST rated both the treated and untreated pork products similarly. This would suggest indifference to the issue of GM or a similar WTP for both the GM and non-GM products. For products with no consumer-oriented benefits, this indifference should lead to equal prices for GM and non-GM food. For enhanced products, these consumers could be willing to pay higher prices. This group may, therefore, overlap with the group willing to pay a premium.

Willingness to buy GM food at a discount to non-GM food has been the focus of much consumer research. On average, consumers seem to prefer non-GM food. The characteristic ‘genetically modified’ as separate from other food characteristics has dis-utility; it has negative value for consumers. For example, researchers at Iowa State University found that Midwestern U.S. consumers were willing to pay 14% less on average for GM food (Huffman, Shogren, Rousu, & Tegene, 2001). Consumers in the U.K. were willing to pay a premium of at least 26% for non-GM food when GM food was produced using plant and animal gene technology (Burton, Rigby, Young, & James, 2001). Similar responses were found in Australia (James & Burton, 2003) and France (Noussair et al., 2004)

Not all consumers are willing to purchase GM food, however. A number of respondents refused to choose GM products in choice experiment surveys (Burton et al., 2001; James & Burton, 2003), or said they were unwilling to purchase GM food regardless of the discount in contingent valuations surveys (McCluskey, Ouchi, Grimsrud, & Wahl, 2001). In a New Zealand choice experiment survey designed to capture unwillingness to pay for GM food, 41 per cent of respondents would not pay for GM food (Kaye-Blake, 2004). Research on consumer attitudes towards GM food confirms the existence of such consumers. Cluster analysis on results of the GM Nation survey in the U.K., for example, found that 47 per cent of the sample were 'Implacably Opposed to GM' (Heller, 2003). Canadian and European research has similarly found sizeable groups of respondents who oppose GM food (Gaskell et al., 2004; Noussair et al., 2004; Sheehy, Legault, & Ireland, 1998). For some of this research, unwillingness to purchase GM food occurred even with the presence of positive consumer benefits, such as health or environmental benefits (Burton et al., 2001; James & Burton, 2003; Kaye-Blake, 2004). This type of consumer response limits the size of the market for GM food.

2.2 New Zealanders and Biotechnology: a Nationwide Survey

In late 2003, the AERU conducted a nation-wide mail-out survey of public perceptions of biotechnology. A total of 2,000 questionnaires were distributed to randomly selected addresses in New Zealand. There were 701 questionnaires with usable responses returned. Adjusting for undelivered questionnaires, the response rate was 36.3 per cent. The survey was representative in terms of gender but not age, income, number of respondents with university qualifications and ethnicity. Details regarding survey administration, response rate, and representativeness are available in Cook, Fairweather, Sattersfield, & Hunt (2004).

As part of this survey, respondents were asked about their intentions to purchase and their willingness to pay for specific food items that were produced using genetic modification. The questions were designed with several issues in mind: identifying different levels of acceptance and willingness to pay, providing examples of different possible uses of gene technology, and estimating demand for key New Zealand export commodities. The questions are provided in Figure 1.

Identifying levels of acceptance and willingness to pay was approached with two separate questions. First, respondents were asked about their intention to purchase the GM food products. Intentions to purchase have been shown to have reasonable correspondence with actual purchasing behaviour (Conner & Sparks, 1995). Responses were recorded on a Likert scale anchored on Strongly Agree and Strongly Disagree. With this question, respondents could indicate whether they wished to avoid GM food. The second question asked respondents to indicate their willingness to pay for these products. The response scale ran from a 40 per cent discount to a 40 per cent premium in steps of ten per cent. The question was thus a contingent valuation question similar to a payment card format. Respondents could also indicate that they would refuse the products. These two questions were designed to provide a picture of the overall potential market for GM food products.

Respondents were presented with six products representing different modifications that could be achieved with gene technology. A range of modifications was presented to respondents in order to gauge the impact of different benefits on the acceptability and WTP for GM food. To date, the major commercial GM crops have been field crops modified for herbicide tolerance

Figure 1
Survey Questions on Intentions Towards and Willingness-to-Pay for GM Food

9. Buying the products of biotechnology

(a) As well as gauging the acceptability of biotechnology we are interested in whether you would purchase products made using biotechnology. Please indicate whether or not you intend to purchase the following products.

Definitely intend not to purchase	Intend not to purchase	No intention to either purchase or not purchase	Intend to purchase	Definitely intend to purchase
1	2	3	4	5

Butter from cows genetically modified to produce 50% less cholesterol in their milk	
Meat from sheep genetically modified for 'double-muscling', producing more meat and less fat per animal	
Bread made from genetically modified wheat that is 25% cheaper to grow	
Apples genetically modified to produce twice as much antioxidants, which may help prevent cancer	
Milk from cows that are grown on pastures containing genetically modified clover	
Sweetcorn that has been genetically modified to resist insects so that it requires 50% less than the usual application of pesticides	

(b) Now please indicate the most you would pay for each of the following products. For some products you may be willing to pay more or only consider purchasing if they cost less. For the products you do not wish to purchase please write an **X** in the box.

Pay 40% less	Pay 30% less	Pay 20% less	Pay 10% less	Pay no more or no less	Pay 10% more	Pay 20% more	Pay 30% more	Pay 40% more
1	2	3	4	5	6	7	8	9

Butter from cows genetically modified to produce 50% less cholesterol in their milk	
Meat from sheep genetically modified for 'double-muscling', producing more meat and less fat per animal	
Bread made from genetically modified wheat that is 25% cheaper to grow	
Apples genetically modified to produce twice as much antioxidants, which may help prevent cancer	
Milk from cows that are grown on pastures containing genetically modified clover	
Sweetcorn that has been genetically modified to resist insects so that it requires 50% less than the usual application of pesticides	

and insect resistance (C. James, 2003). These input-oriented crops are considered the first generation of GM crops, but the second generation promises modified output characteristics that consumers may find desirable (Caswell et al., 1998; Shoemaker et al., 2001). Second-generation crops may include better-tasting tomatoes, crisper carrots, and more nutritious strawberries (Biotechnology Industry Organization, 2003b). For the survey, three products offered health benefits, such as less fat, less cholesterol, or more nutrition. One product offered an environmental benefit: a reduction in the use of pesticides. A fifth product was cheaper to produce. The last product offered nothing in the way of producer or consumer benefit; it was simply genetically modified.

These products seem to be realistic representations of potential GM products (Information Systems for Biotechnology, 2003; Biotechnology Industry Organization, 2003a). However, these products are not currently commercially available nor are they likely to be in the next six to eight years. Bringing a GM product to market can take eight years or more (Shoemaker, et al., 2001) and none of these example products is expected to come onto the market within the next six years (Biotechnology Industry Organization, 2003a).

A final consideration in developing these questions was obtaining results for key agricultural commodities. New Zealand produces and exports large amounts of dairy products and meat. The survey questions therefore included butter, milk, and sheepmeat. Sweetcorn is a product that has currently commercialised GM cultivars available, and has been the subject of media scrutiny in New Zealand. Wheat is another product for which GM cultivars have been developed, but it has not yet been commercially released. The sixth commodity included in the survey was apples, which have been the subject of other GM consumer research in New Zealand (Kaye-Blake, 2004; Richardson-Harman, Phelps, Mooney, & Ball, 1998) and is a commodity included the trade model.

The full descriptions of the products in the survey, the related commodities in the trade model, and the type of modification offered are presented in Table 1.

2.3 Survey Results

Results from these two questions provided information about the extent of rejection of GM food as well as the range of willingness to pay for GM food. These two issues are discussed in turn.

The survey included two questions designed to indicate rejection of GM food. The first was an intention-to-purchase question, results of which are presented in Table 2. A respondent could indicate either a positive or a negative attitude towards purchasing the GM food product. This question was included mainly to determine whether the respondent had a negative intention, that is, whether the respondent would like to avoid purchasing the specific GM food product. The willingness-to-pay question also allowed respondents to indicate refusal of GM food, as shown in Table 3. For that question, a respondent could place an 'X' in the response box rather than indicate some positive willingness to pay (see Figure 1 for the actual survey questions).

The data from the intention-to-purchase question (Table 2), exhibit two interesting patterns. The first pattern is that each product is rejected by a large minority of respondents: for each item, from 36 per cent to 43 per cent of respondents disagree or strongly disagree that they would purchase it. The second pattern is that there is variation in the negative intentions. The percentage opposed to purchasing each product varies, so that some products encounter less resistance than others. Further data analysis found that the percentage of respondents who do not intend to purchase any of the products is 27.8 per cent, but on average the products are rejected by 39.5 per cent of respondents. The difference in these figures suggests that some respondents wish to reject some but not all GM food products.

The second question, regarding willingness to pay, provided two important estimates: a second measure of the extent of product rejection and an estimate of willingness to pay. Rejection in the willingness to pay data (Table 3) follows a similar pattern to the data in the intentions question. For each product, the percentage of respondents refusing the product is approximately the same. However, this percentage includes both a core of total refusers – who do not want any of the GM food products – and a group of respondents who refuse some products but not others. The willingness to pay question also provided data about the percentage of respondents who would purchase the item at each price level (Table 4). For all products, responses (excluding rejection) are concentrated around a nil discount/premium. For consumers who would purchase an item, most would be willing to pay the same price for the GM product as the non-GM product. About one-half of all respondents would be willing to pay the same price or higher for each of the products, with one exception (bread from GM wheat that was cheaper to grow).

Table 1
Products in the Survey

Product	Commodity	Type of change	Note
Butter from cows genetically modified to produce 50% less cholesterol in their milk	Butter / Dairy	Health benefit	Impact of GM on the food product is indirect
Meat from sheep genetically modified for 'double-muscling', producing more meat and less fat per animal	Sheepmeat / Meat	Health benefit / Possible environmental benefit	
Bread made from genetically modified wheat that is 25% cheaper to grow	Wheat	Cost reduction	
Apples genetically modified to produce twice as much antioxidants, which may help prevent cancer	Apples	Health benefit	
Milk from cows that are grown on pastures containing genetically modified clover	Milk / Dairy	Merely GM – no benefit	The food product is not modified
Sweetcorn that has been genetically modified to resist insects so that it requires 50% less than the usual application of pesticides	Sweetcorn / Maize	Environmental benefit / Possible cost benefit	

Table 2
Responses to Intention-to-Purchase Question
(percentage of respondents)

	Definitely intend not to purchase	Intend not to purchase	Neither	Intend to purchase	Definitely intend to purchase
Butter with less cholesterol	19.3%	20.9%	33.3%	23.1%	3.5%
Milk from cows fed GM clover	17.5%	19.7%	40.2%	19.8%	2.9%
Meat from double muscled sheep	21.3%	22.0%	30.2%	23.8%	2.8%
Antioxidant apples	17.6%	20.1%	29.9%	26.5%	6.0%
Bread from efficient wheat	18.5%	23.6%	32.7%	22.3%	2.9%
Insect-resistant sweetcorn	17.6%	18.8%	33.2%	26.8%	3.6%

Table 3
Willingness to Pay Categories
(percentage of respondents in each category)

Products	Rejection	Discount	Indifference	Premium
Butter with less cholesterol	44.0%	7.0%	33.0%	16.0%
Milk from cows fed GM clover	40.7%	10.4%	44.8%	4.2%
Meat from double muscled sheep	44.9%	8.7%	30.6%	15.8%
Antioxidant apples	38.8%	6.5%	33.5%	21.2%
Bread from efficient wheat	40.3%	26.8%	28.6%	4.3%
Insect-resistant sweetcorn	41.5%	12.8%	36.0%	9.8%

Table 4
Willingness to Pay for GM Food Products (percentage of respondents)

Products	Willingness to pay (as percentage change from non-GM price)								
	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%
Butter from cows genetically modified to produce 50% less cholesterol in their milk	2.2%	1.0%	2.1%	1.6%	33.0%	12.9%	2.8%	0.0%	0.3%
Milk from cows that are grown on pastures containing genetically modified clover	2.4%	1.5%	3.6%	3.0%	44.8%	4.0%	0.1%	0.0%	0.0%
Meat from sheep genetically modified for 'double-muscling', producing more meat and less fat per animal	2.4%	1.3%	2.8%	2.2%	30.6%	12.4%	3.0%	0.1%	0.3%
Apples genetically modified to produce twice as much antioxidants, which may help prevent cancer	1.3%	0.3%	3.0%	1.9%	33.5%	15.1%	4.6%	1.0%	0.4%
Bread made from genetically modified wheat that is 25% cheaper to grow	3.6%	3.0%	11.9%	8.4%	28.6%	3.7%	0.6%	0.0%	0.0%
Sweetcorn that has been genetically modified to resist insects so that it requires 50% less than the usual application of pesticides	3.0%	1.5%	4.8%	3.6%	36.0%	8.2%	0.9%	0.4%	0.3%

NB: Figures are percentages of valid responses, which excludes non-response. Rows do not sum to 100% because respondents who refused products are not included.

Figure 2
Willingness to Pay for Genetically Modified Foods

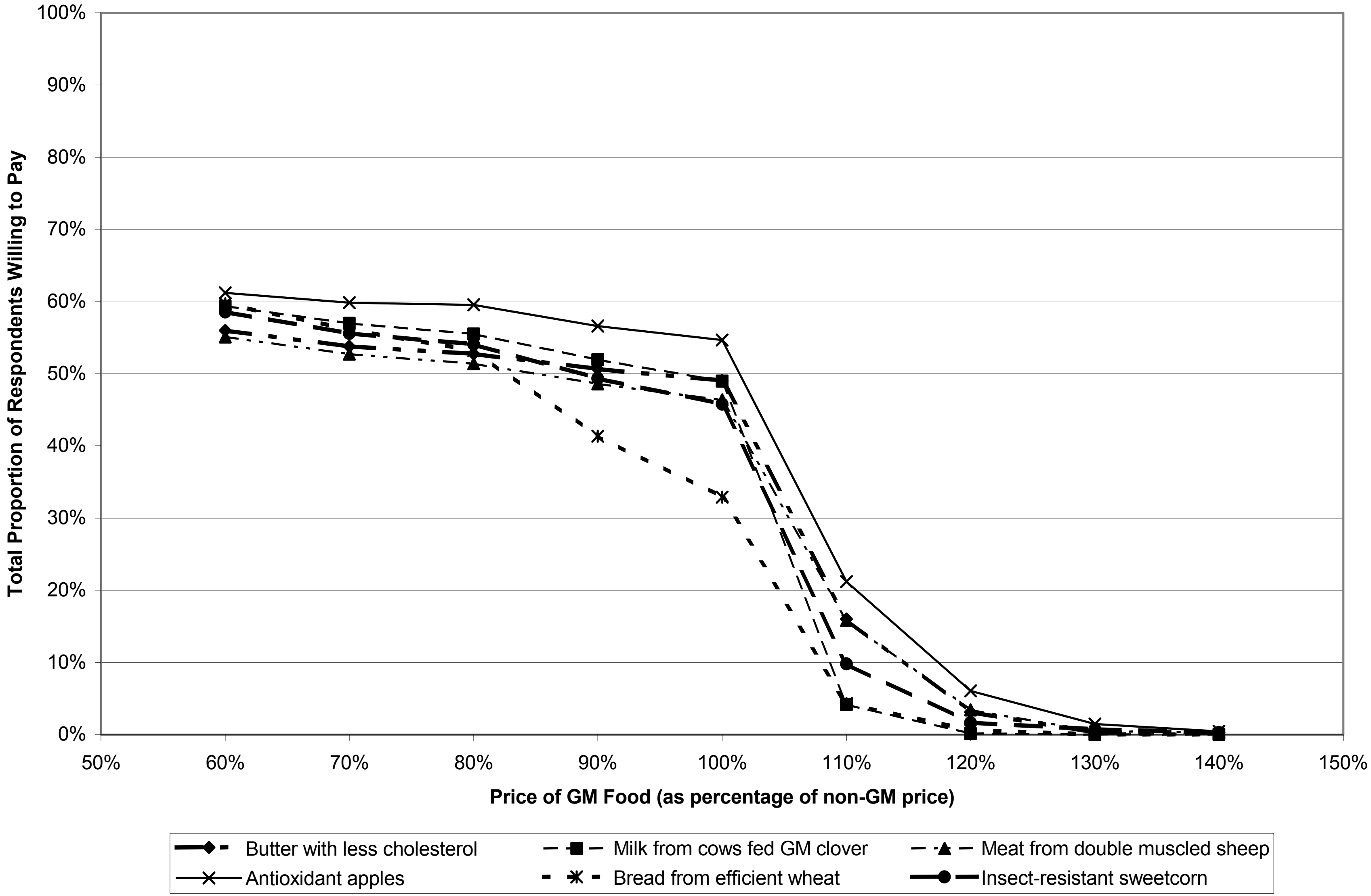


Figure 2 provides another view of the same data. In this figure, the horizontal axis represents the price of the GM food product as a percentage of the non-GM counterpart. Prices to the left of 100% represent discounts for GM food, and prices to the right represent premia. Each ten per cent step represents a different willingness to pay from the range of options provided. The vertical axis is the percentage of respondents who indicated they were willing to pay at least that price for the GM food product. It is therefore a cumulative measure. Several interesting characteristics of the data are apparent in this figure. None of the willingness-to-pay curves rises higher than 62 per cent of the sample; for all products, there was an upper limit to the percentage of respondents who would purchase them. Furthermore, each curve represents a different product, but they are all the same shape and largely in the same position on the diagram. This similarity suggests that the respondents' reactions were about the same for all products.

2.4 Estimating the Demand Curve

The willingness to pay diagram (Figure 2) is not the standard economic presentation of demand. In a demand diagram, price is on the vertical axis and quantity is on the horizontal axis. This is done in Figure 3. In this figure, price is again given as a percentage of the non-GM price, making it the relative price of GM to non-GM. Quantity is given as the percentage of respondents who would purchase the GM product at each relative price. It can therefore be interpreted as a market share percentage. The curves for the products are quite steep near the vertical axis – relatively few respondents will purchase GM food at high premia. The demand curve flattens out between relative prices of 110 per cent and 90 per cent of the non-GM price (a premium of 10 per cent and a discount of 10 per cent), which can be read from the vertical axis. Generally, about one-half of respondents express a willingness to pay in this range. At higher discounts, the demand curve is again rather steep. Larger and larger discounts do not entice many more people into the market.

The demand curves in Figure 3 are sigmoid or S-shaped. Such a curve can be represented by a number of functional forms. We chose to use a Weibull distribution, given its tractability. The average demand curve can thus be represented by the following equation:

$$f(Q_G) = \exp(-\exp(g(P_G))),$$

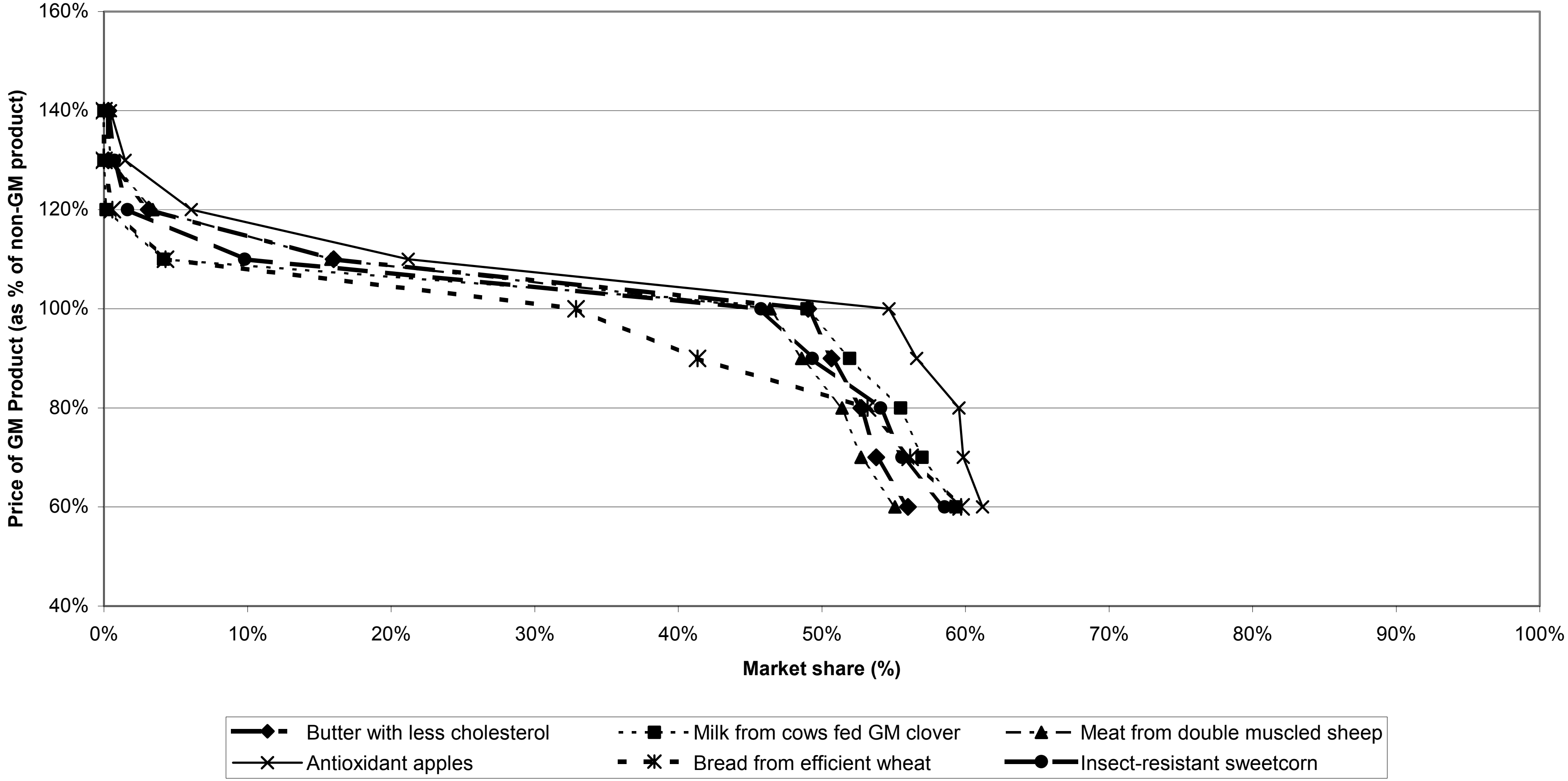
where $f(Q_G)$ is some function of the percent of product that is GM and $g(P_G)$ is some function of the price of GM food. It is necessary to consider the function of quantity and the function of price because the curve does not follow the Weibull distribution exactly. The quantity, for example, does not cover the full interval from 0 to 1, but only reaches at most 0.62 of the survey sample. This yields the function:

$$f(Q_G) = (Q_G) / 0.62.$$

Two aspects to the price function need to be considered. The centre of the function is not where quantity equals zero (as in the unadjusted function), so the true centre needs to be estimated. In addition, the curvature of the function needs to be estimated. These two adjustments can be made by including parameters β_0* and β_1, respectively. This yields the equation:

$$Q_G / 0.62 = \exp(-\exp((P_G + \beta_0^*) \cdot \beta_1)).$$

Figure 3
Demand for Genetically Modified Food Products – Survey Results



Rearrangement of the terms leads to a linear function on the right-hand side:

$$\ln(-\ln(Q_G / 0.62)) = \beta_1 P_G + \beta_0 ,$$

where β_0 is equal to $\beta_0^* \cdot \beta_1$ and β_0 and β_1 are the parameters to be estimated. The dependent variable is calculated from the percentages of respondents who are willing to buy the GM food products at each price level, and price is the independent variable. The parameters can be estimated via OLS regression.

It is also possible to add a vector of dummy variables to this equation to account for differences in reactions by type of product offered. If the type of product affects the placement of the curve and not the curvature, then the dummy variables are simply additive:

$$\ln(-\ln(Q_G / 0.62)) = \beta_1 P_G + \beta_0 + \mathbf{D},$$

where **D** is a vector of five dummy variables, one for each product less one omitted base product.

From the survey results, we had 54 observations, being the percentage of respondents willing to pay for each product at each price (six products x nine prices = 54 observations). Estimating the full equation with seven variables resulted in 47 degrees of freedom. Three different equations were estimated in Excel using the Regression tool from the Data Analysis menu. The results of the regression analysis are presented in Table 5.

Model one estimated only the parameters β_0 and β_1, so it considered only the impact of price on the percentage of respondents willingness to purchase GM food. It shows that there is a strong relationship between the dependent and independent variables. Furthermore, the high adjusted R^2 suggests that the functional form (the sigmoid curve) chosen for the analysis is correct.

Model two included the vector of dummy variables, so it estimated a different regression intercept term or distribution centre for each product, with the GM sweetcorn as the base product. The dummy variables increase the fit of the model slightly. However, the only one that is significant is the parameter for GM apples. The low t-scores for the other dummy variables suggest that all the product except apples are eliciting similar reactions from the respondents.

This finding for model two led to the specification of model three. It included β_0 and β_1 and one dummy variable, for the GM apples with greater antioxidants. This model seems to represent the survey data best, showing the strong relationship between price and quantity and including the additional impact from the differential reaction to the GM apple product.

The estimated model is plotted in Figure 4. For this figure, percentage of product that is GM was plotted against the estimated price for GM food at that percentage. Two curves were estimated, one for apples and one for all other products. This figure also includes the average raw results from the survey for purposes of comparison. The figure shows that the estimated curves mimic the survey data well. As a result of the good fit of the regression models and the appearance of this figure, we are confident in our estimate of the relationship between price of GM food and the percentage of people willing to purchase it.

We do realise that this analysis of willingness to pay data is somewhat different from the standard treatment of interval contingent valuation data. Standard practice would be to generate a probabilistic function based on whether or not respondents were willing to purchase GM food at each price level. The probability that a respondent would agree to purchase the product would be a function of the relative price, the type of product, and perhaps some socio-demographic variables.

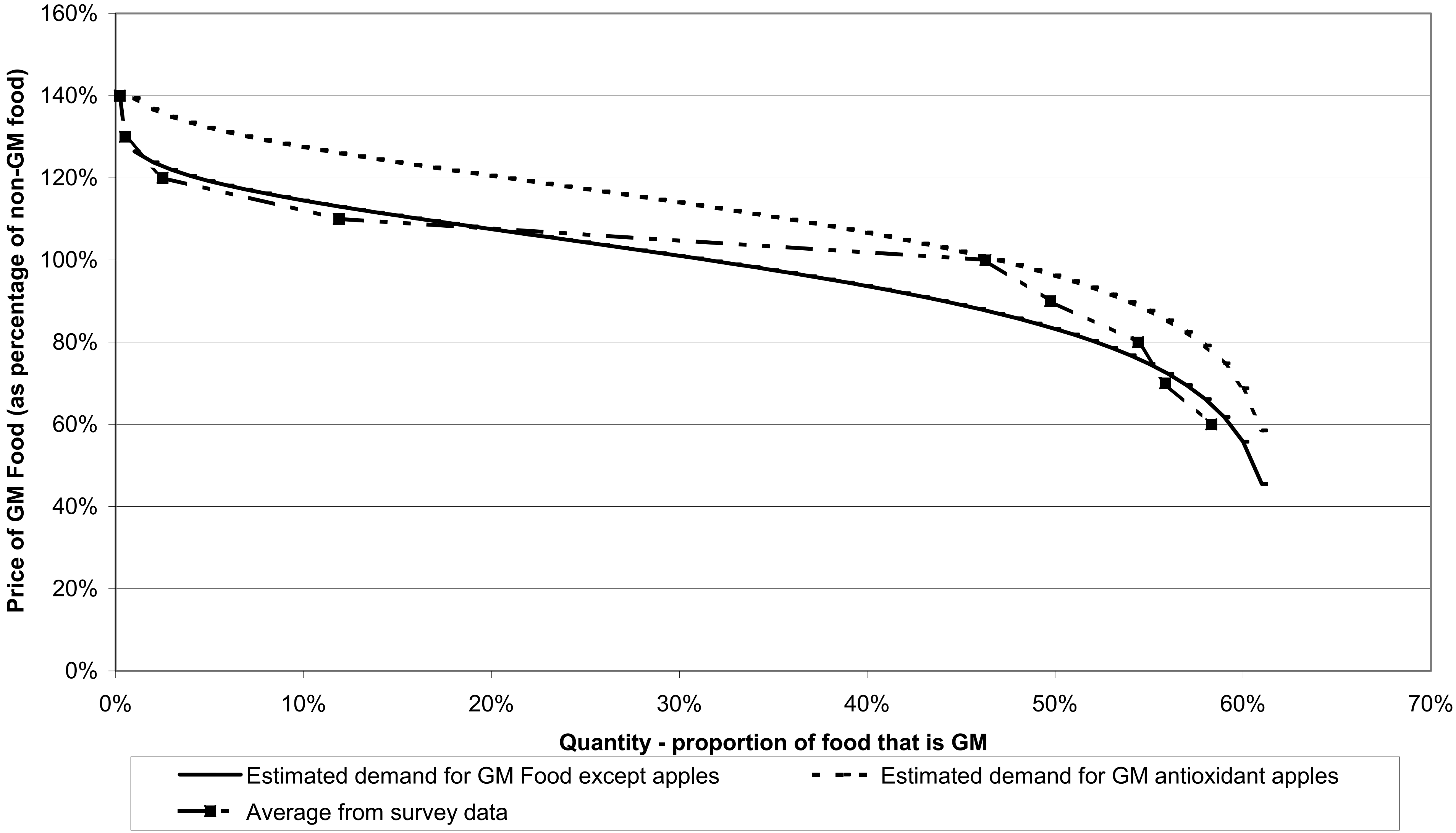
There are two reasons for our treatment of the data here. The first concerns problems with indifference, that is, with a relative price of GM to non-GM food equal to 100 per cent. The large number of respondents who chose an indifferent response suggests that it is important to model this accurately. In an interval treatment, given the data collected, these respondents would be modelled as willing to pay between 100 per cent and 110 per cent of the non-GM price for GM food. That is, we know that they would pay 100 per cent and we know that they would not pay 110 per cent, but we do not know their exact willing to pay within that interval. In future work, it would be better to specify an interval that includes indifference as its midpoint, e.g., willing to pay 95 per cent to 105 per cent of the non-GM price. However, the present work takes the responses from the 100 per cent category to mean that the respondents are truly indifferent, rather than that 100 per cent is a lower bound. It therefore avoids ascribing to respondents a willingness to pay a premium, although as a consequence it might have biased downward the true willingness to pay by 5 per cent overall.

Table 5
Results of Regression Analysis

	Parameters (*t statistic*)		
	Model 1	**Model 2**	**Model 3**
β_0	-7.38*	-7.36*	-7.23*
	-21.58	*-21.71*	*24.70*
β_1	6.84*	6.84*	6.84*
	20.66	*23.88*	*24.29*
Dbutter		0.034	
		0.134	
Dshpmeat		0.143	
		0.557	
Dwheat		0.115	
		0.449	
Dapples		-0.762*	-0.891*
		-2.973	*-4.563*
Dmilk		0.352	
		1.371	
Dswtcorn		base	
Adjusted R^2	0.889	0.917	0.920

* significant at 1% level

Figure 4
Demand for Genetically Modified Food Products – Results of Model Estimation



The second reason for the regression estimate of the demand curve rather than a probabilistic estimate of willingness to pay was the importance of including refusal responses. In order to estimate a probabilistic model, one needs to assume the probability distribution of the responses, which, furthermore, needs to be a continuous function and which generally has a central tendency. If one considers just the responses of those willingness to pay for GM food, then these assumptions are not likely to cause difficulties. If one is concerned with how the entire market for food could react in the presence of these GM food products, then it is important to consider refusal responses, as well. How to include refusal responses in an analysis of willingness to pay that is based on notions of probability is a technical issue beyond the scope of this report. Their inclusion, however, would make probabilistic analysis of interval data difficult and would render the results questionable.

For these reasons, we have opted for the simpler approach described above. The result is an equation that expresses relative demand for GM and non-GM food as a function of their relative price. Obtaining this estimated equation allowed us to take the analysis to its next logical step, as described in the following section.

2.5 Optimal Uptake of GM Crops

By transforming the raw willingness to pay data from the survey of New Zealanders into a demand curve that relates market share to relative price of GM food, we are able to extend the analysis further. We can calculate the relationship between industry revenues and percentage adoption of GM crops. This allows us to identify the adoption rate or uptake percentage that maximises industry revenues.

Recall first that total revenue is found by multiplying price times quantity:

$$TR = P * Q,$$

where TR is total revenue, P is price, and Q is quantity for a given commodity.
In a segmented commodity market, both GM and non-GM commodities would need total revenue calculated separately:

$$TR = (P_N * Q_N) + (P_G * Q_G),$$

where the subscripts N and G denote non-GM and GM versions of the same commodity, respectively.

We can reduce the number of terms in the equation by fixing the amount of production in the commodity, so that the proportion of a commodity that is non-GM is simply:

$$Q_N = 1 – Q_G .$$

This simple specification does not make an allowance for greater productivity of GM crops, although that complication can be included by reducing the Q_G term by the productivity gain:

$$Q_N = 1 – (Q_G /(1 + gain)).$$

This more complex equation is not used further. We can also normalise the prices in the equation, such that the price of the non-GM commodity is set to unity (1). Thus we have:

$$TR = (1 - Q_G) + (P_G * Q_G),$$

which is essentially an index of total revenue, equal to 1 when all production is non-GM.

The regression models estimated above allow total revenue to be expressed as a function of one variable, Q_G. Using the parameters estimated for model three and excluding the case of GM apples, we have:

$$TR = 1 + (P_G * Q_G) - Q_G$$

$$TR = 1 + Q_G (P_G - 1)$$

$$TR = 1 + Q_G((1 / 6.84) * (\ln(-\ln(Q_G / 0.62)) + 7.23) - 1)$$

When some GM crops are adopted and they represent a small fraction of total output, the GM food products can be sold at a premium over non-GM commodities. This is evident in the demand curve shown in Figure X and the underlying survey data. At these small fractions, total revenue is increasing. As the amount of GM product increases, the price must fall in order to clear the market. At some percentage uptake, total revenue stops climbing and starts to decline. At higher uptake percentages, the prices of GM and non-GM products reach parity and the industry as a whole has no more revenue than it had at a nil uptake of GM crops.

The point at which the industry has maximum total revenue represents the optimal production of GM crops. Evaluation of the above equation at different levels of GM production reveals that the uptake of GM crops that maximises total revenue is 15 per cent. This level of uptake leads to a total revenue index value of 1.0162, which indicates that a 15 per cent uptake of GM crops would lead to an increase in industry revenues of 1.62 per cent. For GM apples with greater antioxidants, the optimal uptake rate is 26 per cent, leading to increased revenues of 4.33 per cent.

The maximum level of total revenue is driven largely by two factors: the percentage of respondents who rejected each GM product and the percentage of respondents who were indifferent to the products. Consumers who refuse GM products limit the potential market share of GM products and, conversely, guarantee a minimum share for non-GM. In this survey sample, the percentage of respondents who refuse each product was about 40 per cent. This is an unsurprising percentage given the literature cited above. Indifferent consumers also affect the total revenue calculations because they limit the possibilities for charging premium prices. For this survey, the percentage of respondents who were willing to pay the same price for GM and non-GM products was 30 per cent to 45 per cent. The net result is apparent in the calculation of total revenue: growers of the most popular GM product, anti-oxidant apples, can charge some consumers a 17 per cent premium to maximise industry revenues. However, they can only charge 26 per cent of the market this price. Once the increased revenue is averaged into the whole industry, total revenues are only 4.3 per cent higher.

The fairly small increases in average industry returns can be increased in several ways, which can loosely be separated into changes in the overall market and changes to New Zealand's position in that market. As should be evident from the above analysis, two broad changes to the market for GM food would improve estimates of total revenue. The first would be to have fewer consumers refusing the product. The more consumers are willing to purchase GM food, the larger the revenues from those crops can be. A second beneficial change would be a decrease in those who are indifferent to the products. The anti-oxidant apples in the survey are a case in point: over 20 per cent of respondents were willing to pay a premium for them, and the increase in total revenue was over twice the average increase.

The impacts of these changes in the market for GM food can easily be analysed with the demand equation generated from the survey data. In the regression analysis, the maximum percentage of the market that could be GM was set at 62 per cent. This figure was based on survey data for the most acceptable GM product. Changing the maximum percentage of consumers willing to buy GM food from 62 per cent to 90 per cent changes the increase in total revenue from 1.62 per cent to 2.35 per cent. This figure is the result of a 22 per cent uptake of GM crops and an 11 per cent premium. Reducing the number of indifferent consumers is not as straightforward. However, the following equation has a higher percentage of consumers WTP for GM food (90 per cent), a smaller region of indifference, and a wider spread of maximum and minimum relative prices than the estimated equation above:

$$\ln(-\ln(Q_G/0.9)) = 4.0 * P_G - 4.50 .$$

If this equation is used to evaluate total revenue for agriculture, optimum uptake is 24%, the price premium is 19%, and the increase in total agricultural revenues is 4.67%.

Changes to New Zealand's position in the market could increase revenue even more. One possibility is that New Zealand could concentrate on supplying the GM product. In this scenario, New Zealand would have a very high uptake of GM crops, but its contribution to the total world market would be small enough that high premiums could still be maintained. A second possibility is to segment the market so that consumers who are willing to pay more are charged higher premiums. This would require New Zealand to market and price its products effectively. Either strategy has the possibility of increasing revenues for agriculture.

2.6 Conclusion

In this chapter, we have examined consumer reactions to GM food. In particular, responses to the New Zealanders and biotechnology survey have been presented, discussed, and analysed. From the responses, we have estimated a demand curve for GM food that accounts for the full range of consumer reactions, from outright rejection to a willingness to pay a premium. Analysis of this demand curve allows us to draw a few conclusions about the market for GM food. The market is strongly affected by the large minorities who are indifferent to GM food and who refuse to consume GM food. These two groups limit the possibilities of charging a premium for quality-enhanced products, so that the optimal uptake of GM crops for the agricultural industry is less than one-quarter of total production. Reducing the number of consumers rejecting GM food has been shown to increase industry revenues, but only by a small amount. On the other hand, reducing the number of indifferent consumers could have a larger impact on revenues.

Chapter 3
Trade Impacts of GM Production

This chapter of the report combines the above analysis of the data from the survey of public perceptions of biotechnology with the Lincoln Trade and Environment Model (LTEM), a model of trade in agricultural commodities. The LTEM has in the past been used to assess possible impacts from adopting GM crops, using assumptions and data to create various scenarios (Saunders & Cagatay, 2003, 2001; Saunders, et al., 2003). With these new data, we are able to extend previous work by incorporating better estimates of optimal uptake rates and possible price impacts. The following sections begin with a review of prior work, then present the key information about the LTEM, and finally analyse the survey data using the model.

3.1 Review of Prior Work

Several studies have estimated the impacts of adopting GM crops. Both partial equilibrium and general equilibrium models have been used to examine the impacts of productivity increases and consumer heterogeneity. Generally, these models have considered current GM crops (soybeans and maize/corn) and/or GM wheat, all with input-oriented modifications. Some research has also examined commodities that are important to New Zealand's agricultural trade, such as meat and dairy products. This research was summarised in Saunders, et al. (2003).

One example of partial equilibrium modelling is Frisvold et al. (2003). The model was similar to the LTEM, and demonstrated that genetic improvements in US crops can lead to substantial increases in total welfare. These gains were largely the result of increases in consumer surpluses, although the US, in contrast to the rest of the world, also increased its producer surplus. This distribution of effects between consumers and producers is to be expected because of the price-inelastic nature of demand for agricultural commodities. It is also similar to the findings of Moschini et al. (2000) in their modelling of the soybean sector. Importantly, they found that U.S. farmers fared worse when GM technology was made available to others countries and when the technology increased yields as opposed to simply reducing costs.

Computable general equilibrium (CGE) trade models have also been used to analyse the impact of GM crops on international trade (Anderson and Nielsen, 2000a, 2000b; Anderson et al., 2000; Stone et al., 2002; Jackson and Anderson, 2003). The first and most basic finding of this research was that GM crops, by using the factors of production more efficiently, reduced prices and improved total social welfare. Countries extensively adopting GM crops gained by increasing their productivity at a faster rate than their competitors. They thereby increased their market share relative to non-adopting countries. Importing countries improved their welfare, too, because of lower commodity prices and reallocation of agricultural resources.

We are aware of only one example in the peer-reviewed literature of an attempt to model preferences for genetically modified crops that have consumer benefits. The focus of the literature has instead been on input-oriented GM crops like Roundup Ready (RR) soybeans and RR wheat. Saunders & Cagatay (2003), however, included scenarios in which consumers preferred certain GM products. As industry and government look towards future impacts of

GM technologies, estimating the impact of second-generation products will require modelling of such preferences.

The research on trade impacts has reached several key conclusions. First, consumers in all countries are better off when GM crops are more productive, provided that these consumers are not opposed to the technology. Consumer welfare increases because the increased supplies lower food costs. Secondly, agricultural producers in countries extensively adopting GM crops can gain by increasing their productivity, provided GM crops are not universally adopted. Widespread international adoption of productivity-enhancing GM crops can hurt agricultural producers by causing commodity prices to fall.

3.2 The Trade Model

The LTEM was used to quantify the price, supply, demand and net trade effects of producing the GM crops described in the New Zealand survey on public perceptions of biotechnology. 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, the methodologies used to incorporate trade and domestic policy shocks, and the various parameters of the LTEM, as well as its modified version used to simulate impacts of GM production, are described in detail in Saunders & Cagatay (2001; 2003), and Cagatay & Saunders (2003). However, a brief description of the model is provided here in Table 6. 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.

A partial equilibrium 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 traceability 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 for examining New Zealand trade.

There are nine countries and 16 agricultural commodities included in the model (see Appendix Table A1 for a list of these). The model works by simulating the commodity-based world market-clearing price on the domestic quantities and prices in each country, which may or may not be under the effect of policy changes. 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) and 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 represent substitute commodities. Therefore, supply of a GM product (qsg_i) was specified as a function of the supply side shifters (shf_{qsg}), producer price 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

Table 6
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 (see Appendix?)
Commodity Coverage	16 (see Appendix A)
Country Coverage	9 (see Appendix A)
Behavioural Equations (per commodity, country)	Domestic supply Domestic demand* (food, feed, processing) Stocks 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: (Cagatay & Saunders, 2003; Saunders & Cagatay, 2001, 2003)

(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.

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

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

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 were 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.

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

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

3.3 Modelling the Survey Results

The survey results were used to adjust three sets of LTEM inputs. First, some products offered to respondents were more productive than their GM counterparts; the LTEM was adjusted to reflect this. Secondly, the responses to the survey indicated consumers' willingness to pay for GM food. The calculated demand for GM food was included in the LTEM. Finally, the optimal uptake of GM crops as estimated above was used to estimate the impact of GM crops on New Zealand. The following discusses these three sets of inputs in detail.

3.3.1 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 either the commodities or countries. In the second one, productivity increases were simulated according to the descriptions in the survey. These descriptions from the survey were translated into percentage productivity increases for the trade model. The exact changes are given in Table 7. Of the survey products, wheat was the only one whose productivity change was stated in the survey; GM wheat was described as 25 per cent cheaper to grow. In the model, this became a productivity shift of 25 per cent. 'Double-muscling' was described as producing more meat per animal, although the exact productivity shift was not specified. In the model, this shift has been set at 25 per cent for both Beef and Sheepmeat. For the other products, no productivity change was offered in the survey, so no shifts were included in the model.

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 commodities in the first scenario, in the second scenario the exogenous productivity shock was reflected in an exogenous increase in shift variable for all GM commodities, shf_{qsg}, 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.

Table 7
Productivity Shifts

Commodity	Increased Production from GM
Wheat	25%
Coarse grains	no change
Maize	no change
Oilseeds	no change
Oilseed meals	no change
Oils	no change
Apples	no change
Kiwifruit	no change
Beef and veal	25%
Sheepmeat	25%
Raw milk	no change
Liquid milk	no change
Butter	no change
Cheese	no change
Whole milk powder	no change
Skim milk powder	no change

3.3.2 Consumer Demand for GM Food

The analysis of the survey data presented in the first part of this report yielded demand inputs for the trade model. The price level that led to the highest total revenue for the industry was used to create a price premium in the model for GM food. For all products except Apples, a demand preference of 11 per cent was included; for apples, demand was shifted by 17 per cent. The preference shift was modelled for all products in the survey. The exact preference shifts used are contained in Table 8.

The same preferences shifts are modelled for all countries in the model. This assumption of common preferences in all countries is the result of two considerations. First of all, the results we have found regarding the extent of indifference to and rejection of GM food for New Zealand are fairly similar to responses in Australia (James & Burton, 2003), Canada (Sheehy et al., 1998), the EU (Gaskell et al., 2004), and the UK (Burton et al., 2001); Japan's consumers may be even less accepting of GM food (McCluskey et al., 2001). As discussed above, the size of these two groups of consumers is a main driver of the optimal uptake rate and the market premium for GM food. Thus, while the estimated demand equation may not apply universally, it does apply for much of the world's food market and for many of New Zealand's main export markets. Secondly, our estimated demand equation considers the full range of possible prices and quantities. By contrast, other research has calculated an average price from those consumers willing to pay for GM food and then applied that price to the entire market. At the worst, we have substituted one assumption of universality for another. In fact, the demand equation in the present research better represents the range of consumer reactions that researchers have found in countries around the world.

For purposes of comparison, a second demand level was also used in the model. For the second level, GM food was modelled as having exactly the same demand as non-GM food, that is, consumers had no preference either way. For this level, the shifter variables in equations 3 and 4 stayed at their initial value for all products, $shf_{qcg} = shf_{qc} = 1$.

Table 8
Demand Premium

Commodity	Demand Preference for GM food
Wheat	11%
Coarse grains	no change
Maize	no change
Oilseeds	no change
Oilseed meals	no change
Oils	no change
Apples	17%
Kiwifruit	no change
Beef and veal	11%
Sheepmeat	11%
Raw milk	11%
Liquid milk	11%
Butter	11%
Cheese	11%
Whole milk powder	11%
Skim milk powder	11%

3.3.3 Uptake of GM Crops

The third set of inputs considered in this modelling was the rate of adoption of GM crops. In the LTEM, production of all commodities in all countries is assumed to be segregated into GM and non-GM varieties. For all countries except New Zealand, the data for the GM adoption rate were obtained from several sources (Dargie, 2002; ISAAA, 2003; Miles, 2002; Schnepf, Dohlman, & Bolling, 2001; Stone, Matysek, & Dolling, 2002). For New Zealand, the uptake rate is a key consideration in the modelling. The earlier analysis calculated an optimal uptake rate of GM crops, and the demand for GM food used in the modelling was the level that would result from the optimal quantity of production. Therefore, the uptake of GM crops in New Zealand was set at 26 per cent for Apples and at 15 per cent for all other crops. These are the levels calculated above. The full list of uptake rates are given in Table 9.

Table 9
Share of GM Production and GM Feed Consumption in Total

GM Production	AR	AU	CN	EU	JP	MX	NZ	US	RW
Wheat	0.2	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Coarse grains	0.2	0.1	0.15	0.1	0.1	0.001	0.15	0.4	0.15
Maize	0.2	0.1	0.15	0.1	0.1	0.001	0.15	0.4	0.15
Oilseeds	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.65	0.15
Oilseed meals	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.65	0.15
Oils	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.65	0.15
Beef and veal	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Sheepmeat	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Raw milk	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Liquid milk	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Butter	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Cheese	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Whole milk powder	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Skim milk powder	0.5	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15
Apples	0.2	0.1	0.15	0.1	0.1	0.1	0.26	0.4	0.15
Kiwifruit	0.2	0.1	0.15	0.1	0.1	0.1	0.15	0.4	0.15

Sources: (Dargie, 2002; ISAAA, 2003; Miles, 2002; Schnepf et al., 2001; Stone et al., 2002)

3.4 Results of Empirical Analysis

In the modelling, the specified changes are modelled over ten years. For each year, data on consumer, producer, and trade prices and volumes are generated. To summarise these data, the total revenue for the agricultural sector is calculated. This total revenue is then compared to the base scenario, in which there are no shifts, and the percentage change is found. Table 10 presents only this summary statistic for each scenario: how much does total revenue to the agricultural sector change as a result of the modelled shifts in productivity and consumer demand? If the only change is in productivity of GM crops, and no price change is assumed, then agricultural revenues fall by two per cent. This level of change is not significant in the context of the LTEM, given the levels of estimation and abstraction present in such a model; it is nearly a nil result. If consumers are willing to pay the estimated premiums for GM food, then revenues to the New Zealand agricultural sector increase by six per cent. Finally, if GM crops are more productive and GM food attracts a price premium, then New Zealand agricultural revenues increase by four per cent. Overall, these results indicate that increased productivity slightly decreases sector revenues, and price premiums lead to somewhat higher returns.

Table 10
Changes in Producer Returns from Optimal Uptake of GM Crop

Consumer impact	No productivity impact	Productivity increased
No demand effect	Base	-2%
With demand effect	6%	4%

These results do reflect basic economic theory and experience relating to increases in productivity, especially for agricultural products. Increased production reduces agricultural revenues because agricultural commodities tend to have an inelastic demand. The price fall required in order to sell the extra production is proportionally greater than revenue from the extra supply itself. Without a consumer reaction, lower costs of production can be expected to lead to lower producer returns. With a consumer reaction, New Zealand can obviously benefit by selling products for which consumers are willing to pay a premium.

It is also important to note that the revenue changes calculated here are rather small. The impact of productivity increases – rather large increases of 25 per cent for the meat sector, an import export sector for New Zealand – does not lead to greater returns. The impact of a consumer preference for GM food is also not very large. It is certainly on the order of the changes in total revenue calculated in the Chapter 2 of this report. Those calculations suggested that total revenue could increase 1.62 per cent to 4.33 per cent, depending on the GM food product in question. The trade modelling indicates potential sector gains of six per cent, roughly the same magnitude.

3.5 Conclusion

There are several important qualifiers to these results. The first qualifier is that this model explicitly assumes that a country can produce both GM and non-GM commodities and segregate them in such a way that they can be identified by consumers. For example, New Zealand is able to produce both GM and non-GM meat. This assumption is often presented as a case of GM-sensitive consumers wanting to know whether their food has been contaminated with altered genetic material. In the present research, this assumption also means that the agri-food sector is able to identify quality-enhanced GM commodities and segregate them through the supply chain. The end consumer would have to be assured that the product being purchased was, in fact, the enhanced GM product it claimed to be. Otherwise, a price premium for GM food could not be maintained.

The second qualifier for these results concerns the consumer reactions modelled. As discussed above, the market price for GM food derived from the survey data depends heavily on the amount of GM product offered. The optimal uptake of quality-enhanced GM crops might be 15 per cent to 26 per cent, considered over the worldwide market. This raises the question of which producers will provide those GM products, and who will control the level of uptake. If the uptake is controlled so as to maximise agricultural revenues, then GM-adopting farmers (and countries) can increase their gross incomes and capture rents from constraining supply. On the other hand, if these GM varieties are freely available to farmers, then one would expect production to expand until the cost of providing the products was just covered by the income they generated. In that case, GM products would be no more profitable than non-GM products, and total revenue to the sector could even fall. At even higher rates of GM crop uptake, a premium for non-GM food would be expected to develop, given the percentage of consumers who wish to avoid GM food or who would buy it only at a discount.

A third caveat with these results is that the price response estimated from this survey of New Zealanders was extrapolated to the rest of the world. It is highly likely that this is not exactly correct. It is a commonplace in research on consumer attitudes to GM that respondents in different countries have different attitudes and different willingness to pay for GM and non-GM products. Nevertheless, as discussed above, the demand curve estimated here is a reasonably good approximation until further information is available.

Chapter 4
Conclusion

This research has examined the intentions to purchase and willingness to pay for several specific products of genetic engineering. Using data from a recent survey of New Zealand public perceptions of biotechnology, we have estimated a demand curve for GM food, estimated the optimal uptake of GM food crops in the agricultural sector, and used this information to analyse the impacts of GM crop adoption on New Zealand's agricultural sector.

The survey allowed for a range of willingness to pay responses for each specific GM food product. For all products, about 30 per cent to 45 per cent of respondents were indifferent to the GM products. They stated they were as willing to pay for a GM product as a non-GM substitute. For four of the six products, there were respondents willing to pay up to 40 per cent more for the GM products, reflecting the value that these respondents felt they would receive from the consumer-focused enhancements described in the survey. For the other two products, the maximum premium was 20 per cent. The number of respondents willing to pay a premium varied from four per cent to over 20 per cent of the sample, depending on the product. Those willing to buy GM food at a discount showed similar variation over the six products, with between seven per cent and 27 per cent of the sample expressing a willingness to pay for GM food at a discount. The discounts ranged from –10 per cent to –40 per cent for all products.

This survey also allowed respondents to register their refusal of GM food on a product-by-product basis. For each product, rejection was fairly consistent at about 40 per cent of respondents. Interestingly, each product was rejected by a somewhat different 40 per cent of the sample, so that only 31.4 per cent of the sample rejected all GM products whereas 51.6 per cent rejected at least one product.

Respondents' willingness to pay for GM food exhibited a strongly sigmoid pattern: very few were willing pay a high premium, many were concentrated around an indifferent reaction, and high discounts attracted fewer and fewer respondents. By using an appropriate functional form, we were able to use regression analysis to estimate the impact of the price of GM food on the percentage of respondents willing to purchase the products. This appears to represent the first attempt in the published literature to account for the full range of consumer responses in a single market demand estimate.

This estimated demand curve, in turn, allowed for a calculation of maximum total revenue possible from adopting GM crops. The results indicate that the agricultural sector as a whole can maximise its income from adopting GM crops with an uptake rate of 15 per cent for most crops and 26 per cent in the case of apples with greater anti-oxidants. Although the other five products did not have identical numbers of respondents expressing identical willingness to pay, the variation was not enough to affect the demand curves of the specific products. The analysis of the optimal uptake rate for GM crops found that agricultural revenues could increase by two to four per cent. This idea of the optimal uptake of GM technology, given consumer demand, has not been raised elsewhere, although it is a straightforward extension of a willingness to pay analysis. By moving away from an analysis of average demand or average price for GM food, and by avoiding an all-or-nothing approach, we have been able to provide a more useful estimate: what the agricultural industry can do to make optimal use of GM crops. An important caveat to this analysis is that it assumes that the GM and non-GM products can be segregated in ways acceptable to consumers of both products.

Using an estimate of optimal uptake of GM crops, the productivity changes from the products in the survey, and the data on respondents' willingness to pay, we modelled potential impacts on the New Zealand agricultural sector. From these results, it is clear that if the worldwide industry can control access to GM cultivars so as to maximise total revenues, New Zealand agriculture can increase its producer revenues by four to six per cent, given proportionate access to the technology. If New Zealand is one of only a few providers of GM crops and can keep production low enough to maintain a consumer premium, then it could gain even more. Again, this analysis depends on appropriate segregation of GM and non-GM products.

These results also point to areas that require further investigation. An important area for future research is the demand curve for different countries. It is now a commonplace in consumer research on GM food that consumers in different countries have different reactions to GM products. The demand estimate provided here is specific to New Zealand. The general proportions of indifferent and refusing consumers are approximately the same as in some countries, but are likely quite different from others. Given New Zealand's dependence on export markets, more precise estimates of demand for GM food in other countries are desirable. A second important area of research is the impact of different product enhancements on willingness to pay. In the present research, both the product and the enhancement were varied simultaneously. It is therefore unknown whether consumers have different preferences regarding which food is modified, whether they have preferences regarding the modifications themselves, or whether there is some interactive effect between the specific food product and the enhancement.

In conclusion, the results from this New Zealand survey suggest that quality-enhanced GM products could be a strong niche product that attracts a premium. The industry has the best performance when it can limit supply of quality-enhanced products. Without limits on production or access to the technology, the sector can expect any excess profits from biotechnology to be squeezed out of the sector rapidly. The uptake rates that lead to increased total revenues are not very high, in fact. The large number of indifferent consumers and the sizeable minority who wish to refuse GM food limit the sector's ability to charge a premium for these products. Finally, increases in productivity that are not accompanied by consumer premiums would lead to reduced producer returns.

Appendix

Table A1
Country and Commodity[a] 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	

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

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