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Neoclassical consumer theory and genetically modified food

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Summary

Three axioms underpin consumer choice in neoclassical theory: weak order, independence, and continuity. Two of these axioms may not hold, however, for consumers' choices regarding genetically modified (GM) food. Consumers may evaluate product attributes differently depending on whether the food is GM or not, violating attribute independence. Some consumers may not want GM food at all, violating continuity. The axioms were empirically investigated with a choice experiment survey. The paper discusses evidence of violations of both independence and continuity, as well as a non-neoclassical approach to modelling consumer choice.

Key words: genetically modified food; neoclassical; bounded rationality; choice modelling

Introduction

The research reported in this paper addresses two issues. The first is whether consumers consider the specific attributes of genetically modified food (GMF) products, or instead react generally to the process of genetic modification (GM) in food. Some research has found that consumers make judgements about specific GM products offered (Burton & Pearse, 2002; Frewer, Howard, & Shepherd, 1997). Other research has found a strong correlation between general attitudes to GM and product-specific reactions, concluding that consumer reactions are driven by these general attitudes (Bredahl, 2001). The second issue addressed is whether some consumers demonstrate non-compensatory preferences. Public opinion research suggests that a significant minority of consumers are categorically opposed to GMF: they do not want it at all (Bredahl, 2001; Gaskell et al., 2003; Heller, 2003). Because these consumers do not appear willing to accept compensation in return for consuming GMF, their preferences may be considered non-compensatory.

Research on demand for GMF is important because consumer reactions to GMF are creating difficulties and uncertainties in the agri-food complex. The introduction of GM crops has affected world commodity trade, both commodity prices and quantities traded. A price premium for non-GM commodities has developed, although it has been suggested that there is sufficient supply of non-GM crops so that large premiums are not required (Parcell, 2001; USDA, 2001). The impact on trade volumes is more difficult to assess, and evidence is largely anecdotal. Some reported impacts are: Canada no longer exports canola to the EU, US maize exports to the EU have nearly disappeared, and Brazil has gained ground in the world soybean market, possibly as a result of its non-GM soybeans (Foster, Berry, & Hogan, 2003). These trade impacts are due, in part, to retailers and processors avoiding GM foods and ingredients in New Zealand and other countries (CEC, 2000; Chapple, 2001; Robertson, 2002).

Consumer reactions to GMF have also hindered the introduction of new GM crops. For example, biotechnology company Monsanto has abandoned plans to grow GM canola in Australia (Black, 2004) and decided not to pursue GM wheat, a new biotech crop, at all (BBC News, 2004). Consumer reactions even seem to be important enough to retard scientific research and development in agriculture (Huffman, Rousu, Shogren, & Tegene, 2003). Thus, research on demand for GMF is important for understanding the current market and for assessing the potential demand for any future GMF products.

Theory

One theoretical basis for an investigation of consumer demand for GMF is the neoclassical model of consumer choice. Individuals are held to consume goods, in this case food, because the goods provide satisfaction or enjoyment, *i.e.*, utility. The goods they choose to consume out of all possible goods are the ones that provide the most utility, subject to constraints such as budgets and time.

Three axioms underpin the neoclassical theory (Fishburn, 1988):

1. Every good in the market belongs to a weak order. This order makes it possible to say whether each good is preferred or not preferred to each other good. Because it is a weak order, there may be goods about which a consumer is indifferent: they are neither preferred nor not preferred to each other. This can be expressed as follows: the relationship $\succ$ is a weak order (where $\succ$ expresses the relationship ‘is preferred to’), such that for any two alternatives either $x \succ y$, $y \succ x$, or $x \sim y$ (where ~ indicates indifference).

2. The ordering of any two goods is independent of the other goods available. The following expression indicates that the preference relationship between two goods is independent of other alternatives: $x \succ y \Rightarrow \lambda x + (1 - \lambda)z \succ \lambda y + (1 - \lambda)z$.

3. Preferences are considered to be continuous. Thus, it is possible to add a little of something ‘bad’ to something preferred without affecting that preference. For example, given the preference pairs $x \succ y$ and $y \succ z$, then there are values for α and β in the open set (0, 1) such that $\alpha x + (1 - \alpha)z \succ y$ and $y \succ \beta x + (1 - \beta)z$.

The first two axioms are fundamental to the rationality of consumer choice (Arrow, 1963). It is the existence of a stable, irreversible order that rules out the possibility of circular preferences and economic irrationalities (Rabin, 2002). The third axiom, continuity, guarantees the existence of trade-offs between items in the choice set (Fishburn, 1988). The following discussion looks more closely at the last two axioms, independence and continuity.

The independence axiom is often applied to whole goods, as described above. After Lancaster (1966), it is also applied to the attributes of goods. His insight was that goods could be considered bundles of attributes. The attributes of goods entered into the consumption process, and the task of the consumer was to maximise utility from these attributes. The same choice axioms hold, whereby preferences for attributes are weakly ordered, independent and continuous. Lancaster's insight is core to the issue of GMF, because whether food is GM or not can be viewed as a discrete attribute, separate from taste, nutrition, price, etc.

When consumers make their choices with respect to GMF, the fact that a product is GM could affect their utility calculations in two ways. First, the process of GM could be a discrete product attribute, evaluated separately from other attributes. For some consumers, GM may make no difference to a food's utility. For others, it may decrease a food's utility, even to the point that they will not choose to consume GMF. Either way, the value of GM does not vary according to the product offered; its value is independent.

The second possibility is that GM could affect utility in more complex ways. For example, GM has been found more acceptable when it is used to reduce pesticides than when it is used to reduce prices (Pew Initiative, 2003). It is commonly asserted that second-generation GMF, that will have consumer-oriented benefits as opposed to production-oriented benefits, will be more positively viewed by consumers (*e.g.*, Rousu, Monchuk, Shogren, & Kosa, 2003). This assertion suggests that the specific benefit produced through GM affects the perception of the technology, that the value of GM is not discrete but the result of an interaction with the offered benefit. If this is true, then the value of GM is not independent of other attributes.

The continuity axiom is reflected in the saying, 'everyone has a price'. The mathematical representation of continuity presented above, $\alpha x + (1 - \alpha)z \succ y$ and $y \succ \beta x + (1 - \beta)z$ (Fishburn, 1988), suggests that the consumer may prefer not to have z, but if z is added in sufficiently small quantities to x (and reducing x by that amount) the consumer will still choose the composite basket over y. Once the proportion grows above a certain threshold, y becomes preferred over the combination of x and z.

This threshold amount is particularly important, because it establishes the *indifference* relation. This relation forms the basis of neoclassical consumer theory (Earl, 1983). The relative price of two goods is the (reciprocal of the) ratio at which a consumer is willing to trade one for the other. At the equilibrium price, the market is indifferent between a little more of one good and a little less of the other.

Using Lancaster's model, this relationship has been extended from baskets of goods to collections of attributes. By comparing the willingness to pay for different configurations of attributes, it is possible to impute prices for each attribute (McFadden, 2001). For GMF, it is possible to compare different potential configurations of GMF and non-GMF to determine when consumers are indifferent between, for example, a low-priced GM product and a higher-price non-GM product. This establishes the WTP for the food attribute 'GM' (Burton, Rigby, Young, & James, 2001).

If public opinion research is accurately describing consumer reactions to GMF, however, then some consumers do not have a price at which they are indifferent between GMF and non-GMF. That is, any amount of GM-ness (z) at all renders the other food attributes (x) inferior to the non-GM food (y without z). This type of preference is discontinuous (Earl, 1983) and poses a problem for neoclassical analysis. Without continuity, there is no trade-off between two different attributes (Fishburn, 1988), and without a trade-off, there is no relative price for the attributes (Earl, 1983).

If the independence and continuity axioms are violated, then a neoclassical analysis the demand for GMF has a weak theoretical foundation. An alternative model of consumer choice behaviour can be found in the economic theory called *bounded rationality* (Conlisk, 1996; Simon, 1955, 1956). Although the term is variously defined, one stream of bounded rationality research rejects the possibility or necessity of an optimum (Todd & Gigerenzer, 2003). Instead, decision makers attempt to make ‘good-enough’ decisions that allow them to survive in their environments (Simon, 1956).

Bounded rationality has two components: the limitations of the human mind and the structure of the environment (Gigerenzer & Selten, 2001; Gigerenzer, Todd, & the ABC Research Group, 1999). Decision makers can exploit regularities and structure in their choice environments to make better decisions, given that they have limited cognitive capacity (Gigerenzer et al., 1999; Simon, 1956). Research in this vein has thus examined both possible heuristics and the choice situations in which they would be appropriate. Some of these specific decision strategies have been investigated as part of a research programme on ‘fast and frugal heuristics’ (Gigerenzer & Selten, 2001; Gigerenzer et al., 1999), which includes several non-compensatory decision strategies

The reactions of some consumers to GMF may conform to a boundedly rational, non-compensatory model of decision-making. As mentioned above, some consumers seem to be categorically opposed to GMF and will refuse it at every turn (Gaskell et al., 2003; Heller, 2003). Bredahl (1999) found that many consumers have non-compensatory objections to genetic modification, so that other attributes of GMF are not examined. These findings suggest that consumers may not be examining all of the attributes of food products and then comparing the relative values of GMF and non-GMF. Instead, they may be deciding on GMF by using simple heuristics – GM either is or is not acceptable – as theorised by bounded rationality research.

Methodology

The Choice Models

Neoclassical theory posits that people choose a good from a choice set because it is preferred in some way (McFadden, 2001). McFadden (1974) showed that such a choice can be modelled probabilistically with a conditional or multinomial logit (MNL). The derivation of this model is presented by various authors (*e.g.*, Louviere, Hensher, & Swait, 2000; Maddala, 1983; McFadden, 1974), and the equation for a MNL is:

$$\Pr(a_i) = \frac{\exp\left(V_i\right)}{\sum_j \exp\left(V_j\right)},$$

where a_i represents the chosen alternative from a choice set with j alternatives and V represents the observed value of the alternatives to the decision-maker.

There are three expansions to make to this basic equation. First, the alternatives can be decomposed into their constituent attributes (Burton et al., 2001; Lancaster, 1966). Secondly, the impact of personal characteristics may be added to the model by a term that accounts for the interaction of individuals' characteristics with the attributes in the choice set (Louviere, 2001). These first two changes lead to the following:

$$\Pr(a_i) = \frac{\exp\left(\sum_k \beta_k X_{ki} + \sum_{kp} \phi_{kp} X_{ki} Z_p\right)}{\sum_j \exp\left(\sum_k \beta_k X_{kj} + \sum_{kp} \phi_{kp} X_{kj} Z_p\right)},$$

where X is the k-element vector of attributes, β is the k-element vector of weights that respondents attach to the different attributes, Z is a p-element vector of personal characteristics, and ϕ_{kp} is a matrix of weights attached to different attributes by people with different characteristics.

The third change to this equation is to expand the vector of attributes to include interaction terms. As above, each attribute can enter the equation individually, representing its independent impact on choice probability. In addition, interaction terms can be included in this attribute vector, to account for any two-way interactions between the attribute 'GM' and other attributes. The expanded vectors X and β include $k + r$ elements: the k attributes and the r interactions. If the interaction terms significantly affect choice probability, then the attributes are not independent of each other in the choice process.

MNL models have been used to analyse data from a specific type of surveys: choice experiment or choice modelling surveys. These surveys ask respondents to choose one of a set of alternatives or products, which are described by several attributes. Theoretically, the chosen alternative is the one with the greatest utility. In the surveys, the attributes of the products are systematically varied to examine the impact of changes in attribute levels on choices of products. These surveys are useful for assessing consumer responses to GMF because they efficiently gauge reactions to many different combinations of product attributes (Bateman et al., 2002). They are also appealing because they highlight the trade-offs that consumers might face between different product attributes, such as between taste and price. If price is one of the product attributes, the estimated model also allows calculation of implicit prices, or 'partworths' (Bennett & Blamey, 2001).

For research on GMF, an important property of the MNL is that it assumes continuity. Each attribute enters the utility function linearly and the resulting sum of weighted attributes for one food product is compared against the sum for another. Thus, the economic valuation problem is to find the price such that:

$$V\left(GM + discount\right) + \varepsilon_i = V\left(nonGM\right) + \varepsilon_j .$$

If data are collected from a group of respondents and some of them choose the GM alternative and some do not, then it is possible to estimate a sample-wide discount for GM. This average price discount is held to compensate consumers in general for the use of GM.

When there are consumers who categorically refuse GMF, this average discount cannot compensate them for having to consume GMF. What seems to apply at the sample level because of the assumption of continuity does not apply to these consumers. In theory, they would be infinitely harmed were GMF thrust upon them; no price discount would compensate them sufficiently.

Bounded rationality is an alternative to help explain non-compensatory choices. The theory views choices as the outcome of processes or decision protocols (Augier, 2001). This area of research has thus focussed on understanding the protocols that people actually use in decision situations. In modelling these decisions, researchers have focussed on decision protocols or decision heuristics (Gigerenzer & Selten, 2001; Gigerenzer et al., 1999). As McFadden (1986) showed, decision protocols translate a given set of inputs – *e.g.*, the attributes of food – to a set of outputs – the decision about which product to buy.

For the present research, a simplified choice model is hypothesised. The model has two parts, a screening procedure and a simple additive compensatory component (Bettman, Luce, & Payne, 1998; Coombs, 1964; Payne & Bettman, 2001). The screening procedure is a lexicographic or non-compensatory rule that eliminates all GM options. If an alternative is GM, no amount of other attributes compensates for this fact. Some consumers may make non-compensatory choices regarding GMF, while others may not. To accommodate these differences, three different responses to GM are incorporated. One response is complete refusal of GM alternatives. The second response is wariness towards GM, so that GM is a negative attribute but is given no more consideration than any other attribute. The third response is complete indifference to GM: the attribute is not considered in the decision-making process.

The second part of this choice model is compensatory, as in the MNL. All of the remaining attributes enter into the evaluation of each option. However, in keeping with the idea of limited cognitive ability that is central to bounded rationality, the attributes are unweighted. This has been called an equal weight strategy (Payne & Bettman, 2001), and is similar to the (1,0,-1) weighting Simon (1955) proposed. Consumers thus examine the products on offer and determine whether they are better or worse on each attribute. However, there is no attempt to compute a universally valid ‘score’ for each alternative. As a result, no trade-off price or partworth is implied over the different attributes.

The final semi-lexicographic choice model expresses the value assigned to each alternative as a linear model of compensatory and non-compensatory weights:

$$V(j) = \sum_{k=1}^{K-1} x_{kj} - 10x_{GM,j}z_1 - x_{GM,j}z_2,$$

where x designates whether the alternative is best, worst, or neither for attribute k in a specific choice set, z_1 is equal to one if a consumer refuses GMF, and z_2 is equal to one if a consumer is wary of GMF (z_3, indifference, is the omitted base case).

This semi-lexicographic choice model assigns a different set of attribute values to those estimated by the MNL. It is important to note that the MNL estimates parameters for the attributes, while the alternative model uses the theory of bounded rationality and consumer research regarding GMF to develop a likely set of parameters. These parameters are then used to create the choice model.

There seems to be little use of heuristic models in analysing choice experiment data. One the one hand, researchers in discrete choice analysis have suggested investigating heuristic strategies (Ben-Akiva et al., 2001), while at the same time suggesting that they are probably unnecessary (Bolduc & McFadden, 2001). On the other hand, researchers investigating bounded rationality do not seem to have employed choice experiment surveys in gathering data, although they have used experimental methods that appear similar (Broder, 2000; Newell & Shanks, 2003).

Comparing the models is difficult because the underlying theories approach choice behaviour differently. For the MNL model, the preferred goodness-of-fit statistics are a likelihood ratio and a pseudo-R^2 (Maddala, 1983; McFadden, 2001). The fit of both models can be assessed with a prediction success index (Louviere et al., 2000; McFadden, 1978). Although this is weaker measure of goodness of fit for the MNL model, it allows the two models to be compared.

The Survey

A choice experiment survey was developed to collect data to test the two models. To add realism to the research, the survey focused on a specific food product, apples. The attributes included in the choice experiment and the levels or values they took are shown in Table 1.

Examples of choice surveying on GMF in the literature have used main effects designs to create the choice questions (Burton & Pearse, 2002; Burton et al., 2001; James & Burton, 2003; Onyango et al., 2004). This design has the benefit of achieving orthogonality amongst the attributes of the choice sets with the smallest number of choice alternatives. However, by expanding the choice set, the present research could examine the independence and continuity axioms.

To expand the choice set, the present research first set aside the GM attribute and created an orthogonal, main effects design on the remaining attributes. The resulting choice set was then doubled (Hahn & Shapiro, 1966; Louviere et al., 2000), so that each combination of attributes was available in both non-GM and GM versions. This process increased the variety of non-GM alternatives over that used in prior research. The choice set was further modified to account for the binary attribute for flavour and for the six levels of prices. The final design was nearly orthogonal, *i.e.*, the attributes were nearly uncorrelated. The design was somewhat inefficient (D-efficiency = 45 (Kuhfeld, Tobias, & Garratt, 1994)), due to the imbalance in the number of levels, but the design was retained in order to have a practical, realistic choice survey design.

Table 1: Apple attributes for choice experiment

Attribute	Levels
Price ($ per kg) (*Price*)	1.50, 2.40, 2.70, 3.00, 3.30, 3.60, 4.50
Genetic modification (*GM*)	non-GM, GM
Level of chemical insecticide use (*Chem*)	30% less, current level, 10% more
Level of antioxidants (*Health)*	Current level, 50% more, 100% more
Flavour (*Flavr*)	Current, improved

This expanded choice set allowed the assumptions of independence and continuity to be tested. Independence could be tested, because the design allowed two-way interactions between GM and each other attribute to be statistically estimated (Hahn & Shapiro, 1966). A main effects design would only allow the independent impact of each individual attribute to be estimated (Louviere et al., 2000). The continuity axiom could be assessed because the design allowed respondents a wide choice of GM and non-GM alternatives. If respondents always avoided GM alternatives, then their choices would be discontinuous, suggesting preference discontinuity. Prior research has often used smaller choice sets with limited choices of non-GM alternatives. In extreme cases, the only non-GMF alternative was the *status quo* (Burton & Pearse, 2002; Onyango, Govindasamy, & Nayga Jr., 2004). Respondents who wished to avoid GM alternatives would thus always choose the *status quo* alternative. This type of response is considered a ‘protest response’, and is usually removed from the dataset before model estimation (Burton et al., 2001; James & Burton, 2003). The present research designed allowed respondents to choose non-*status quo* alternative but still avoid GM alternatives.

Results

The survey was conducted in November 2003 at supermarkets in Christchurch, New Zealand. Shoppers were approached at random and asked if they would participate in a survey on preferences for apples. In addition to the choice experiment data, demographic and attitudinal information were collected. For ethnic identification, age, and household income, the sample (n = 353) is not statistically different from

New Zealand national figures at a probability of 0.10, as confirmed by χ^2 tests. The sample is significantly different from national educational attainment statistics, with the sample being more highly educated than average.

Respondents' attitudes towards GMF were captured by the responses to the statement 'Producing genetically modified food is too risky to be acceptable to me'. Only those respondents who used the 5-point Likert scale were included in the modelling; those who did not answer or responded 'Don't know' were excluded.

The data were analysed using Microsoft Excel, Maple, and Biogeme (Bierlaire, 2003). The MNL was solved via maximum likelihood with the donlp2 algorithm, while the semi-lexicographic choice model was analysed with Excel. The models were estimated using 2378 choice observations, three-quarters of the dataset. An additional 782 observations were excluded as a holdout sample in order to assess how well the estimated MNL performed on data not used to estimate the model.

Parameter estimates for the MNL are presented in Table 2. One parameter is estimated for the independent impact of each attribute, with the exception of insecticide use. Two parameters were estimated for insecticide use, corresponding to either an increase or decrease from current levels. This specification is consistent with Burton *et al.* (2001) and was used because the data exhibited strong non-linearity. Overall, the model performs well, with a pseudo-R^2 of 0.208. The parameters generally have the expected signs and levels of significance. There is a bias towards the *status quo*, or the apples currently available. Amongst the product attributes, increases in antioxidants, improvement in flavour, and decreases in insecticide use all increase choice probability, indicating that respondents value these improvements. By contrast, increased insecticide use and increased price both decrease choice probability. The signs of these parameters are all as expected. Finally, although GM apples are less likely to be selected, the parameter is not significant at the 5% level.

The impact of the GM attribute on choice probability is complex. The GM attribute by itself, estimated by the parameter *GM,* is not significant. This result suggests that there is no average impact across all products and consumers. All of the parameters estimating the impact for attitudinal groups are significant at the 10% level, and three are significant at the 1% level. They all have the expected magnitudes and signs. Those who strongly disagreed that GMF was too risky (that is, those who find the risk acceptable) were the base case. All other respondents were less likely to choose a GM apple. The more they agreed with the statement, the less likely they were to choose such an apple.

The results of the interactions are mixed. GM technology does not seem to interact with two of the four other product characteristics: the parameters for *GM-Flavr* and the two insecticide variables are not significant. The parameter for *GM-Health* is significant at the 10% level (and very nearly at the 5% level) and negative. The parameter for the interaction of GM with price is highly significant and positive.

One unexpected result is that the estimated parameter for gender was essentially zero. In most research on attitudes towards GM, men and women are found to react differently; an exception is Rigby and Burton (2003). One possible reason for this lack of significance is that over half (55.3%) of the male respondents were main household shoppers. These respondents are thus a non-random sample of the male population (Johnson, 2004).

Table 2: Model parameters

Variable	Estimated MNL parameters	Assigned Semi-lexicographic parameters
Status quo constant	0.258 (0.111) †	1
Product attributes		
Antioxidants	0.428 (0.114) ‡	1, 0, -1
Flavour	0.389 (0.102) ‡	1, 0, -1
GM	-0.566 (0.414)	--
30% less insecticide	0.495 (0.113) ‡	1
10% more insecticide	-0.766 (0.131) ‡	-1
Price	-0.755 (0.053) ‡	1, 0, -1
'GM food is risky'		
Strongly agree	-3.055 (0.342) ‡	-10
Agree	-1.882 (0.243) ‡	-10
Neutral	-0.872 (0.216) ‡	-1
Disagree	-0.358 (0.211) *	0
Strongly disagree	(base)	0
Gender – respondent male	0.001 (0.144)	--
Interaction terms		
GM-Antioxidants	-0.363 (0.189) *	--
GM-Flavour	0.135 (0.169)	--
GM-30% less insecticide	0.089 (0.185)	--
GM-10% more insecticide	0.262 (0.210)	--
GM-Price	0.263 (0.085) ‡	--
Log-likelihood at convergence	-2070.07	--
Likelihood ratio test	1084.86	--
pseudo-R^2	0.208	--

*significant at the 10% level
†significant at the 5% level
‡significant at the 1% level

The parameters for the semi-lexicographic model are also included in Table 2. These parameters were not estimated, but were developed from *a priori* expectations to create a model whose fit was then compared to the observed choices.

The fit of the two models is compared in Table 3. The first statistic in the table is the prediction success index for both models. This index compares predicted choices to observed choices, adjusted for the proportion of choices for each alternative. It represents the success of a model over one that is based only the observed percentage chosen of each alternative. The prediction success index was computed both for the estimation set and for the holdout sample. This statistic suggests that the MNL model performs better than the semi-lexicographic choice model, but that both are a definite improvement over a random model. The MNL also fits the holdout sample nearly as well as the in-sample data, indicating that the model does not overfit the data.

Table 3: Comparison of model fit statistics

Statistic	MNL	Semi-lexicographic
Prediction success index, all choices		
In-sample data	0.237	.202
Holdout sample	0.222	.186
Percent of GM choices correctly modelled		
In-sample data	29.7	36.7
Holdout sample	28.6	37.9
Likelihood ratio test [A]	1085	-909
Pseudo-R^2 [A]	0.208	-0.177

[A] These are probability-based statistics, so they are incompatible with a heuristic framework. The values reported for the semi-lexicographic choice model are the model fit statistics for a RUM model with parameters that mimic the semi-lexicographic choice model.

The second statistic is the percentage of GM choices correctly predicted by the models. The data are limited to those choice questions in which a respondent chose a GM alternative. For this subset of the data, the MNL does not perform as well as the semi-lexicographic choice model. However, both models are worse at predicting GM choices than they are on average. The MNL predicted 58 per cent of in-sample and holdout choice correctly, while the semi-lexicographic model predicted 55 per cent of in-sample choices and 54 per cent of holdout choices correctly. By contrast, the MNL predicted 30 per cent of the in-sample GM choices and the semi-lexicographic model predicted 37 per cent.

The last two statistics in Table 3 are the likelihood ratio test and pseudo-R^2. These are probability-based statistics calculated from the likelihoods of an intercept-only model and the final estimated model. They are standard statistics for MNL models, but the semi-lexicographic choice model does not generate its own probability statistics. However, it is possible to use the parameters from the semi-lexicographic model to calculate probability-based fit statistics that would be generated from a MNL model that mimics the semi-lexicographic choice model. While this is not an exact measure of the semi-lexicographic model nor is it an exact comparison of the goodness of fit of the two models, it can provide some suggestion of the relative fit of the different models. As the results demonstrate, only a suggestion is required, because these statistics suggest that a MNL model estimated with this dataset would never generate the parameters associated with the semi-lexicographic model. The semi-lexicographic parameters create a model that fits the data worse than an intercept-only model. Thus, the likelihood ratio and the pseudo-R^2 are negative, where these statistics are positive for the MNL model.

Table 4. Partworths for MNL model

Attribute	Partworths for non-GM alternatives (NZ$/kg)	Partworths for GM alternatives (NZ$/kg)		
		Main effects	Interaction effect	Total
Status quo constant	0.342			
Product attributes				
Antioxidants	0.567	0.869	-0.737	0.132
Flavour	0.516	0.792	0.275	1.066
GM	--	-1.150		-1.150
30% less insecticide	0.656	1.006	0.181	1.187
10% more insecticide	-1.015	-1.557	0.532	-1.025
'GM food is risky'				
Strongly agree		-6.210		-6.210
Agree		-3.825		-3.825
Neutral		-1.772		-1.772
Disagree		-0.727		-0.727
Strongly disagree		--		--

Calculations of the partworths or WTP for product attributes are presented in Table 4. Partworths for non-GM and GM alternatives are calculated separately. The significance of the GM-Price parameter signals that the partworths for the two types of apples must be calculated with different denominators. The denominator for non-GM alternatives is the parameter for Price; the denominator for GM alternatives is the sum of the parameters for Price and the GM-Price interaction. The WTP for non-GM apple attributes is straightforward: respondents would pay a premium for more antioxidants, better flavour, or less insecticide use. The WTP for GM apples is not as straightforward. The main effects follow the same pattern as the non-GM apples (they are calculated with the same numerators but a different denominator). The interaction terms show different effects, however. The GM-Antioxidant interaction nullifies nearly the entire WTP for more antioxidants. The WTP for that attribute is $0.567 for non-GM apples, but only $0.132 when the antioxidants are in a GM apple. The interaction between the two attributes suggests that greater antioxidants are not viewed positively when achieved through GM. The WTP for greater flavour and less insecticide are, on the other hand, increased by the interaction effects. That is, respondents prefer apples with greater flavour and have negative WTP for GM apples. Adding just the main effects together, however, overstates respondents' reluctance to purchase these GM apples. The positive interaction suggests that respondents are willing to set aside some of their aversion to GM apples when presented with apples with better flavour or less insecticide.

Table 4 also contains partworths for respondents' attitudes. Their magnitudes relative to apple attributes indicate that respondents who view GM food as risky would on average not purchase GM apples. Other respondents, however, are less negatively disposed and would choose GM apples given the right incentives. Respondents who agreed or strongly agreed that GM food is risky apply total discounts to the GM apples greater than the base price for *status quo* apples, which was $3.00. The partworths associated with other attitudinal groups are not as large, and suggest that GM apples would have a market, given the right prices and product enhancements.

The survey successfully recorded non-compensatory choices for non-GM apples without classifying them as ‘protest responses’. Only 5% of respondents could be classified as protestors. The other 95% of respondents chose an alternative other than the *status quo* apple at least once from the nine choice questions. Furthermore, responses to follow-up questioning suggested that ‘protest response’ choice patterns arose for valid reasons, rather than protest reasons. The respondents simply found that the *status quo* apple was always preferable.

Although 95% of respondents varied their choices in response to the attributes in the choice questions, still almost one-half (48.2%) of respondents never chose a GM apple. These respondents were clearly willing to consider changes to apples’ price, flavour, antioxidant level and/or chemical use, but they were never led to choose a GM apple.

Two groups of respondents, those who chose GM alternatives and those who did not, were compared using their responses to the attitudinal statements and demographic questions in the survey. On nearly every attitudinal statement, the two groups responded significantly differently, as tested with a χ^2 test. In their attitudes to food, to GM, and to the environment, the two groups were measurably different. Demographically, however, the two groups were nearly identical. Gender, age, income, education, and ethnic identification were all statistically similar.

Discussion

The results of this survey allow the neoclassical axioms of independence and continuity to be assessed empirically. The MNL suggests that some respondents’ choices do not conform to the assumption of attribute independence. The significance of the interaction parameters indicates that the assumption of attribute independence does not hold for GMF. The presence of the GM attribute can change preferences regarding other attributes. The specific example evident in the present research is the preference relationship between antioxidants and improved flavour. The model results suggest that greater antioxidants are preferred to (are more highly valued than) improvements in flavour for non-GM apples, but the opposite is true for GM apples. Thus, the presence or absence of GM affects the preference relationship between two other attributes, in violation of the independence axiom.

The results also suggest that some respondents’ choices are inconsistent with the continuity axiom. Nearly one-half of respondents did not ever choose GM alternatives. Their choices therefore do not indicate what compensation would be necessary for them to choose GMF – they have not indicated the compensation that would make them indifferent. Nor can their compensation be deduced from the choices of the other respondents. The two groups of respondents, those who chose GMF and those who did not, have significant differences in their attitudes towards food and GM. Thus, the two groups do not seem to have been drawn from the same population and their willingness to pay for GMF is not likely to be similarly distributed.

One positive result of this research was that the survey design led to a low proportion of protest responses. Reducing the proportion of ‘protest responses’ to 5%, when other GM choice experiment surveys have recorded protest rates of 30% or more, means that many more observations can be retained in the dataset. Thus, this design gives a clearer picture of non-compensatory refusal of GMF. Nearly one-half of respondents never chose a GM alternative on any choice question, and all these responses could be included in the analysis. An important group of consumers – those who want to refuse GM apples – are not excluded from the analysis.

Because the survey results are inconsistent with the axioms underpinning the MNL model, it is interesting to compare those results with the non-neoclassical semi-lexicographic choice model. First, the boundedly rational model does not fit the data as well as the MNL. Although the semi-lexicographic model was designed to mimic the actual choice behaviour that a large group of consumers profess – non-compensatory refusal of GMF – the MNL has more predictive success. One possible interpretation is that by assuming categorical behaviour, the semi-lexicographic model does not capture the nuances of choice behaviour. The MNL model, by estimating less extreme parameters for each attribute and parameters for some interactions, avoids this problem. Another interpretation is that attitudes towards riskiness of GMF may be imperfectly correlated with GMF choice. Nearly one-half of respondents never chose a GM apple, so some categorical behaviour could be occurring. The error may be in linking such behaviour to risk attitudes.

The difference between the results of the MNL and the semi-lexicographic models can be likened to the difference between type I and type II errors. Given a null hypothesis, a type I error is defined as rejection of the hypothesis when it is in fact true, while a type II error is defined as non-rejection of the null hypothesis when it is false (Geng & Hills, 1989). This research in essence assessed the following hypothesis for each respondent: ‘This respondent would choose a GM apple’. The semi-lexicographic choice model, with its categorical treatment of the GM attribute, tended to reject the hypothesis when it was in fact true, a type I error. Thus, respondents who agreed that GMF was too risky were never expected to choose a GM apple. In fact, some of them did, which reduced the fit of the model. The MNL model tended toward the type II error, in which it accepted that respondents would choose GM apples when in fact they do not. This error is tied up in the issue of continuity: the MNL model assumes that all respondents would choose GMF at some price level, when in fact some respondents have rejected GMF at every opportunity.

Conclusions

This research demonstrates the value of investigating possible respondent reactions when designing choice experiment surveys. Prior research has suggested that some consumers might employ complex evaluations of GMF that depend on the specific types of benefits offered, which led to the investigation of the independence axiom. Research has also suggested that some respondents are not at all willing to purchase GMF, which led to consideration of a design and model for non-compensatory choice.

The results suggest that a neoclassical model does not fully describe consumer reactions to GMF. Specifically, the willingness to pay for GMF is in part determined by the type of consumer benefit offered, in violation of attribute independence. In addition, other consumers appear to avoid all GM alternatives, so that the data is discontinuous for the GM attribute.

The results further demonstrate that it is possible to develop a heuristic model that is theoretically consistent with bounded rationality, that mimics consumers' expressed reactions to GMF, and that has a reasonable goodness of fit to the data. Unfortunately, the results also indicate that the heuristic model did not fit the data as well as the neoclassical model. In particular, it predicted refusal of GMF for consumers who in fact chose GM alternatives, and also failed to account for attribute interactions.

There are opportunities for the research to be extended. First, respondents' knowledge or awareness of antioxidants was not tested. It is therefore not clear that respondents were fully informed about the health benefits associated with higher levels of antioxidants. Reactions to antioxidants might have been affected by ignorance and would therefore not be representative of demand for healthier food.

Secondly, this research did not address the issue of the type of genetic modification. Other research has shown that consumers react differently to plant-only GM versus inter-kingdom transgenic GM (Burton et al., 2001). The generic designation 'GM' in this survey could be masking such a differential response.

A third possible extension of the research is a model of consumer choice in which respondents choose how to make choices regarding GMF. In the present research, all respondents were modelled with the same decision process, either a fully compensatory model or a boundedly rational model. Better understanding of consumer decision processes and better model fit might be achieved by allowing some respondents to decide with a MNL-type process and other to use a boundedly rational process.

This research contributes to existing literature and knowledge regarding GMF by demonstrating both categorical behaviour with regard to GMF and complex assessment of the specific consumer benefits on offer. The main effects in the MNL showed that increased antioxidants, improved flavour and less insecticide use are valuable to consumers. The interaction terms in the model further show that the implied price for these attributes cannot simply be added to the discount on GM food; they in fact interact differently. It also found evidence of discontinuous preferences regarding GMF and demonstrated a heuristic model to account for non-compensatory demand. Finally, the success of these models depended on the original design of the choice experiment, which allowed investigation of these choice behaviours.

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