Quasi-option values for enhanced information regarding genetically modified foods

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Abstract:

Issues concerning the long-term environmental and health risks associated with the production of genetically modified foods remain highly topical in Australia. It is unclear how consumer values for a precautionary approach to the release of genetically modified crops compares to the opportunity costs of forgoing economic growth associated with the use of these technologies. In this paper, an application of the contingent valuation method is reported. That technique was used to estimate quasi-option values held by consumers regarding a potential five year moratorium on the use of genetic modification in Australian agriculture. The results are compared to the estimated opportunity costs of imposing such a ban on Queensland consumers.

Key words: Quasi-option values, genetically modified organisms, contingent valuation

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1.0 Introduction

The production of genetically modified (GM) foods has created substantial public debate in Australia. The development of GM food industries and associated food safety regulations has, to date, involved scientists and regulators much more than economists. Recently there has been growing recognition that to address environmental, food safety issues and other uncertainties, expertise from other disciplines will need to be considered (Appell 2001). Public and private interests associated with food production need to be assessed and evaluated.

Consumer concern is growing over the potential introduction of additional GM organisms (GMO's) into the Australian farming landscape. These concerns have to date been addressed through Australia's political and regulatory processes. Economic assessment of these issues has been restricted to rudimentary market-based benefit cost analysis (BCA). The challenge for economists and governments interested in estimating the net social benefit of approving additional GMO's for commercial release lies in developing an appropriate economic framework to compare the benefits and costs of either adopting a precautionary approach or pursuing economic growth associated with the use of GMO's. The difficulty in establishing such a framework is that many consumer preferences associated with GMO's cannot be readily observed from market data.

Stated preference valuation techniques provide an alternative means for policy makers to estimate the welfare obtained from the opportunity to delay the decision to introduce new GMO's into Australian farming systems whilst more information regarding the likely risks of such action is obtained. The question for decision makers is whether or not the benefits of a precautionary approach outweigh the opportunity costs of forgone development opportunities.

The contingent valuation method (CVM) is one stated preference technique capable of estimating the value of a precautionary approach through the estimation of consumer welfare obtained from the opportunity to get better information by delaying a decision that may result in irreversible environmental loss. This welfare gain is referred to as a quasi-option value. Quasi-option values have been estimated for climate policy choices (Ha-Duong 1998), protection of marine ecosystems through the establishment of marine reserves (OceanUpdate 2001) and timber products and services forested lands provide to communities (NSW Government 1998).

In this paper the findings of a CVM experiment designed to estimate quasi-option values associated with delaying the release of additional GMO's in Australia are reported. The paper is structured as follows. In section two the background literature regarding GM technologies is reviewed. Section three explores consumer surplus measures and BCA and in section four risk perceptions and the precautionary principle are applied to GMO's. Non-market valuation techniques are reviewed in section five and in section six a description of the methodology used in this research is provided. Section seven provides an analysis of the sampling structure and technique used in the research and in section eight the findings of the CVM research are reported. In section nine the results of the research are presented and in section ten conclusions are drawn.

2.0 Genetically modified agriculture

While most GM products in Australia are already regulated by agencies such as the Therapeutic Goods Administration (TGA), Food Standards Australia New Zealand (FSANZ); and the Australian Pesticides and Veterinary Medicines Authority (APVMA), those products not already covered by an existing national regulation scheme will be regulated by the Office of the Gene Technology Regulator (OGTR) under the *Gene Technology Act 2000*. As at the 1 November 2003, the OGTR had considered nine applications for the general, commercial release of a GMO in Australia. Of these, only four applications were approved for general release. These comprised a carnation with improved vase life, a violet carnation, Bt[1] insect resistant cotton and herbicide resistant cotton (OGTR 2003).

GM foods currently available in the Australian market place include foods derived from soybeans, canola, corn, potato, sugar beet and cotton. The majority of these foods are derived from GM crops grown overseas (ANZFA 2000). There are a number of other GM crops being trialed under license in Australia.

The global area growing GM crops has risen dramatically, from 1.7 million hectares in 1996 to 58.7 million in 2002. In 2002, four countries – the US, Argentina, Canada and China – grew 99 per cent of global GM crops, with the US accounting for about two-thirds of the total area. In contrast, the European Union grew virtually no commercial GM crops over the period (Abdalla et al. 2003).

To date, only a few developing countries, such as Argentina, have had high uptake rates of GM technologies concentrated in crops that are exported to developed country markets. Some other countries (mainly China and India) have started exploring their own national research capability in biotechnology. The low adoption levels of biotechnology in developing countries reflects poorly functioning financial and economic markets, an inability to purchase or develop enabling technologies and political factors. They also reflect a lack of transparent regulatory capacity necessary in dealing with risks associated with biotechnology as well as in addressing the issues of property rights development and protection (Abdalla et al. 2003).

The major benefits of biotechnology can be grouped under agronomic, humanitarian, phytoremediation, pharmaceutical or environmental themes. Agronomic benefits of GM crops include increased yields and reduced pesticide costs, improved disease resistance, enhanced crop adaptation to adverse climates (dry, saline, or cold), enhanced durability of crops during harvest and transport and considerable savings in labour through reduced herbicide and insecticide application (Ballenger 2001; Xue and Tisdell 2000; Wackett 2000, Marra 2001 and Pinstup-Anderson 2001).

Despite these potential benefits, the introduction of GM crops is not without controversy. The potential risks associated with GMO's can be summarised into two

[1] Scientists have developed insect resistant crops through the introduction of a gene from the soil bacterium Bacillus thuringiensis (Bt). The Bt gene directs cells to manufacture a crystalline protein that is toxic to certain insects – especially caterpillars and beetles that gnaw on crops. This protein is commonly referred to as the Bt toxin (Brown 2001).

main categories. The first is where GMOs have some potential impact on human and animal health, while the second (and perhaps most controversial) is where GMOs have irreversible impacts on the environment.

To date there has been no scientific evidence to suggest that genetically modified foods are causing health problems in humans (Feldmann et al. 2000). However, there are lingering fears in the public and scientific arena that as yet unspecified effects may cause health problems in humans in the future.

Some commentators have raised possibilities that GM foods may pose a health risk to consumers through potential allergenicity and carcinogenicity, alterations in nutritional qualities of foods, and the development and accidental release of antibiotic resistant microbes and toxins (Uzogara 2000; Brown 2001; Nemecek 2001; WHO 2000). There have also been concerns that animals fed GM grain could develop a build-up of antibiotic resistance. However, little scientific evidence has been found for any of these risks. Different gene transfer techniques and quality assurance procedures have been introduced to minimise those risks further (Feldmann et al. 2000).

The second group of concerns relate to risks of environmental consequences. Given the power of biotechnology to produce combinations of genes not found in nature, Krimsby & Wruberl (1996), Rissler & Mellon (1996) and Altieri (2000) list some of the most serious ecological risks posed by the commercial-scale use of transgenic crops as:

- Reduced crop genetic diversity by simplifying cropping systems and promoting genetic erosion;
- Potential transfer of genes from herbicide resistant crops (HRC's) to wild or semi-domesticated relatives, thus creating super weeds;
- HRC volunteers becoming weeds in subsequent crops;
- Reduced agro-biodiversity in time and space;
- Vector mediated horizontal gene transfer and recombination to create new pathogenic bacteria;
- Vector recombination to generate new virulent strains of virus, especially in GM plants engineered or viral resistance with viral genes;
- Development of insect resistance to Bt toxin;
- The untargeted elimination of beneficial insects and soil biota from the massive use of Bt toxin in GMO crops.

There are tradeoffs involved in the development of genetically modified agriculture in Australia. Whilst farmers, government agencies, agribusiness and GMO advocate groups pursue the agronomic, humanitarian and pharmaceutical benefits of GMOs, consumer fears over food safety, ethical practices and irreversible environmental outcomes remain. Whilst governments are aware of these concerns they remain unsure how best to trade these concerns off against the production benefits of GMOs. Given the substantial consumer concerns over GMOs and other food safety issues, and the current levels of government regulation and investment of public funds, the debate over where these tradeoffs should be set is likely to intensify.

Governments are currently making choices relevant to these issues. For example the Australian government is responsible for the provision of adequate food safety standards, food labelling, the allocation of research funds and the development of risk assessment frameworks for new GM crop trials. This commitment involves an allocation of resources and tradeoffs. Determining how efficient the given choices are requires estimates of program costs, the opportunity cost associated with investing in a program, community values for the choices in question and the development of appropriate strategies for dealing with risk and uncertainty. Understanding these interactions will better enable governments to broker compromises between GM proponents, community and organic agriculture stakeholders.

3.0 The economic framework

Genetically modified agricultural production systems can involve externalities to society (eg the untargeted elimination of beneficial insects through the use of GM crops). There may also be public good aspects of food production and distribution that are unattractive for private enterprise to supply (eg. food safety standards and quality assurance programs). Responding to these characteristics of market failure governments are increasingly relying on risk assessment and BCA to evaluate whether existing or proposed food regulations enhance public welfare (Caswell 1998). BCA is an economic tool that seeks to provide an assessment of the benefits and costs of a policy initiative such as setting a new environmental quality of food standard relative to the status quo. These regulations and services are not costless. Estimating the economic value for all attributes of food production (including those not reflected in markets) is a key factor in establishing a BCA framework to assess the net social benefit of introducing regulatory controls.

Estimating the benefits and costs to society of investing in alternative agricultural production systems poses several challenges. Firstly not all product attributes associated with alternative production systems have readily observable markets and prices. Secondly, it remains difficult to identify the relative impact of each attribute on the choices being made. What is required is a measure of consumer welfare gained from consuming a good or service that can be incorporated into a benefit cost analysis. Consumer surplus is such a measure and represents the maximum amount that a consumer of a good would pay for its purchase minus the actual payment made (Pindyck and Rubinfeld 1989).

Obtaining a measurement of consumer surplus for non-marketed goods is a complex task. Through the work of John Hicks[2] came the development of the four "Hicksian" consumer surplus measures comprising compensating variation, equivalent variation, compensating surplus and equivalent surplus. Each of the four welfare measures may involve willingness to pay (WTP) or willingness to accept (WTA) payments to maintain utility at some specified level (Mitchell and Carson 1989). Choosing the correct measure to use is dependent on whether or not (1) consumer utility is held constant at the initial level and (2) whether or not an individual is able to vary the quantity of the good in question. In instances where utility is held constant at the initial level (i.e. the individual remains on his/her original indifference curve after a

[2] Hicks (1984) provides a detailed description of each of the four Hicksian consumer surplus measures.

change) compensating variation or compensating surplus are the correct measures to apply.

When estimating welfare measures using a CVM experiment, compensating surplus is often used to estimate consumer surplus as respondents are being offered fixed choices in the choice sets, and cannot simply vary the amount on offer. Similarly for general environmental policy issues compensating surplus is usually the appropriate measure as the amount of public good on offer is normally fixed. In the case of the CVM experiment reported in this paper a compensating surplus measure was obtained to estimate the welfare change associated with the introduction of a five year moratorium on the release of GMO's in Australia.

4.0 The Precautionary Principle

The precautionary principle states "when there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:

- Careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
- An assessment of the risk-weighted consequences of various options" (Deville and Harding 1997 pp13).

The precautionary principle is often cited by critics of GMO's as a reason for banning or delaying the introduction of new GMO's into rural landscapes. For these critics the precautionary principle would act as a barrier preventing the commercial use of GMO's that posed any form of risk or uncertainty. Application of the precautionary principle is usually justified on the basis of an ethical or moral belief. Many opponents of GM crops use the precautionary principle, based on ethical or moral grounds, to argue that GM crops should be banned while there remains any uncertainty about their outcomes.

Application of the precautionary principle varies according to the philosophical framework used to justify it (Rolfe 1995). Under an economic approach, a precautionary principle reflects the benefits of dealing with risk and uncertainty in a cautious manner (i.e. the quasi-option value). When the cumulative quasi-option value to society of undertaking a precautionary approach to the use of GMO's outweighs the opportunity costs of not introducing GM crops, a precautionary approach is justified. In instances where the cumulative quasi-option value is less than the opportunity costs, the development or other activities should proceed (Rolfe 1995).

Applying these principles to GMO foods suggests that the precautionary approach is warranted if the benefits of dealing with risk and uncertainty factors (eg quasi-option value) outweigh the opportunity costs of introducing GMO's (potential agronomic, humanitarian, phytoremediation, pharmaceutical or environmental benefits). One measure of the benefits of adopting a precautionary approach is the value that the community holds for deferring a decision that may lead to irreversible environmental harm (eg releasing additional GMO's), whilst more information regarding the long term impacts of the decision are gathered. By measuring and incorporating a community's quasi-option values into any BCA of approving additional GMO's, the precautionary wishes of consumers are properly considered.

The precautionary principle has been applied to the evaluation of GMO's as a reason to delay or prohibit the release of genetically altered crops with unknown properties (Nelson 2001). The European Commission applied the precautionary principle to freeze the approval of genetically altered maize that was related to the variety reported to harm Monarch butterflies, even though this claim subsequently received considerable scientific criticism (Hodgson 1999).[3] Scientific evidence of harm is not required for such action under a precautionary approach. Uncertainty about future serious or irreversible damage is sufficient reason to delay release. The less costly the delay the easier it is to justify precautionary actions or policies.

Kimball (1990) demonstrated that consumer willingness to forgo current benefits to protect against the risk of future loss (prudence) results in consumers giving greater weight to uncertain future losses in benefit cost analysis. An implication of this observation is that a populations' quasi-option values may be substantial. These might relate to the opportunity to get better information about the long-term impacts of GMOs while delaying their introduction and possible irreversible impacts. Whilst significant work has been undertaken in assessing the short term environmental and health impacts of producing and consuming GMO's, insufficient time has lapsed for a detailed assessment of any long-term impacts.

5.0 A review of non-market valuation techniques

Economists developed an array of techniques classified as "revealed preference" or "stated preference" methods in response to demand for dollar estimates of non-market values, especially those associated with environmental impacts (Bennett 1999).

Revealed preference techniques for estimating non-market values rely on the use of information from markets that are specifically related to the non-marketed value under consideration. The travel cost method and hedonic pricing are examples of revealed preference techniques[4]. Revealed preference techniques have been limited in their usefulness due to their retrospective nature and inability to value changes that have not been experienced. In addition they cannot be used in the absence of a related well-functioning market (Morrison et al. 1996). For example the Australian food market does not differentiate products according to food safety attributes because of high standards set by government regulation. This makes it difficult to isolate out price premiums for food safety.

Stated preference techniques rely on participants in a survey responding to questions regarding willingness to pay or willingness to accept tradeoffs in hypothetical situations. The attraction of stated preference techniques comes from their ability to estimate the full array of use and non-use environmental benefits and costs through an

[3] Scientific findings published in the scientific journal *Nature* demonstrated that pollen from genetically engineered maize produced by Monsanto, Pioneer, and Novartis may harm butterfly caterpillars. See Juanillo (2001).

[4] Bennett (1996) and Fraser and Spencer (1998) provide applications of these two techniques.

ex ante application. The most commonly applied stated preference technique has been the CVM.

5.1 The Contingent Valuation Method

Contingent valuation first emerged through the seminal works of Davis (1963) and Braford (1970). The CVM involves asking a sample of respondents whether or not they are willing to pay to prevent or secure a particular environmental outcome. Consumer surplus estimates are derived from the responses that are made.

There are a number of formats available for eliciting WTP estimates using the CVM. These include the use of open-ended questions, dichotomous choice, double bounded dichotomous choice and polychotomous choice[5]. In each a payment vehicle such as increased income taxes is used (Morrison et al. 1996).

Usually CVM studies employ either a dichotomous choice or open-ended survey format (Greiner and Rolfe 2003). Under a dichotomous choice survey respondents are asked whether they support a change given a specified additional payment eg whether or not respondents are willing to pay a specified amount to cross a river using a ferry. Using the open-ended question format respondents are directly asked what their maximum WTP for the good in question is.

A number of potential biases have been identified in the use of CVM[6]. Restricting the presence of these biases is controlled largely through careful questionnaire design and survey administration and adherence to the recommendations of the NOAA panel[7].

6.0 Estimating Consumer Quasi-option Values in a Contingent Valuation Experiment

A dichotomous choice CVM experiment was run to estimate consumers' quasi-option values relating to the delayed introduction of additional GMO's into Australia. The CVM is suitable for estimating consumers' quasi-option values. Also, the use of respondent's income tax to fund research into the long-term risks associated with GM foods provides a realistic payment vehicle for estimating the populations' quasi-option values.

The CVM experiment was included in a survey on GM foods conducted in 2001. Some framing benefits were available because the CVM experiment was accompanied by choice modelling questions. Prior to asking the CVM question respondents were given the following information:

> *"It would be possible to have a moratorium (temporary halt) on the release of genetically modified organisms into Australia while more research was done to quantify the unknown risks on human health and*

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5 Morrison et al. (1996) and Bateman et al. (2002) provide an overview of each CVM format.

6 Morrison et al. (1996) and Bateman et al. (2002) provide an overview of the biases associated with using stated preference techniques, including CVM, to estimate non-market values. These biases include embedding effects, part-whole bias, hypothetical bias, payment vehicle bias, strategic bias, starting point bias, information bias, metric bias and non-response bias.

7 See Portney (1994) for a summary of the NOAA findings.

the environment. It would take approximately 5 years to quantify the risks more accurately, and crops may or may not be introduced once that information in known. The research would be expensive and would have to be funded by the Australian taxpayer. This could be a one-off levy on income tax paid to the Government".

Respondents were then asked:

"Would you be prepared to pay $X in additional income tax for a delay in the introduction of additional GM crops into Australia and further research so that the risks can be properly quantified?"

The general form of the logistic regression function used to estimate consumer quasi-option values took the following form:

$$\text{Log(Probability of choosing yes/no)} = (ß + ß_1 Z_1 + ß_2 Z_2 + \ldots ß_n Z_n)$$

where ß is the constant term, and $Z_{1 \text{ to }} Z_n$ represent a number of factors thought to influence household utility including the cost variable and a number of socio-economic characteristics of respondents. $ß_{1 \text{ to }} ß_n$ are coefficients that measure the impact of each attribute on utility.

Data for several explanatory variables were collected in the survey to help explain respondents' choices over the options available. Table 1 describes the variables included in the CVM analysis.

Table 1 Variable definitions

Variable	*Definition*
Price	Bid price offered to respondents. Eight bid prices were offered at random which were $5, $20, $40, $70, $100, $150, $200, $250.
Income	Respondents income by categories from (under $6,239) to 8 ($104,000 +). The midpoint of each income range was coded into the model.
Age	Age of respondent by categories from (18-24) to 6 (65+). The midpoint of each age bracket was coded into the model.
City	Dummy variable taking on a value of 1 for respondents from Rockhampton and 2 for respondents from Brisbane.
Donsex	A variable created by combining the gender and donate variables. The gender variable refers to the gender of respondents (male/female) and the donate variable refers to whether or not respondents have donated funds to any environmental organisation in the past.

Note: The inclusion of the combined variable *Donsex* provided the best fitting model in the analysis.

7.0 Sampling structure and technique

Eight "bid prices" (X) were offered at random. These were $5, $20, $40, $70, $100, $150, $200 and $250. Respondents were then asked to tick either a yes or no box indicating their support for the additional tax. The survey was administered to 240 Rockhampton[8] and 300 Brisbane residents using a drop-off and collect distribution

[8] Rockhampton is a regional city in Queensland Australia. It has a population of approximately 59,000 residents and a strong association with the region's rural industries, particularly beef production.

method with respondents having up to seven days to complete the survey. Market researchers were contracted to undertake the surveys in December 2001. Questionnaires were collected from nodes in each city using a random selection technique eg every third house in every fourth street. For Rockhampton two hundred and eight questionnaires were returned giving an 87 per cent response rate. Of the returned questionnaires, 203 were suitable for analysis giving an effective response rate of 82 per cent. 221 Brisbane questionnaires were returned giving a 74 per cent response rate. Of the returned surveys 203 were suitable for analysis giving an effective response rate of 68 per cent.

One-sample t-tests were conducted to determine whether or not respondents' mean age and income levels were significantly different from the appropriate city population means for age groups 18 years and over (ABS 2001). In addition to the t-test, a chi-square test was run to evaluate whether the proportion of male and female respondents was significantly different to hypothesized values of 50% male and 50% female.

For the Rockhampton sample, respondents' mean household income of $33,891 (standard deviation = $22,398) was significantly different than the city's average annual household income of $41,324 [t(147)= -4.037, p=0.000]. Respondents' mean age of 43.57 years (Standard Deviation = 13.569) was not significantly different than the Rockhampton population mean age of 43.586 years [t(176)=-0.15, p=0.988]. The one-sample chi-square test indicates that the proportion of male and female respondents is also significantly different (59% female respondents) from the hypothesized values of 50% male and 50% female, [χ^2 (1, N=176)=5.818, p=0.016]. The mixed results suggest that the sample population does have significantly different income and gender characteristics to the Rockhampton population, but similar age characteristics.

For the Brisbane sample, respondents' mean income of $41,436 (standard deviation = $27,295) was significantly smaller than the city's average annual income of $50,519 [t(168)=-4.326, p=0.000]. However respondents' mean age of 42.73 years (Standard Deviation = 12.85) was not significantly higher than the Brisbane population mean age of 42.726 years [t(199)=.004, p=0.000]. The one-sample chi-square test indicates that the proportion of male and female respondents is also significantly different (61% female) from the hypothesized values of 50% male and 50% female [χ^2 (1, N=199)=10.176, p=0.001]. The results suggest that the sample population does have significantly different age and gender characteristics compared to the Brisbane population.

8.0 Results of the Contingent Valuation Method experiment

The CVM question in the survey was asked after the CM choice sets. The CVM took the form of a single dichotomous bid. Table 2 summarises the responses to the single dichotomous choice CVM question asked in the survey.

Table 2 CVM data summary

Bid level	$5	$20	$40	$70	$100	$150	$200	$250
Number of respondents	52	43	61	59	39	40	41	53
Number Yes	35	26	38	36	26	23	27	19
Number No	17	17	23	23	13	17	14	34
% Yes	67%	60%	62%	61%	67%	58%	66%	36%
% No	33%	40%	38%	39%	33%	42%	34%	64%

The estimated logit function used to predict the probability of respondents answering yes (i.e. prepared to pay $X in additional income tax for temporary moratorium on the release of GMO's) took the following form:

Combined Cities Quasi-option Utility Function

$$\text{Log (Prob of yes/no)} = 1.0782 - 0.0027(Z_{price}) + 0.0002(Z_{income}) + 0.0012(Z_{donsex}) - 0.0050(Z_{age}) - 0.4705(Z_{city})$$

The results of the logit model are reported in Table 3, with the natural log of bid value identified as a significant dependent variable. Several tests were made to find the best fitting model.

Table 3 Logit model for the single dichotomous choice model

Variables	coeff.	s. error
Constant	1.0782**	0.5122
Income	0.0002***	0.0000
Donsex	0.0012*	0.0007
Age	-0.0050*	0.0029
City	-0.4705*	0.2606
Bidprice	-0.0027*	0.0014
Model Statistics		
Number of Observations	319	
Log L	-207.2897	
Chi-squared [5]	20.6986	
Median	$220.03	
Mean	$386.16	

Notes: 1. *** Significance at the 1% level, ** Significance at the 5% level, * Significance at the 10% level.
2. Rho^2 was estimated at 0.0476 indicating a generally poor fitting model.

A median and mean WTP of $220 and $386 per household respectively was estimated from the logit function. For both the median and mean WTP estimates, mean values for the non-monetary variables were substituted, so as to represent the average respondent characteristic. To calculate the median WTP estimate a proportion of 50% was substituted for both the yes and no bids and the utility function solved for price. For the mean WTP estimate a proportion of 1% to 100% was successively substituted for the yes bid and the utility function solved for price at each support level. The mean of those price estimates was then calculated.

The results of the analysis indicate that Brisbane and Rockhampton households' would value an opportunity to delay the introduction of additional GM crops into Australia whilst further research was undertaken to properly quantify any risks associated with this action.

The *income* variable reported in table 3 is positive and strongly significant indicating that as respondents' income levels increase so to does their quasi-option value. This is in line with a priori expectations. For respondents *age* a weaker (significant at the 10% level) negative relationship was estimated indicating that younger people hold higher quasi-option values. The *city of origin* attribute was also significantly negative indicating that respondents in Rockhampton hold lower quasi-option values than those in Brisbane. Finally the *donsex* attribute was significantly positive indicating that male respondents that do not donate to environmental organisations were more likely to hold higher quasi-option values for taking a precautionary approach to the use of additional GMO's than female respondents and male respondents who did donate to environmental organisations. This did not meet with a priori expectations.

9.0 Discussion

In this paper the findings of a CVM experiment designed to value consumer quasi-option values for deferring additional releases of GMO's in Australia has been reported. The results confirm that Brisbane and Rockhampton consumers are concerned about the long-term risks associated with the introduction of additional GMO's into Australian agriculture. The median quasi-option value estimated for the two sample populations reported in this research was $220.03 per household.

The results reflect that consumers are concerned about the long term (potentially irreversible) risks associated with the introduction of additional GMO's irrespective of numerous studies failing to identify any significant detrimental impacts to human health from their consumption. Consumers still value the right to defer their introduction whilst a more thorough risk assessment is performed.

The magnitude of respondents' quasi-option value also highlights the importance of product labelling to consumers. If consumers are genuinely concerned about the long-term impacts of ingesting GM foods the easiest remedy is to avoid consuming GM products. Choosing to avoid GM foods is dependant on food products having their GMO content clearly labelled. The Australian and New Zealand governments decision to require the mandatory labelling of GM foods through *Standard 1.5.2* of the *Australian New Zealand Food Authority Act 1991,* facilitates consumer product discrimination and provides the Australian and New Zealand public with an opportunity to avoid any potential health threatening impacts of GM foods without the introduction of an embargo on future GMO releases. However labelling does little to address consumer concerns regarding long-term environmental impacts of GMO's.

An important policy question is whether or not the quasi-option value for deferring the introduction of GMO's outweighs the opportunity costs of restricting agricultural growth through a moratorium on the release of new GM technologies. To explore this question a comparison of the cumulative quasi-option values for Queensland households was made with the opportunity cost of commercially available GMO's (GM cotton) and GMO's likely to be released in Australia during the next 5 years[9]. Currently in Australia no GM grain crops have been commercialised, however canola, lupins and field peas are at advanced stages of development. In addition Monsanto announced its intention to pursue the commercial release of herbicide tolerant wheat in the US as early as the 2003 growing season (Foster 2001).

Assuming only agronomic benefits (yield improvements and reductions in the cost of production), the adoption of GM canola in Australia is estimated to increase Australian canola production by 9 per cent (Foster 2001). Similarly Monsanto claims GM wheat will boost yields by 10 per cent compared to existing varieties. The canola agronomic advantage includes a yield advantage of 7 per cent and a decrease in weed control costs (including GM seed purchase costs) equivalent to a 3 per cent reduction in total production costs (Foster 2001). The agronomic advantage of GM wheat used in the analysis comprised a 10% yield advantage and an increase in weed control costs (including GM seed costs) equivalent to a 1 per cent increase in total production costs (Foster 2001).

Adoption rates for other herbicide tolerant food groups throughout the world have been approximately 60% (Foster 2001). A review of the performance of Ingard cotton (Doyle et al. 2002) indicates a net benefit of $374[10] per hectare over conventional varieties. Similar industry estimates for Roundup Ready Cotton are currently not available[11]. Instead it was assumed that the same benefit per hectare observed for Ingard cotton would also apply to Roundup Ready cotton. In the 2003-2004 cotton season transgenic cotton will be grown on 60% of Australia's cotton land, i.e. 245,000 hectares (Pyke 2003). Table 4 provides a summary of the agronomic benefits likely to flow from GM cotton , wheat and canola used in the BCA analysis reported in this paper.

Table 4 Parameters used in the Comparative BCA

Crop	**Adoption Rate**	**Economic Benefit**
GM Wheat	**60%**	**10% yield advantage**
GM Canola	**60%**	**9% yield advantage**
GM Cotton	**60%**	**$374/ha**

[9] The national opportunity cost was apportioned on a per household basis to estimate the Queensland opportunity cost.
[10] Calculated as the weighted average net benefit and cost from table 2.2 of the Cotton Research and Development Corporations report into the performance of Ingard cotton (Doyle et al. 2002).
[11] Doyle et al (2003) provide a qualitative assessment of the benefits and costs of Roundup Ready cotton in Australia observed during the 2001-2002 cotton season.

Assuming 60% adoption of GM canola, wheat and transgenic cotton in Australia, and a 6% discount rate the net present value (NPV)[12] of the agronomic benefits of these three crops over a five-year period equates to $407 million[13].

Implicit in this analysis is a benefit transfer hypothesis that states the quasi-option values estimated for Brisbane and Rockhampton households will be similar across all Queensland households. Queensland currently has 1,275,420 households (ABS 2001). Extrapolating the median quasi-option value of $220 per household for Brisbane and Rockhampton to include all Queensland households yields a cumulative median quasi-option value of $281 million. In this instance the opportunity costs of adopting a five-year moratorium on the use of GMO cotton, wheat and canola clearly outweighs consumers' quasi-option values.

A sensitivity analysis was undertaken to explore the variability of this result to changes in expected adoption rates and agronomic improvements for canola and wheat (cotton was held constant). The results of the sensitivity analysis are presented in table 5. The shaded cells in table 5 demonstrate instances where the opportunity cost of adopting a precautionary approach to the release of GMO's are greater than the estimated quasi-option value for all Australian households.

The sensitivity analysis suggests that once the yield advantage of GM wheat and canola goes above 10 and 9 per cent respectively, only a modest rate of adoption is necessary for the opportunity costs of foregone development to outweigh the benefits of a moratorium on the use of GMO's. Alternatively once the rates of agronomic improvement drop below 5 per cent and 4.5 per cent for GM wheat and canola, consumer quasi-option values outweigh the opportunity costs of foregone development.

Table 5 Sensitivity of NPV calculations to total agronomic benefits and rate of adoption

% Adoption	Rate of Agronomic Improvement (%)				
	2.5% wheat 2.25% canola	**5% wheat 4.5% canola**	**7.5% wheat 6.75% canola**	**10% wheat 9% canola**	**12.5% wheat 11.25% canola**
20%	$101m	$128m	$156m	$184m	$212m
40%	$128m	$184m	$239m	$295m	$351m
60%	$156m	$239m	$323m	$407m	$490m
80%	$184m	$295m	$407m	$518m	$629m

Note: Changes to % adoption relate only to canola and wheat. The cotton industry has already achieved 60% adoption of GM cotton. The % wheat and canola figures in the top row of the table relate to agronomic improvements from the adoption of GM varieties. All figures are reported in Australian dollars (billion). The analysis excludes any identity preservation costs.

The results of this analysis suggest that the adoption of a five-year moratorium on the release of new GMO's and a ban on currently approved GMO crops in Australia

[12] The NPV represents the sum that results when the discounted value of the expected costs of an investment are deducted from the discounted value of the expected returns (Pearce 1992).
[13] The NPV calculations are based on estimates of the 2001/2002 wheat (24,299,000 tonne) and canola harvest (1,756,000 tonne) and average prices received of $259/t for wheat and $435/t for canola (ABS 2003). The total Australian cotton crop for the 2001/2002 season was 409,000 hectares (Doyle et al. 2002).

could not be justified on economic grounds. Whilst the analysis undertaken has considered only three applications of GMO's, the OGTR has issued a further 28 licenses for the intentional release of GMO's into the environment[14] for cholera vaccine and cotton, grapevine, carnation, pineapple, papaya, sugarcane, poppy and canola crops (OTGR 2003). The results of the BCA are reinforced further if consideration is given to the potential production gains available from the commercialisation of any of these crops during the moratorium period.

A caveat to this research that should be considered is the omission of any identity preservation costs associated with exporting GM and non-GM canola and wheat, and industry development costs associated with the adoption of a new GM variety. An analysis by Foster (2001) suggests that if elaborate identity preservation arrangements are required for export the commercial release of GM canola and wheat may not be warranted in some parts of Australia. It should be noted however that some industries (eg organic grains) have successfully implemented and absorbed the costs of elaborate identity preservation arrangements, suggesting that in practice the costs may not be as severe as suggested in the literature. Development and extension costs for new GM technologies in the cotton and grains industry whilst likely to be significant are not readily available in the literature and were omitted from the analysis. Finally caution should be used in extrapolating the results presented in this paper due to the generally poor fitting model used to generate the quasi-option values.

10.0 Conclusions

The quasi-option values reported in this research confirm that Brisbane and Rockhampton consumers would value an opportunity to obtain more information relating to the long term impacts of GMO's prior to any additional release of GMO's in Australia. However, based on the findings of the research reported in this paper, the introduction of a five-year moratorium on the use of existing commercially available GMO's and the commercial release of additional GMO's (eg herbicide resistant canola and wheat) cannot be justified on economic grounds. The opportunity costs to society from the exclusion of these GMO's (i.e. transgenic cotton, and herbicide resistant wheat and canola) is too high to enable such a policy to be implemented. This finding is however sensitive to changes in agronomic benefit and rates of industry adoption.

There are several caveats that should be noted with these results. Firstly respondents' mean income levels were significantly lower than the population mean and the proportion of male and female respondents was significantly different to the hypothesized values indicating that the sample population is not fully representative of the Rockhampton and Brisbane populations. Care should be taken in extrapolating respondents' WTP for food attributes beyond the sample population due to the generally poor fitting model. Further research is needed to undertake similar studies in other major cities and regional centres throughout Australia to authenticate the findings of this research.

[14] A license for the intentional release of a GMO into the environment does not constitute approval for the commercial release of the product, rather the supervised trialing of the crop.

Secondly it remains unclear how significant an impact identity preservation costs are likely to have on these findings if incorporated into the analysis. Further work is needed in this area that incorporates several case studies in addition to the modelling experiments reported in the literature to identify how other industries have successfully managed the introduction and cost of maintaining identity preservation costs (eg organic grain and sugar).

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