ECONOMIC EVALUATION OF THE RELEASE OF GENETICALLY MODIFIED ORGANISMS IN NEW ZEALAND

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Abstract

Surveys indicate that the release of GMOs in New Zealand would affect foreign consumers' purchase intentions. Some consumers state their purchasing behaviour would remain unchanged, others that they would cease purchasing New Zealand commodities, and a third group whose responses would be contingent on price.

Three specific examples of GMO releases (pastoral agriculture, pest control, and human therapeutics) were investigated with a multi-industry General Equilibrium model. The general conclusions on the economic outcomes are that while the impact of single influences (either world market demand effects or New Zealand production opportunities) are potentially large, together many of the influences counter each other. Hence the effect on New Zealand's annual GDP over ten years hence is thus not very great under any of the scenarios. However, impacts at the level of the individual industry (eg agriculture) can be large.

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1 INTRODUCTION

This report is drawn from research conducted by the authors as part of two separate, but linked projects.[2] The aim of the research was to determine the effect on New Zealand's clean green image (CGI) of the release into the environment of genetically modified organisms (GMOs), and the risks and opportunities to New Zealand's international trade and economy of such release.

The project conducted surveys in export markets to ascertain the extent of New Zealand's CGI and the effect that releasing GMOs has on New Zealand's CGI. From we determined by how much this affects the New Zealand economy.

The two fundamental issues which make the decisions on releasing GMOs important to the New Zealand economy are that the potential risks and the potential opportunities presently attached to GM are cornerstones of the strength of the New Zealand economy.

Potential economic risks: Using GM technology in New Zealand, or releasing GMOs into the environment could bring the risk that people in overseas markets would buy fewer New Zealand goods and services, or New Zealand may lose access to certain export markets for some products. New Zealand's economic wealth is highly dependent on the sale of goods and services to people in overseas markets.

Potential economic opportunities: New Zealand's economic wealth is highly dependent upon the productive and environmental characteristics of plants and animals. GM can provide the opportunity to change characteristics of these plants and animals, change how they grow, or create entirely new products and sectors of economic activity.

While the current world market for the first generation of GM food products is not positive, these products are generally not ones that are important to New Zealand's agricultural production (being soyabean, corn and, canola). Other first generation GM products have been successful, particularly cotton and some animal feed products. There is, however, much uncertainty as to the future possible costs and/or benefits, as opinions and buying habits change and evolve, and as a second generation of GM products emerges which might have more attractive qualities for consumers. Similarly the opportunities for New Zealand will be different across food, fibre, environmental and medical applications of the technology.

The need is therefore to measure the potential effects which each may have on New Zealand's CGI and on consumer purchasing in overseas markets, and also the effects which adoption of that type of GMO would have within the New Zealand economy.

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[2] Stroombergen (2000), *Economic Modelling of Biotechnology Impacts*. Submission to the New Zealand Royal Commission on Genetic Modification, on behalf of the New Zealand Life Sciences Network, Wellington, November.
BERL (2003), *Economic Risks and Opportunities from the Release of Genetically Modified Organisms in New Zealand*, Report to Ministry for the Environment and the Treasury, April.

2 IMPACT ON NEW ZEALAND IMAGE AND MARKETS OF GM STATUS

The diagram depicts the influences that are the focus of this study.

In particular, the demand-side survey of consumers and gatekeepers is attempting to measure the impact labelled 'A' (the impact that the release of GMOs has on the CGI), as well as that labelled 'B' (the impact that the release of GMOs has on New Zealand's international trade). By implication, we can then infer the influence labelled 'C'.

The economic modelling component of the survey attempts to measure the impact labelled 'B' (using, in part, the outputs from the demand-side survey, as well as information from the supply-side scenarios).

The overall layout of the questionnaire comprised three sections:

- an initial section aimed at placing a range of countries, including New Zealand, along a 5-step[3] 'relative image of the environment' spectrum
- a second section to determine by how much "the image of the state of the environment in New Zealand" may or may not change as a result of the release of certain (specified) GMOs.
- a third section ascertaining the impact of the release of GMOs in New Zealand on foreigners' purchase intentions of New Zealand products and holidays.

The issue arises as to the amount of information to put 'in front of' respondents concerning the type, method, use and benefits and risks of the particular GMO being released. *EITHER* specify the details of the GMO release but provide **no** information on either expected benefits or potential risks; *OR* specify the GMO release with additional information on expected benefits **and** potential risks. The former option was chosen as this approach allows the respondent to answer using all his/her inherent preferences and beliefs whether informed or otherwise. The parallel of business confidence surveys is useful. Respondents to such surveys are not fore-armed with information as to the current economic situation, prospects, influences etc. Rather they respond given their *own* pre-determined disposition to the current environment formed from their own knowledge whether informed or otherwise.

[3] i.e. 'very good, among the best'; 'good, above average'; 'average'; 'not good, below average'; 'bad, among the worst'.

There are at least two factors that influence survey results that need to be borne in mind when generalising from scenarios as presented in a survey to 'real life' The first relates to information at point-of-sale. It is unlikely that consumers would know, or bring-to-mind at point-of-sale, the GM attributes of New Zealand in other contexts, and yet in the survey context, of necessity this has been brought specifically to their attention.

Secondly, the price-quality characteristics of the product, relative to those from other countries can assume a powerful if not predominant influence in the product choice for many consumers, notably including trade-offs of immediate tangibles (cost, appeal) against intangible and more remote perceptions of other consideration like GMOs.

There is one type of consumer response that is not sensitive to price. These consumers exhibit an aversion to GM food which is categorical, a similar purchasing behaviour to vegetarians or consumers guided by religious codes.

Furthermore, the durability of the survey results will depend on the dissemination of favourable, unfavourable and neutral information about GMOs, and the way this is received by the public. Repeat measures are appropriate in the relatively early phase of public understanding. In particular, it is common for people to be cautious about such innovations until sufficient time has elapsed for them to be proven or otherwise.

In conclusion, the results of consumer surveys are subject to a range of influences which make it difficult to translate stated preferences into actual market effects. Some influences require an assessment of the 'fading' of stated preferences, while others 'amplify' consumer concerns out of proportion to stated results. Consequently, it is essential that all understandings of survey results be interpreted within the context of sophisticated knowledge of specific key markets.

2.1 International market survey results

A net sample of 444 people were interviewed on the basis of one per household. Interviews were conducted in three countries : Australia (150), United Kingdom (150) and United States (144). In order to focus the study on areas where New Zealand produce is thought to be more widely available, the following regions of each of these countries were sampled: Australia (all); United Kingdom (England); and United States (California, Oregon and Washington). A summary of results follows.

2.1.1 Relative Image of the New Zealand Environment

1. Respondents' image of the New Zealand environment was excellent, with about one-third of all respondents rating New Zealand "Very Good, among the best", and a further 48% thinking New Zealand's environment "Good, above the average".

2. New Zealand's environment was rated highly by respondents from all three countries, along with those of Switzerland and Canada.

3. The New Zealand environment was rated highest in the United Kingdom, where 41% of respondents thought it to be "Very Good, among the best".

Table 2.1 Image of the New Zealand Environment

	Australia %	United Kingdom %	United States %	Total %
Very good – among the best	27	41	29	32
Good – above average	58	44	41	48
Average	9	8	9	9
Not good – below average	1	2	1	1
Bad – among the worst	1	-	-	-
No image	5	5	19	10

NB. Percentages may not add to 100 due to rounding.

2.1.2 Image Change

Approximately 55% of respondents stated their image of the New Zealand environment either would not change or would improve should New Zealand release GMOs in pest control or livestock feed. Approximately one-third of all respondents stated that their image of the New Zealand environment would get worse in such a situation.

Table 2.2 How Respondents' Image of the New Zealand Environment Would Change Under Different GMO Release Scenarios

		Pest Control %	Livestock Feed %	Disease Prevention %	No GMOs %
Get Better	Australia	33	31	35	29
	United Kingdom	19	18	41	45
	United States	24	29	40	24
	Total	25	26	39	33
Stay the Same	Australia	30	27	32	59
	United Kingdom	27	23	27	44
	United States	30	37	29	58
	Total	29	29	29	54
Get Worse	Australia	27	34	21	8
	United Kingdom	43	51	17	3
	United States	27	24	18	8
	Total	32	37	19	6
Don't Know	Australia	10	8	12	4
	United Kingdom	11	7	15	8
	United States	19	10	13	10
	Total	14	9	13	7

NB. Percentages may not add to 100 due to rounding.

1. Respondents were more tolerant of the use of GMOs in disease prevention with 68% of all respondents said that New Zealand's environmental image would stay the same or improve. Conversely, 19% overall stated that their view of the New Zealand environment would worsen under this scenario.

2. One-third of the respondents stated that their image of the New Zealand environment would improve under a scenario in which New Zealand did not use GMOs, while over half said that their view would remain unchanged.

3. Respondents in the United Kingdom were most averse to New Zealand's use of GMOs, with 43% stating their image of the environment would worsen under the pest control scenario, and 51% stating this under the livestock feed scenario. However, 41% said their image of New Zealand's environment would improve should it use GMOs to prevent disease.

4. Australian and American respondents were more open to New Zealand's use of GMOs under the different scenarios.

2.1.3 Purchase Change

1. When confronted with a scenario in which the respondent was choosing a non-GM product that came from New Zealand which used genetic modification in other ways (that is, not in relation to the given product), the majority of respondents said that they would feel no different to before. This accounted for 43% of all respondents in the fruit scenario and 54% of respondents under the dairy products scenario.

2. Between one-quarter and one-third of respondents said that they would be less inclined to purchase the product under the fruit and dairy scenarios. Of these respondents, the majority stated that they would not buy the product regardless of any discount applied.

3. Respondents appeared more comfortable buying a dairy product from New Zealand should it use GM, than they were purchasing fruit.

4. When choosing a holiday, respondents were less likely to be affected by New Zealand's GM status, with 72% overall stating that they would feel no different about choosing a New Zealand holiday should New Zealand use GM.

5. Respondents reacted far more favourably to a scenario in which New Zealand did not use GMOs. A group of 47% stated that they would be more inclined to buy New Zealand fruit, and another 43% stated it would make no difference. The majority of the 47% of respondents who stated they were more inclined to buy remain prepared to buy this product when a price premium was applied.

Table 2.3 How Respondents' Purchasing Behaviour Would Change Under Different GMO Release Scenarios

		Purchasing Fruit %	Choosing Holiday %	Purchasing Dairy Prod. %	No GMOs %
More inclined	Australia	14	11	13	45
	United Kingdom	6	7	7	55
	United States	16	9	11	40
	Total	12	9	11	47
No Different	Australia	43	73	58	47
	United Kingdom	41	65	47	33
	United States	44	77	57	49
	Total	43	72	54	43
Less Inclined	Australia	36	13	25	2
	United Kingdom	37	13	32	1
	United States	30	11	26	4
	Total	35	12	28	2
Depends on product	Australia	7	4	4	6
	United Kingdom	16	14	13	11
	United States	10	3	6	6
	Total	11	7	8	8

NB. Percentages may not add to 100 due to rounding.

2.2 Translating the survey results to model inputs : demand changes

The survey results were extrapolated to apply to all New Zealand export markets for dairy, meat, horticulture and tourism. The translation of these results to model input assumptions is outlined below.

2.2.1 GMO scenarios

Various questions surveyed the change in purchasing behaviour upon the introduction of a GMO in New Zealand. From responses the calculated average price - 'willing to pay' - for New Zealand products amongst those that remain in the market, was almost unchanged.

That is, amongst those that responded that they may continue to purchase New Zealand products, there were some who would only buy if the price was lower than before and there were others who remained prepared to buy at a higher price. Upon calculation, it was clear that the influences from these two groups of consumers - following the release of a GMO in New Zealand - in effect, 'balanced each other out'.

In other words - amongst consumers that continue to exhibit a demand for New Zealand products - the balance between those consumers willing to pay a higher price and those requiring a lower price to purchase New Zealand products is close to evenly matched.

On the basis of these results, the surveys indicated that the 'horizontal' shift of the demand curve facing New Zealand exporters of dairy, meat, horticulture and tourism is almost wholly identified by those that 'withdraw totally from the market' upon the introduction of GMOs in New Zealand. By 'withdrawing totally from the market', we mean that they responded to the survey questions with the statement that there was no price at which they would purchase New Zealand products subsequent to New Zealand releasing GMOs.

The figures for those that withdraw totally from the market are: Fruit purchase – 23.2%, Dairy purchase – 19.6%, Holiday purchase – 5.7%. These figures were then adjusted to allow for the significant component of New Zealand dairy and meat exports that are not sold directly to consumers. Furthermore, following industry consultation, this component is not identifiable as New Zealand-made products but are, rather, ingredients or component inputs into other commodities. It is estimated that 40% of New Zealand's dairy exports and 45% of New Zealand's meat exports are 'open to a direct consumer' response. As such, the above shifts were translated into horizontal shifts in demand curves as listed in Table 2.4.

Table 2.4 Assumed demand curve shifts (horizontal) with GMO release

% shift in demand curve	% open to consumer response	for CRP and PST scenarios		for HUM scenarios	
		from survey	input to model	from survey	input to model
Dairy exports :	40	-19.6	-7.8	-9.8	-3.9
Meat exports :	45	-19.6	-8.8	-9.8	-4.4
Horticulture exports:	100	-23.2	-23.2	-11.6	-11.6
Tourism exports :	100	-5.7	-5.7	-2.9	-2.9

Notes:
CRP = scenarios involving the release of a crop-based GMO. PST = scenarios involving the release of a pest or bio-control GMO. HUM = scenarios involving the release of a human medicine GMO

2.2.2 No GMO scenarios

In the case of no GMOs in New Zealand, the average prices willing to be paid by those that remained in the market were significantly above those of the base case. This can be interpreted as a vertical shift of the export demand curve faced by New Zealand exporters. The horizontal shift implied by such a movement was calculated as 34.3%. These were imposed in the 'no GMOs' scenarios, after adjustments to allow for the proportions of dairy and meat exports 'open to a consumer response', as per Table 2.5.

Table 2.5 Shift in demand curve facing New Zealand exporters given no GMOs

% shift in export demand curve	% open to price change	for NOG scenarios	
		from survey	input to model
Dairy exports :	40	34.3	13.7
Meat exports :	45	34.3	15.4
Horticulture exports:	100	34.3	34.3
Tourism exports :	100	34.3	34.3

Note: NOG = scenarios where there are no GMOs in New Zealand

2.2.3 Note on human medicine scenarios

The shifts imposed for the PST, CRP and NOG simulations follow from the calculations described previously. The shifts imposed for the HUM simulations are half those imposed for the PST and CRP simulations. This is imposed on the basis that the responses to the image change questions indicated an order of magnitude difference in the expressed attitudes towards human medicine GMOs on the one hand and pest control and crop GMOs on the other. This difference is summarised in Table 2.6.

Table 2.6 Effect on New Zealand's image if there was a release of GMO survey

	pest control GMO (%)	crop GMO (%)	human medicine GMO (%)
get better	25.3	26.0	38.7
get worse	32.3	36.3	18.7

2.3 Translating the survey results to model inputs : sensitivity to price changes

Within the survey questions, respondents were asked whether or not their purchase decisions would change in the face of price changes. From the responses to these questions we obtained a set of 15 observations concerning price and demand changes associated with purchases of each of New Zealand fruit, New Zealand dairy & meat and New Zealand holidays.

These observations were deduced from the set of consumers that 'remained' in the market. For example, there were a total of 10% of Australian respondents who were less inclined to purchase New Zealand fruit upon the release of GMOs, but still signalled a willingness to alter their response if there was a price change. In particular, a 10% price reduction resulted in the proportion that remained less inclined to purchase falling from 10% to 7%. This increase of 3% out of a total of 10% (ie a 30% change) in the face of a 10% price change implies a 'sensitivity to price change' of 3[4].

Calculations across the 15 observations for each of the three commodities provided estimates of the magnitude of such 'sensitivity' ranging from 1.4 to 7.5. Furthermore, the majority (ie 33 out of 45) of these estimates lay in the range 2.5 to 5.0. In addition weighted average of the estimates suggested sensitivity of 3.8, 3.9 and 3.6 for horticulture, dairy and holidays respectively. Taking these calculations into account, the model experiments were undertaken using a price sensitivity equal to 4.0 for NZ exports of each of the dairy, meat, horticulture and tourism categories.

[4] This 'sensitivity' is formally termed the 'price elasticity of demand' and is defined as the percentage change in quantity demanded divided by the percentage change in price.

3 NEW ZEALAND'S PRODUCTION SYSTEM

The adoption of policies to allow the managed release of GMOs that have been tested and legally approved as safe, provides the opportunity to continue and significantly extend the process of genetic improvement in New Zealand's biota-based production industries as well as other improvements to production in New Zealand.

Genetic improvement has already enabled New Zealand producers to achieve significant productivity gains, and the use of GM technology can take this further. In pastoral agriculture, cropping, horticulture and forestry, GM may allow producers to control pests and reduce pesticide use, thereby achieving economic and environmental benefits. GM may also allow the production of further medicinal remedies to improve human health and wellbeing. These three types of effects are modelled in scenarios specified in this section.

3.1 Opportunities for GM-enhanced agricultural production in New Zealand

The potential opportunities to enhance production in New Zealand from GM in the plant and animal production area include pest control, productivity increase and reducing any adverse environmental impact of production by reducing herbicide and pesticide use, and reducing methane emissions from ruminant animals (cattle, sheep, goats, deer). The range of potential applications will differ between agriculture, horticulture, plantation forestry and aquaculture.

It is not possible to identify at this time all potential opportunities for the application of GM, nor to specify the economic effects and model the impact of them all on the New Zealand economy. What can be done is to identify a small number of types of GM applications, to specify a range of possible effects from each and model the outcomes to obtain order-of-magnitude economic effects from these opportunities.

While the major application to date of GM technology globally is in arable field crop production the more important potential applications in New Zealand are expected to centre on the two largest biota-based industries of pastoral agriculture and plantation forestry.

For this reason the scenario selected to test for potential economic impact from production GMOs is based in pastoral agriculture.

3.2 The pastoral scenario

Over a reasonably long term, i.e. 1975 to 2001 average production per cow in the New Zealand dairy herd has increased at about 1% per annum.[5]

[5] Livestock Improvement Corporation Ltd, *Dairy Statistics*, various dates.

The initial scenario is a GM induced improvement to one component, say ryegrass, and the assumed productivity increase is 2.5% per annum. It is assumed that the uptake of the GM technology would be 50% within pastoral agriculture, and that this advantage (over the Rest of the World, or RoW) would be maintained for 5 years. This results, by year 10 in an increase in the average productivity in pastoral agriculture of 6.4%. This scenario is called *Run #2*.

These Reference numbers are the labels for the experiments carried out using the economy-wide model. They are shown at the top of the relevant columns in the tables of results.

The second approach is to assume that a range of ongoing incremental improvements are made such that the advantage gained from the induced productivity improvements of 2.5% per annum with an uptake of 50% is maintained over the 10 year period. This scenario is *Run #3*. The 'counter-factual' or *'Control'* approach on pastoral productivity is to assume that there is no productivity increase, but that the negative effects on demand in the world markets as a result of the GMO release remain. This is called *Run #1*. Finally there is the counter-factual or '*Control*' on the demand side, namely assuming that productivity is improved as in *Run #3*, but with no demand shift for or against New Zealand products. This scenario is *Run #6*.

3.3 The pest control scenario

The second scenario tested in this study concerns a GMO possum control. Possum control is a key concern for New Zealand agriculture, primarily because possums are a vector for bovine tuberculosis as well as reducing grazing loss to possum. Possum control is also important for conservation, but this is not covered in this study. Bovine tuberculosis is estimated to afflict about 1.3% of cattle herds on a period prevalence basis i.e. at any given point in time about 1.3% of herds have bovine tuberculosis. For dairy cattle this implies that approximately 7% of animals become infected over their lifetime. However, about 12% of animals have to be killed as they are deemed to be infected as a result of testing.

The incidence of bovine Tb in New Zealand is currently about six times higher than the guidelines prescribed by the Office Internationale Epizooties (OIE) which are used by the World Trade Organisation. The fact that we still export to Europe, US, Japan and other high value markets is primarily attributable to our high standards of meat inspection and pasteurisation. However, there is always a danger that consumer sentiment will turn against products from any country with a higher than acceptable incidence of bovine Tb.

The Animal Health Board provides some of the costs which are relevant to an economic evaluation of possum control.

- Current national expenditure on Tb possum control of $50-$55m per annum. The Animal Health Board estimates that this expenditure needs to be sustained until 2013 for New Zealand to meet the OIE/WTO standard for Official Freedom from bovine Tb (infected herd prevalence less than 0.2%). Expenditure of $20-$30m per annum is likely to be required thereafter to maintain official freedom status.

- Loss of agricultural and forestry production, plus damage to plantings for erosion control estimated at $40m per annum.

- Other expenditure on managing bovine tuberculosis (eg Tb testing of herds) of $22m per annum.

- On-farm costs of $22m pa.

These costs total around $130m per annum, relating to possum control in agriculture and plantation forestry, providing a minimum benchmark against which the application of GM technology to controlling bovine Tb may be evaluated. In fact this benchmark may be much too low as the whole of New Zealand's dairy and beef exports are potentially at risk. Thus even if GM based methods of controlling bovine Tb are not cheaper than current methods, if they provide more effective control and lower the risk to New Zealand's exports, there could be a greater net benefit that with present methods.

Two possibilities have been suggested; GM-based fertility control and GM vaccines. The former is aimed directly at possum physiology, the latter at a micro-organism. Both could be distributed by using a possum-specific parasite (nematode) as a vector. Fertility control is considered unlikely to be viable for another 5-10 years, but a Tb vaccine is probably viable within 2-5 years.

Funding under the Public Good Science Fund for research on possum control was $14.8m in 1999/00 and has been at similar levels for the last five years, although not all of this is targeted purely at the control of Tb. Fewer possums would also have environmental benefits.

- For modelling purposes it is assumed that a GM based vaccine for the control of Tb in possums will be in common use by 2010 in dairying areas afflicted by Tb. This scenario is simulated as:

- A saving in expenditure on managing bovine Tb and on existing methods of possum control of approximately $50m per annum.

- An assumed cost recovery by the model's 'GM research' industry of 10% of this saving.

- On-going research and development costs of at least $25m per annum over 2005-2010.

- By 2010, a 6% increase in dairy output due to lower culling rates. This assumes that the incidence of bovine Tb is reduced by one-half, and the scenario is *Run #4*.

- By 2010, a 12% increase in dairy output due to lower culling rates. This assumes that the GMO has been fully successful in eliminating the incidence of bovine Tb. The scenario is *Run #5*.

3.4 Human therapeutics scenario

There a number of current research projects in biotechnology and GM that relate to human health. Examples are the production of a-1-antitrypsin in sheep or cattle for the treatment of cystic fibrosis, the production of A2 milk to reduce the risk of heart disease, and better ways of treating certain types of diabetes. From a modelling point of view these are all difficult examples to work with because the costs and benefits are too vague at this stage – for various reasons such as commercial secrecy or imprecise cause and effect relationships.

A more promising development is the research being undertaken by AgResearch to produce proteins for use in enzyme replacement therapy (ERT) for the treatment of lysosomal diseases which cause skeletal, muscular and neurological problems. There are more than 40 known lysosomal disorders, but ERT is available for only 2 or 3 of them. The proteins themselves do not consist of a live GM organism, but AgResearch is intending to produce them via transgenic cows. Their research is estimated to cost around $5m per annum. The proteins are currently made in laboratories, but manufacture via cows is estimated to be around 1000 times more efficient.

AgResearch's aim is to produce more than 100kg of proteins annually. At a value of more than $100/mg, export earnings could potentially exceed $10 billion. Whether such a high unit price can be sustained in the presence of large amounts of product which is made at much lower cost is certainly questionable. Nevertheless it is clear that export earnings measured in the hundreds of millions is a plausible scenario.

Note too that New Zealand is likely to retain an advantage in the production of these proteins for some time, as proteins produced from cows will not gain world-wide acceptance for human use, unless the source country is free from BSE. Our main competitor is likely to be Australia.

For modelling purposes it is assumed that between 2005 and 2010 there is a strong export market for proteins derived from transgenic cows for use in ERT in the treatment of lysosomal disorders.

Specifically this scenario is simulated as:

- Export earnings of $200m per annum.
- On-going research and development costs of $5m per annum.

3.5 New Zealand refrains from releasing GMOs scenario

This scenario postulates a 'GM free' New Zealand, while the Rest of World (RoW) pursues GM technology. We acknowledge the difficulty in defining the 'GM free' label, but in this context we interpret it (as per the survey questionnaire) to mean "New Zealand were not to use genetically modified organisms in production, nor release GM organisms into the environment".

On the demand side it is then assumed that some of New Zealand's exports would be able to attract a price premium, being traded in the GM-free market. The effect of this demand premium is shown in experiment *Run #7*.

The main effect on production in New Zealand would be felt in the biota-based industries. Firstly the productivity of the producers in the RoW would increase, making them more competitive with New Zealand producers in general markets (i.e. those markets which include GM products). To retain some consistency with the GM scenarios above, the productivity increase assumed in the RoW is 6.4% in total over the 10 year time horizon. This scenario is experiment *Run #8*.

In addition to foregoing access to the RoW GM-induced productivity, the retention of GM-free status would firstly require New Zealand put in place infrastructure to ensure no importation of GMOs. If New Zealand took a purist stance to its GM-free status, and assuming the RoW has adopted GMOs, it would therefore be very difficult to import into New Zealand genetic material for breeding, or for use in production as such material could be contaminated with GMOs.

The plant and animal species used in almost all of New Zealand's production for export are exotic species, namely cattle, sheep, deer, ryegrass, legumes, other pasture and feedcrop species, horticulture crops and *Pinus radiata*. New Zealand would be cut off from the source gene pool for genetic improvement of its production base. The isolation from world genetic improvement implies that New Zealand producers would not participate in the long term trend increase in productivity due to cross breeding and selection within the world gene pool. This trend has been found to be 1% to 3% per annum. Lack of access implies that New Zealand genetic productivity in those industries would remain at present levels, foregoing the normal trend increase. This scenario could thus see the relative productivity of the RoW producers increase by the first 6.4% due to their adoption of GMOs, and a second, say, 6.4% compared with New Zealand producers due to the normal trend genetic selection and improvement over the 10 year time horizon. Due to genetic isolation, New Zealand could no longer participate in this second increase either. The overall effect would be a total of 12.8% relative productivity increase by RoW. This scenario is experiment *Run #9*.

The results of these scenario experiments are given in the following section.

4 ECONOMY-WIDE MODEL EXPERIMENTS

4.1 The model

4.1.1 The economic relationships

Economic models represent the major relationships between the various industries and participants in an economy. These relationships are expressed as equations and together form a coherent - but necessarily simplified - portrayal of the workings of an economy.

The particular model used here is a general equilibrium model. It mimics the outcome of an equilibrating process between the demands for goods and services and the resources necessary to produce those goods and services to satisfy such demands.

4.1.2 The model

The economy is simulated through changes in the prices and quantities of goods, services and/or resources. Key assumptions are:

- The price of a good will adjust to ensure that demand for that good equals the supply of that good. ie. if demand is greater than supply then the price of the good in question will rise; if supply is greater than demand then its price will decline. A similar 'adjustment mechanism' is imposed for resources.

- New Zealand producers will endeavour to adjust their use of resources such that they make their products at 'least cost' - for example, if the price of capital rises the New Zealand producer will attempt to use more labour and less capital (per unit of output).

- Consumers (both New Zealand and foreign) will adjust their purchases towards those that are cheaper in comparison - for example, if the price of a New Zealand-made product becomes cheaper than that of its foreign-made equivalent, both New Zealand and foreign consumers will purchase more of the New Zealand-made product and less of the foreign-made item.

These processes are performed at the individual industry, commodity and resource level - the model used separately identifies 49 industries (covering the whole of the New Zealand economy) and 22 export commodities.

It should be noted that the ability to adjust resource use is limited through the specification of a nested 2-level production function. At the first level it is possible to substitute between capital, labour, energy and materials. At the second level substitution is allowed within the composite energy input which is made up of coal, oil, gas, and electricity. Both levels utilise translog functional forms.

The ability of consumers to adjust their purchases is limited by tastes and preferences, and governed by income and relative prices. The functional form is the Almost Ideal Demand System.

4.2 Inputs for the experiments investigating the release of GMOs

The results presented below explore the impact of three forces : Namely,

- a change in the demand for particular New Zealand exports.
- an improvement in the technology available to particular New Zealand industries.
- an improvement in the technology available to foreign producers.

In isolation, each of these three forces individually will result in unambiguous impacts on the New Zealand economy, given the above modelling framework. In reality, however, these three forces would not act in isolation. In combination the presence of 'opposing' forces means the overall impact on the New Zealand economy is ambiguous. In this case therefore, the model provides information about the balance of these influences and so determines whether the overall impact is positive or negative (again, given the magnitudes of the original forces imposed).

4.3 Interpreting the model and scenario outline

The results presented in the section below measure the effect of these 'opposing forces' after 10 years of their initial impact. The effects are expressed (usually in 'percentage change' terms) in comparison to the *Control* scenario. This is illustrated in Figure 4.1 below.

The model measures the difference between, for example, the level of GDP ten years hence in the *Control* scenario and the level of GDP ten years hence in the experimental scenario. In particular, note that the percentage changes presented in the results tables are NOT differences in per annum growth rates. They are the percentage change in the level of GDP[6] ten years from the initial impact.

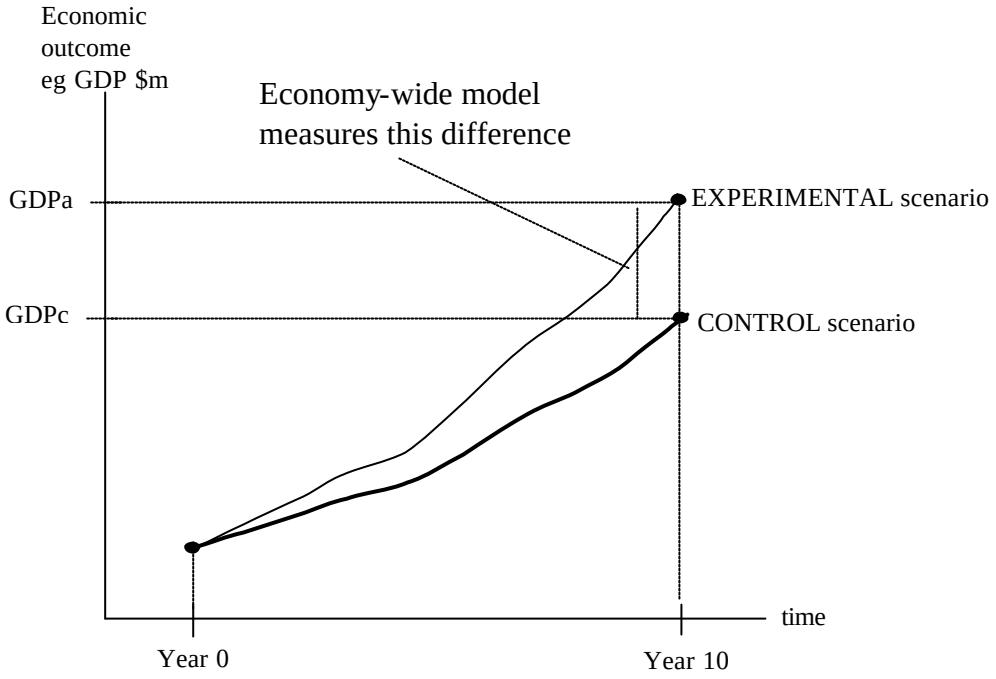
The fundamental of the modelling process depicted in Figure 4.1 below is the 'comparative' framework - ie the outcome measured by the model experiments is the impact of the adoption (or otherwise) of a particular 'GMO scenario' compared to some '*Control*' or Base Case scenario. Such a scenario is sometimes also referred to as a 'business-as-usual' picture of the economy.

Points to note concerning such a *Control* scenario are:

- It is a model solution for the 'target horizon year' to serve as the basis for comparison and represents a continuation of 'status quo'.

[6] or the percentage change in various other economic measures - for example: employment, exports, imports, consumption spending.

Figure 4.1 Interpreting the economy-wide model experiment results



- For the purposes of this project, the model's baseline picture is projected ten years hence.

- in the GM arena, such a baseline picture involves the adoption in New Zealand of technology and productivity as per historical trends. It does not involve the activities and effects which would become necessary were New Zealand to adopt zero-tolerance to GM seeds in all imports. Such a situation should be properly modelled as a scenario variation on the *Control.*

- The *Control* involves projections of export demand curve expansions (reflecting world demand growth), productivity growth and growth in capital resources, labour supply and employment, as well as growth in real government expenditure. Based on numerous general equilibrium model experiments undertaken over many years, the 'comparative' framework provide estimates of the impact of 'an experiment' or 'event' that are relatively insensitive to the outcome of the *Control* scenario projections.

The following sub-sections outline the results of numerous model experiments. The relationship between the experiments are illustrated in Figure 4.2 below.

- Run #1: the **sole** impact of a demand contraction given the release of a crop or bio-control GMO in New Zealand.

- Run #2: the **combined** impact of a demand contraction and a one-off productivity improvement through the release of a crop GMO.

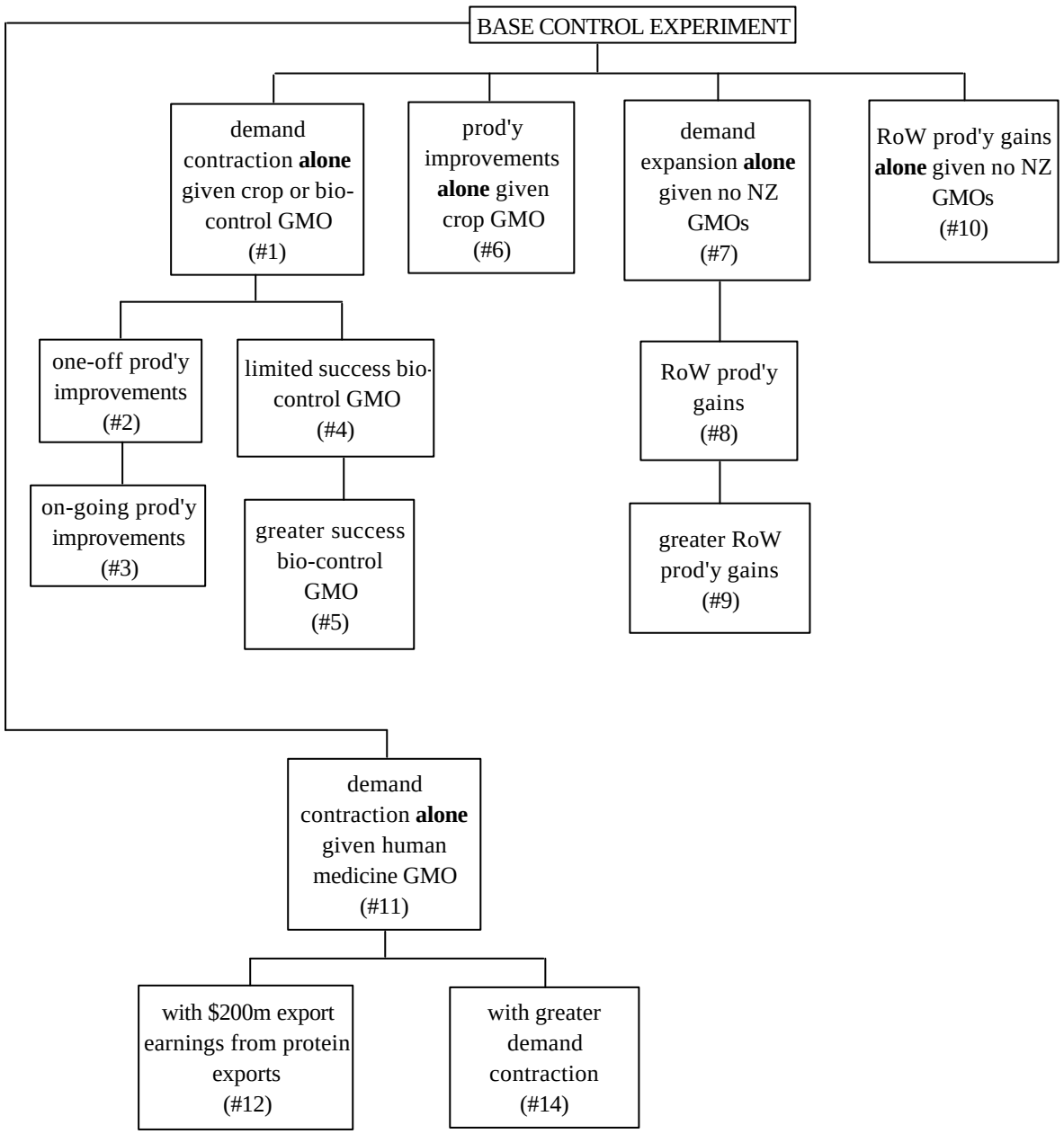
- Run #3: the **combined** impact of demand contraction and on-going productivity improvements through releases of crop GMOs.

- Run #6 : the **sole** impact of a on-going productivity improvements through the release of crop GMOs.

- Run #4: the **combined** impact of demand contraction and productivity improvements through the limited success of the release of bio-control GMO.

- Run #5: the **combined** impact of demand contraction and productivity improvements through the greater success of the release of bio-control GMO.

Figure 4.2 Schema of model experiments



- Run #7: the **sole** impact of a demand expansion as New Zealand refrains from using GMOs.

- Run #8: the **combined** impact of demand expansion and productivity improvements in the Rest of the World through their use of GMOs.

- Run #9: the **combined** impact of demand expansion and greater productivity improvements in the Rest of the World through their use of GMOs.

- Run #10: the **sole** impact of productivity improvements in the Rest of the World through their use of GMOs.

- Run #11: the **sole** impact of a demand contraction given the release of a human medicine GMO in New Zealand.

- Run #12: the **combined** impact of a demand contraction and the effect of $200m of additional receipts through protein exports from the release of a human medicine GMO.

- Run #14: the **sole** impact of a larger demand contraction given the release of a human medicine GMO in New Zealand.

- Run #15: Run #3 combined with Run #12, being the **combined** impact of demand contraction, on-going productivity improvements through releases of crop GMOs, and the effect of $200m of GMO-based protein exports.

Additional combinations of tests have been undertaken, but are not reported here. The results for all scenario are given in Table 4.1.

4.4 Pastoral GMO scenarios (Runs *#1 to #3 and #6*)

The results of the first experiment illustrates the impact of a reduction in demand for New Zealand dairy, meat and horticultural exports as well as a reduction in tourism export demand. In line with the previous argument, the presence of this one force, on its own, means there is an unambiguous negative impact on the New Zealand economy.

The effect of this lower demand for New Zealand exports results in 2.6% lower employment, with GDP lower by 3.4% - in comparison to that in the *Control* simulation.

The large proportion of this impact occurs in the agriculture sector, with flow-on impacts on the processing industries. There is also a noticeable impact on tourism-related transport sectors. Nevertheless, there are also repercussions across all other sectors as domestic household spending is lower as a result of the lower levels of employment.

As has been discussed earlier however, the extent of this impact assumes the full translation of stated survey response to actual purchase behaviour. Where such a translation overstates the

actual purchase response, then the overall economic impact would be consequently less than that reported in this experiment.

4.4.1 Reduced demand with one-off pastoral productivity gains (*Run#2*)

This experiment introduced a 'one-off' productivity improvement. This assumes that all pastoral agriculture output can be produced using 6.4% less labour and capital per-unit. This figure is also the equivalent of 2.5%pa higher productivity, across half of the pastoral agriculture output enjoyed for 5 years. Such a productivity improvement *vis-à-vis* the Rest of the World enables New Zealand exporters to produce and sell their product at a more competitive price (again, compared to the *Control* simulation).

The magnitude of this productivity improvement however, is insufficient to offset the impact of the lower demand. In other words, the 'balance of the two opposing forces' is dominated - in this instance - by the greater impact from the lower demand for New Zealand's exports. Nevertheless, the lower production costs arising from the productivity improvements do mitigate the demand-side impact.

Consequently, the results of experiment #2 give a 1.2% reduction in GDP when the demand contraction is accompanied by the 'one-off' productivity gain. This result compares with the 2.4% reduction in GDP arising from the lower export demand alone, as noted in experiment #1.

Employment is 1.5% lower in experiment #2 (compared to 2.6% lower in experiment #1), while total export volumes are 1.9% lower - with meat, horticulture and tourism exports bearing the brunt at, respectively, -5.4, -22.0 and -5.0% change on the level of exports in the *Control* simulation ten years hence.

4.4.2 Reduced demand and on-going pastoral productivity gains (*Run #3*)

The situation of greater productivity improvement (*vis-à-vis* the Rest of the World) - or, indeed, a sequence of on-going productivity improvements - accompanying the lower export demand, is the next experiment. Here, productivity improvements of the order of 2.5%pa across 50% of pastoral agriculture enjoyed over 10 years is imposed.

This combination of forces results in a close to zero impact on overall New Zealand GDP - with GDP 0.1% below the *Control* simulation. Employment is 0.5% lower than *Control* with total export volumes unchanged.

4.4.3 On-going pastoral productivity gains only (*Run #6*)

The imposition of a productivity improvement, on its own, will have an unambiguous positive impact on New Zealand economic activity.

In such a case the impact amounts to an overall GDP of 2.5% above that of the control, with employment 2.2% higher. The positive gains are concentrated in the agriculture sector, reflecting the nature of the productivity improvements, although 'flow-on' effects across other

industries are evident as a result of higher consumer spending on the back of higher than control employment levels.

Again, and carrying greater weight in regard to this experiment, a cautionary note needs to be acknowledged. As above, these gains may well be difficult to achieve given that they incorporate significant increases (above those in the *Control* simulation) in both dairy and meat exports. Constraints as described above could well limit the actual gains achieved here.

4.5 Pest control GMO scenarios (Runs *#4 and #5*)

Where the productivity improvements imposed are a more focussed result of pest control operations - thereby impacting on the dairy, and sheep & beef farming sectors, their remains a similarity in the overall picture of impacts. That is, the 'balance of influences' is dominated by the reduced level of export demand imposed in the scenario.

In particular, moderate success in controlling possum pests (resulting in a 6% improvement in productivity in these farming sectors) mitigates - to a degree - the impact of reduced export demand. As a result, overall GDP is 1.3% lower than the *Control* simulation (experiment #4). The successful control of possum pests (imposed by assuming a 12% improvement in these sectors' productivity- #5) is still insufficient to counter the negative demand influences facing New Zealand exporters - with GDP in this case 0.3% below the control experiment.

The results from the above scenarios confirm that reducing uncertainty to establish actual (as opposed to surveyed) purchase response to GMO release is pivotal to determining its impact on the New Zealand economy. Similarly, greater information aimed at confirming the actual (as opposed to asserted) productivity gains from GMO release is the other critical element that is a pre-requisite for an conclusive determination of the economic impact.

4.6 Scenarios where New Zealand foregoes GMOs (Runs *#7 to #10*)

The situation where New Zealand foregoes GMOs is mimicked by the modelling framework again through a balance of two influences:

- an increase in the demand for particular New Zealand exports.
- an improvement in the technology available to producers elsewhere in comparison to that available to particular New Zealand industries.

4.6.1 Demand expansion alone (*Run #7*)

The results of the first experiment here illustrates the impact of an in demand for New Zealand dairy, meat, horticultural and tourism exports. Consistent with earlier arguments, the presence of this one force, on its own, means there is an unambiguous positive impact on the New Zealand economy, with 7.5% higher GDP, 8% higher employment and 12.2% higher export volumes in total (all compared to their respective levels in the *Control* simulation).

However, the comment made earlier with respect to simulation Run#6 applies here as well. In particular, the unambiguous positive impact on the New Zealand economy relies on significant and substantial increases in dairy and meat export volumes being sold (over and above those attained in the *Control* simulation). Constraints on New Zealand's abilities to expand export volumes of these commodities (in the form of quotas, regulations and other effective barriers) could well limit the actual gains achieved here.

4.6.2 Demand expansion with RoW productivity gains

Introducing to the model some productivity improvements in the Rest of the World results in potentially significant and substantial consequences for New Zealand dairy and meat export volumes. The primary cause behind this impact is the responsiveness (or sensitivity) of a large proportion of foreign consumers to price differentials.

In other words, as described earlier from the survey results, while a proportion of foreign consumers expressed a clear preference for conventionally produced goods and services, there exists a larger proportion of foreign consumers that are prepared to change their purchasing behaviour on the basis of price.

Run #8

One model experiment imposes an improvement in productivity in the Rest of the World to the extent that the price competitiveness of New Zealand dairy, meat and horticultural products deteriorates by 6.4% in total over a 10 year horizon. This is imposed in tandem with the increase in demand for particular New Zealand exports described in the previous paragraphs.

The balance of these two influences - ie one, the increase in demand for New Zealand exports from some foreign consumers; and two, the loss of price competitiveness of New Zealand exports - continues to result in overall gains to the New Zealand economy. GDP is 3.4% higher than in the *Control* simulation, with employment 3.9% higher.

The benefits here arise, in the main, from the expansion in tourism exports (which are not exposed to the reduction in price competitiveness imposed on New Zealand's commodity exports). As a consequence, tourism related transport and accommodation industries expand considerably (above the *Control* simulation), with the higher employment flowing on to higher consumer expenditure which impacts across the range of domestic industries.

Run #9

Another model experiment imposes greater productivity gains in the Rest of the World. In this case, a deterioration in the price competitiveness of New Zealand dairy, meat and horticultural products of 13.2% is imposed.

In this case the balance of these two influences results in no change to overall GDP - a marginal -0.1% compared to the *Control* simulation - with employment 0.2% higher.

Noticeably though, the expansionary shift in demand in this case, is now insufficient to counter the loss in price competitiveness in dairy, meat and horticulture products. As such, despite the expansion in export demand (originating from those expressing a preference for conventionally-produced goods), export volumes of these products suffer as they bear the brunt of the competitiveness loss.

4.6.3 Foregoing GMOs but with differing demand expansions

Run #10

On the other hand, the imposition of a productivity improvement in the RoW, on its own with no favourable demand expansion assumed, will have an unambiguous negative impact on New Zealand economic activity.

Where New Zealand foregoes the use of GMOs, with productivity improvements in the Rest of the World and no positive demand movement, there are unambiguous losses to the New Zealand economy. The brunt of these losses are borne by dairy, meat and horticulture exports, and in this instance there is no counter expansion in other exports to compensate for these losses.

4.7 Human medicine GMO scenarios (Runs *#11 to #14*)

The situation where New Zealand exporters face a negative demand reaction resulting from New Zealand's release of a human-medicine GMO, clearly imposes losses to the New Zealand economy. The export losses are tilted against those facing the largest demand contraction - ie horticulture, followed by dairy and meat, with tourism exports suffering the least.

Run #11

The role of the #11 scenario is conceptually analogous to that of the first #1 scenario. That is, it provides a picture of the economy on the assumption that the development of a GMO-based human therapeutic (proteins for enzyme replacement therapy - see sub-section 3.4) has a negative effect on the demand for New Zealand's exports, without at this stage considering any of the benefits that the GMO-based development may bring. The fall in economic activity is not quite as severe, simply because the reduction in export is demand is assumed to be less severe than with a GMO-based development related to food production.

Run #12 and #13

Scenario #12 incorporates into #11 the effect of $200m worth of exports of GMO-derived proteins, plus on-going research and development expenditure of $5m per annum. These changes more than the fall in GDP observed in #11.

Where the human-medicine GMO is New Zealand produced and additional export revenues are gained from such a product, the negative demand influences are mitigated to a degree by such export revenues. Net gains to the overall economy are exhibited in the form of additional GDP,

employment and consumption. Export volumes of dairy, meat and horticulture still decline however, (but by less than in #11) as they continue to face the brunt of the demand contraction.

The overall message is that if the development of a GM-based human therapeutic leads foreign consumers to turn away from New Zealand products to the extent assumed in #11, then $200m of additional exports in the form of GM-derived proteins is sufficient to offset the initial negative economic effects of the decline in traditional exports.

From the discussion in sub-section 3.4, the $200m of protein exports could well be a conservative estimate. In scenario #13 it is assumed $400m of such exports are enjoyed. This assumption is sufficient to lift GDP by nearly 1.4% above the *Control* simulation. Employment, private consumption and even exports are also above their *Control* levels. Exports of dairy, meat, and horticulture are however still well down on *Control* levels, but over the 10 year horizon the difference in their rates of growth is less than 1% per annum.

Run#14

Experiment Run#14 imposes a greater negative export demand reduction. This is close to the first #1 scenario in a quantitative sense because the negative shifts in export demand are similar, albeit still not quite as severe. Not surprisingly the fall in GDP is more than in #11, but less than in #1. However, private consumption absorbs relatively more of the fall in export demand in this experiment (ie #14) than in #1, with the net exports (exports less imports) absorbing correspondingly less in #14. This occurs because of a small change between these runs in the way the government sector is modelled. In the human medicine scenarios the potential worsening of the fiscal balance caused by the lower level of economic activity, is prevented by an increase in personal income tax rates. This causes a larger fall in private consumption than in the crop and bio-*Control* GMO scenarios.

The results for GDP and employment imply that these variables are not sensitive to this difference in modelling assumptions.

In conclusion, if the development of GMO-based proteins for human medicine in New Zealand leads to the sort of reduction in demand for New Zealand exports that might occur under the #1 scenario, then protein exports of around $200m-$500m would be required to offset those changes in consumer demand. Again, if there is almost no adverse change in consumer sentiment, then any level of protein exports are positive for the economy.

4.8 A combined scenario

Looked at somewhat differently, if a GMO development along the lines of a #1 scenario (ie a crop or bio-control GMO based productivity improvement) were to occur first, then it is unlikely that there would be any further shift by foreign consumers away from New Zealand products if GMO-based proteins for human therapeutics were also to be developed here. In this there would be very little down-side from exports of GMO-based proteins.

Such a ‘combined’ simulation has been undertaken. It is Run #15 in the Table 4.1. This scenario combines the assumed productivity improvements from the release of a crop GMO along with the demand contractions as per experiment #3 with an assumed $200m in protein exports as per experiment #12. This results in GDP just over 1% higher than the *Control* scenario ten years hence, with consumption 1.2% higher and employment 0.3% higher.

The reverse sequence might also present an interesting scenario. That is, if a GMO-based human medicine is the first GMO development in New Zealand, and this has only a small effect on the demand for New Zealand goods in overseas markets, then demonstrable success in this regard (no adverse health or environmental consequences), might make some overseas consumers less reluctant to buy other New Zealand exports if crop or bio-control type GMO scenarios were to follow later.

Table 4.1 Model Results of GMO Scenarios

GMO Type	Crop GMO and Bio-Control GMO						No GMOs				Human Medicine GMO				
Export demand	Lower export demand				lower export demand		Higher export demand				Lower export demand				
	Alone	With one-off productivity gain	With on-going productivity gain	On-going productivity gain alone	With limited pest control gains	With greater pest control gains	Alone	With moderate productivity gain RoW	With greater productivity gain in RoW	With productivity gain in RoW alone	Alone	With $200m oritein exports	With $400m protein exports	Larger reduction in export demand alone	Crop GMO and human medicine GMO
Run No.	#1	#2	#3	#6	#4	#5	#7	#8	#9	#10	#11	#12	#13	#14	#15
Real GDP	-2.4	-1.2	-0.1	2.5	-1.3	-0.3	7.5	3.4	-0.1	-6.4	-0.9	0.4	1.4	-1.4	1.1
Employment	-2.6	-1.5	-0.5	2.2	-1.6	-0.7	8.0	3.9	0.2	-6.5	-0.9	0.1	0.8	-1.3	0.3
Consumption	-1.4	-0.8	-0.3	1.2	-0.8	-0.4	4.3	2.0	0.0	-3.6	-1.3	0.2	1.5	-2.0	1.2
Export Volumes															
Dairy	-7.8	-0.9	6.2	15.2	-1.3	5.0	13.8	-12.7	-35.5	-43.3	-2.8	-1.9	-1.3	-4.3	7.0
Meat	-8.8	-5.4	-2.0	7.5	-5.6	-2.5	15.5	-11.4	-34.5	-43.3	-3.3	-2.4	-1.8	-5.0	-1.2
Horticulture	-23.2	-22.0	-20.9	3.0	-22.1	-21.1	34.4	3.1	-23.9	-43.3	-10.9	-10.2	-9.6	-16.0	-20.3
Tourism	-5.7	-5.0	-4.3	1.5	-5.0	-4.4	34.4	34.3	34.0	-0.1	-1.7	-0.8	-0.1	-2.6	-3.5
Total (incl not shown)	-3.8	-1.9	0.0	4.1	-2.0	-0.3	12.2	5.9	0.4	-9.9	-0.9	0.2	1.1	-1.4	1.0
Dairy + Meat export receipts	-8.2	-4.1	0.0	8.9	-4.4	-0.7									0.6

5 CONCLUSIONS ON ECONOMIC OUTCOMES

The experiments performed with the model signal a range of outcomes in terms of economic impact.

In particular, given the range of productivity and demand preference shifts modelled, the impact of releasing a crop or bio-control based GMO in New Zealand can result in both negative or positive overall economic outcomes. Critical elements in determining these results may be summarised as:

- The proportion of foreign consumers that exhibit a clear preference for conventional products, irrespective of price. Where the survey responses are reflected in actual purchase behaviour (as has been modelled), such behaviour has significant and substantial negative consequences for New Zealand's conventional export commodities and, consequently, for the wider New Zealand economy. If actual purchase behaviour represents a fading effect from stated intentions, the situation for New Zealand is more positive. If purchase behaviour is amplified by market gatekeepers, the result will be more negative.

- The proportion of foreign consumers that 'remain in the market' following GMO release and the extent of their sensitivity to price differentials, if GMO-based productivity improvements allow such price differentials in favour of New Zealand products to emerge.

- The extent to which GMO releases can improve productivity in the New Zealand pastoral agricultural sector. Where these improvements occur at historically comparable rates, significant gains can accrue to New Zealand

- The extent to which GMO releases can improve productivity in our competitor countries.

- If the development of GMO-based proteins for human medicine in New Zealand leads to the quantum of reduction in demand for New Zealand exports reflected from the survey results, then protein exports of around $200m would be required to offset those changes in consumer demand.

All the model experiments indicate clearly that the modelled economic outcome for New Zealand is extremely sensitive to the size of each of these critical elements. As such, reducing the degree of uncertainty surrounding these elements is a prerequisite to reaching a conclusive statement on the economic outcome of either a GMO release or a policy foregoing GMO release.