The Economic Contribution of Four Biotechnologies to New Zealand's Primary Sector

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Preface

The use of biotechnology in agriculture is an important topic of research, as illustrated by a number of research reports from the AERU. Recent reports have presented findings from survey and focus-group research on New Zealanders' perceptions and interpretations of applications of biotechnology. Prior research, such as that conducted for the Ministry for the Environment, focused specifically on the technology of genetic modification; several research reports have considered growers' and consumers' intentions regarding genetically modified products as well as potential trade impacts of adopting this technology. That research explored the potential or possible impacts of biotechnology on New Zealand and its agriculture: it was forward-looking.

By contrast, this report is the result of a Government initiative to assess quantitatively the current economic contribution of biotechnology to primary sector industries in New Zealand. It was initially envisaged that a study would assess the current impacts of modern biotechnology across all the industries in the primary sector. After consideration of the breadth of technologies and the industries, this initial expectation was modified. The Steering Group for the project concluded that it would be preferable to measure the impact of a selection of biotechnologies across the primary sector in sufficient detail to inform policy development.

This approach enables comparisons across industries in the primary sector and across specific biotechnologies. It is also conceptually simpler for non-specialists to engage with. While using a comprehensive 'value chain' approach is attractive to assess impacts, it then becomes difficult to determine the boundaries for the primary sector. Biotechnologies can and are being used at most stages of the chain and thus in areas, such as waste treatment, that are not normally considered as primary sector industries. This study has concentrated on use of biotechnologies only in production and early stage processing of primary products. Results should be of value to anyone concerned about or interested in the economic contribution of the modern use of biotechnology to New Zealand primary production.

It must be emphasised that the naming of products or firms in this report is not intended as endorsement nor should it be construed as such.

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Definition of Biotechnology

The OECD defines biotechnology as the “application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services” (Organisation for Economic Co-operation and Development, 2005).

They provide an indicative, but not exhaustive, list of biotechnologies as an interpretative guideline:

- DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering;
- Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein glyco-engineering, proteomics, hormones, and growth factors, cell receptors/signalling/pheromones;
- Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridisation, cellular fusion, vaccine/immune stimulants, embryo manipulation;
- Process biotechnologies: bioreactors, fermentation, bioprocessing, bioleaching, bio-pulping, bio-bleaching, biodesulphurization, bioremediation, and biofiltration;
- Sub-cellular organisms: gene therapy, viral vectors; and
- Other.

Biotechnology might then be better described as a cluster of related technologies. Modern biotechnology is generally regarded as comprising techniques coming into widespread commercial usage after about 1980, when the understanding of biology was such that production processes could begin to use the smallest parts of organisms, their cells and biological molecules, in addition to using whole organisms.

Glossary of terms and abbreviations

Biocontrol: Pest control by biological means. Any process using deliberately introduced living organisms to restrain the growth and development of other organisms, such as the introduction of predatory insects to control an insect pest (Zaid, Hughes, Porceddu, & Nicholas, 1999).

CBA: cost-benefit analysis.

Cell culture: The *in vitro* growth of cells isolated from multi-cellular organisms (Zaid et al., 1999).

Clone: 1. A group of cells or individual organisms that are genetically identical as a result of asexual reproduction, breeding of completely inbred organisms, or forming genetically identical organisms by nuclear transplantation. 2. Group of plants genetically identical in which all are derived from one selected individual by vegetative propagation. 3. Verb: to clone. To insert a DNA segment into a vector or host chromosome (Zaid et al., 1999).

Clonal propagation: Asexual propagation of many new plants (ramets) from an individual (ortet); all have the same genotype (Zaid et al., 1999).

Embryo culture: The culture of embryos on nutrient media (Zaid et al., 1999).

Embryo rescue: A sequence of **tissue culture** techniques utilized to enable a fertilized immature embryo resulting from an interspecific cross to continue growth and development, until it can be regenerated into an adult plant (Zaid et al., 1999).

Enzyme: A protein which, even in very low concentration, catalyses specific chemical reactions but is not used up in the reaction. Enzymes are classified into six major groups (1-6), according to the type of reaction they catalyse: 1. oxidoreductases; 2. transferases; 3. hydrolases; 4. lyases; 5. isomerases; 6. ligases. Generally enzymes are named by the addition of the suffix -ase to the name of their substrate, and are classified by a standard numerical system: the Enzyme Commission (EC) number (Zaid et al., 1999).

Gross margin: Total revenue less variable or operating expenses. When production changes, both revenue and variable expenses can change. Gross margin is used in this research to measure changes to net returns to producers after variable expenses.

LTEM: Lincoln Trade and Environment Model, the trade model used in this research for analysing the trade impacts of biotechnology.

MAF: Ministry of Agriculture and Forestry.

Marker-assisted selection (Abbreviation: MAS). The use of DNA markers to improve response to selection in a population. The markers will be closely linked to one or more target loci, which may often be **quantitative trait loci** (**QTL**) (Zaid et al., 1999).

MoRST: Ministry of Research, Science and Technology.

Opportunity cost: The theoretical value of productive resources when used for some other (second-best) purpose.

Protoplast fusion: The induced or spontaneous coalescence of two or more protoplasts (cells that have had their cell walls removed) of the same or different species origin. Where fused protoplasts can be regenerated into whole plants, the opportunity exists for the creation of novel genomic combinations (Zaid et al., 1999).

QTL: Quantitative trait loci. A quantitative trait is a measurable trait that shows continuous variation (e.g. height, weight, colour intensity, etc.), so that the population cannot be classified into a few discrete classes. A QTL is a locus where allelic variation is associated with variation in a quantitative trait (Zaid et al., 1999).

Somatic cell embryogenesis: The process of differentiation of somatic embryos either from explant cells (direct embryogenesis), or from callus generated from explants (indirect embryogenesis) (Zaid et al., 1999).

Somatic hybridization: Naturally occurring or induced fusion of somatic protoplasts or cells of two genetically different parents. The difference may be as wide as interspecific. Wide synthetic hybrids formed in this way (i.e. not via gametic fusion) are known as cybrids. Not all cybrids contain the full genetic information (nuclear and non-nuclear) of both parents (Zaid et al., 1999).

Tetraploid: An organism, or a tissue whose cells contain four haploid sets of chromosomes (Zaid et al., 1999).

Tissue culture: The *in vitro* culture of cells, tissues or organs in a nutrient medium under sterile conditions (Zaid et al., 1999).

Executive Summary

Developments in biotechnology, that is, the use of biological systems, living organisms or parts of them to make or modify products or processes, have contributed significantly to New Zealand's primary sector. The New Zealand economy is strongly reliant on its primary sector. The agribusiness and forestry sectors contribute an estimated 20 per cent of real GDP, 65 percent of merchandise exports, and around 47 per cent of total exports. Key examples of biotechnology developed in NZ for the primary industry include marker assisted breeding to combat footrot in sheep, clonal propagation of pine trees, soil additives to eliminate nitrate leaching into rivers and lakes, and vaccines which increase lambing yield.

Although the economic benefits to the primary sector of biotechnology are recognised, they have not to date been measured. This report begins to fill this gap in our understanding by estimating the economic contribution of biotechnology to the primary sector in New Zealand.

The research focused on commercialised applications of four biotechnologies across the whole primary sector. Data were collected through surveying key informants about the production impacts of the technology, the available alternatives to biotechnological innovations, and the rates at which innovations had been adopted by primary producers.

The major quantitative findings are given in the table below, which shows the contribution of each biotechnology under the assumption that prices for primary products remain constant. The total estimated net benefit of these innovations to the primary sector is currently $266 million per year, assuming constant prices. Clonal propagation/cell manipulation represents the largest contributor to that total, by virtue of its widespread and relatively long-term use. Biocontrol agents had a smaller economic impact, and the impact of enzyme manipulation was smaller still. The least-commercialised biotechnology was marker-assisted selection, with only one innovation currently contributing to the economic performance of the primary sector at a value of less than one million dollars.

The contribution of these biotechnologies to the different subsectors is also apparent in these calculations. Dairy production benefited the most from these innovations, even without calculations of the contributions from enzymes used in dairy processing. This result is not surprising, given that dairy production is the largest of the subsectors. Other pastoral agriculture also benefited, with impacts on sheep production larger than those on beef and veal production. The horticulture subsector showed significant benefits, with some crops heavily reliant on biotechnology and other barely affected. The dollar value of impacts in arable crops was relatively small, but this was a function of the size of the subsector. Finally, impacts were relatively small for forestry as only one of the biotechnologies had commercial application, and they were nil for seafood production.

Estimates of the non-economic impacts were not possible. This research found that non-economic benefits have in general not been specified or measured. While there were suggestions in the literature and in discussions with key informants about possible non-economic benefits, such as environmental improvements, there is essentially no information about the exact impacts. If non-economic benefits are considered an important contribution of biotechnology, then this is clearly a significant gap in the research.

Additionally, the survey yielded qualitative findings, two of which are noted below.

- The economic success of biotechnological innovations is not inevitable, but requires a combination of scientific expertise and commercial acumen.
- Product development takes time, with present commercial applications typically being the result of long term research.

Summary of direct impacts of four biotechnologies

Subsector	Value of clonal propagation/ cell manipulation ($000's)	Value of biocontrol agents ($000's)	Value of enzyme manipulations ($000's)	Value of marker assisted selection ($000's)	Total ($000's)
Dairy	74,914	19,893	3,791	nil	98,598
Beef and veal	20,890	772	nil	nil	21,662
Sheep (meat and wool)	35,287	41,353	nil	770	77,410
Forestry	16,976	nil	nil	nil	16,976
Horticulture and floriculture	32,995	small value	9,960	nil	42,955
Arable crops	8,220	nil	nil	nil	8,220
Seafood	nil	nil	nil	nil	nil
Total	189,282	62,018	13,751	770	265,821

The effect on prices for agricultural commodities and thus on the net contribution to the NZ economy was assessed with the Lincoln Trade and Environment Model (LTEM). Results suggested that if the innovations were adopted by all countries in the model, the direct economic impacts of biotechnology fell to about one-tenth of the original estimate as a result of lower prices for agricultural commodities. If, on the other hand, some innovations affected production only in New Zealand, the direct economic impacts were again reduced but were 90 per cent of the original constant price estimate.

The macroeconomic impact was estimated by calculating the indirect and induced impacts on the New Zealand economy, using the direct impacts described above. Thus the total annual value-added contribution of the four biotechnologies as applied in the primary sector (current year), is calculated to be $453 million, based on the constant price estimate. The two trade scenarios led to estimates of the macroeconomic impact of biotechnology of about ten per cent (Scenario 1) and about 90 per cent (Scenario 2) of the original constant price estimate.

Further analysis of the agricultural sector revealed that the sector has seen significant increases in multifactor productivity over the last ten to 15 years. The productivity increases were much larger than the estimated impacts of the four biotechnologies. In this context of the trend output figure, the impacts of the four biotechnologies considered in this report have had a positive, but not dominant, role in the primary sector.

The report also outlines several areas that would benefit from further investigation. One such area is a survey of biotechnologies and their uses across the whole New Zealand economy. A second area is the dairy industry, as the present research was unable to account fully for the uses and impacts of biotechnology in this industry. One topic that was found to be little-understood was the economic value of non-marketed impacts of biotechnology. Finally, the present research did not examine proprietary control of technology or Intellectual Property Rights (IPRs), which are important in the development of innovations.

Chapter 1
Introduction: The Biotechnologies and Primary Commodities Investigated

1.1 Introduction

This study had two principal aims:

- To develop and demonstrate robust and effective methodologies to assess the economic impact of biotechnologies in the primary sector in New Zealand, and
- To measure the current economic impact of four selected biotechnologies to the New Zealand economy.

The first aim was important to develop a method that could serve not only this research project but also future research. Using a common method for separate research projects allows the results to be compared directly, increasing the usefulness of both present and future results.

This report thus presents not only the results of the research, but also detailed descriptions of the methodology. The first step was to define the biotechnologies to study and the boundaries of the primary sector. The next step, as discussed in Chapter 2, was to identify and interview key people throughout the biotechnology industry and the primary sector. The information they provided was the basis for a cost-benefit analysis, as reported in Chapter 4. The results of the cost-benefit analysis then in turn became inputs for two macro-economic analyses, the trade analysis reported in Chapter 5 and the domestic macro-economic analysis presented in Chapter 6. Using this process, the research identified the specific impacts of biotechnology on specific parts of the primary sector, and then aggregated those impacts to assess the overall effect on New Zealand trade and economic performance.

The second aim was to quantify the economic impact of specific biotechnologies. In order to do this, several aspects of the research needed to be defined specifically. One aspect to define was the biotechnologies to study, which are described in the next section of this chapter. It is important to note that this study is not restricted to New Zealand discoveries or innovations. Instead it ignores the derivation of the technique or application, and concentrates on whether it is currently making a contribution to the New Zealand economy. A second aspect to define was the primary sector. This study concentrates on use of biotechnologies only in primary production and early-stage processing of primary products. For ease of research, the primary sector was divided into seven subsectors, which are also described below.

Another aspect that required specific definition was the stage of commercialisation of the technique, process or application. Many firms and other organisations are involved in biotechnology at the research stage and/or have revenues from research contracts or technology licensing. For the present research, the biotechnology product or process needed to be commercially used in primary sector production.

The rest of this introductory chapter describes and defines the key parameters of this study. It starts with descriptions of the four biotechnologies, and then goes on to descriptions of the subsectors in the primary sector in New Zealand.

1.2 Descriptions of the four biotechnologies

Biotechnology is an example of a horizontal enabling technology (Ministry for Economic Development, 2003), a technology that may have wide application across many businesses and industries and may underpin a number of specific innovations. It is not itself one single technology, but a cluster of related technologies and techniques that may be applied to living organisms or their parts. This research examined specific technologies in order to understand better the impact of biotechnology as a whole.

A key task was thus to choose a set of biotechnologies that were relevant to the primary sector in New Zealand and were also reasonably representative of the biotechnologies utilised. In the choice of specific biotechnologies, this research relied on expert advice to identify examples of biotechnologies that represent a range in terms of the length of time they have been used, the degree of specialisation in their use and the industries in which they are used. It was desirable to consider older, more established biotechnologies as well as newer ones, and to consider generic technologies that could enable many specific commercial innovations. The four biotechnologies chosen were:

- Clonal propagation/cell manipulation,
- Bio-control agents,
- Enzyme manipulations, and
- Marker-assisted selection.

Technical terms used in these biotechnologies are defined according to the FAO Glossary of biotechnology for food and agriculture (Zaid et al., 1999) and are included in the glossary for this report. A brief description of each biotechnology follows.

1.2.1 Clonal propagation/cell manipulation

In vitro cell and tissue culture have many direct and indirect commercial applications. Among techniques used in plant breeding programmes and commercial production systems are meristem and bud culture, culture of cells, anthers, ovules and embryos, protoplast isolation and fusion, and cell selection. Applications of plant cell and tissue culture include:

- Clonal propagation using meristem and shoot culture to produce large numbers of identical individuals;
- Removal of viruses by heat treatment and propagation from meristematic tissues;
- Doubling chromosome numbers of cells to enable wide crosses, to attain homozygous lines more rapidly in breeding programmes, or to produce polyploid plants for sale;
- Crossing distantly related species, rescuing the embryo and regeneration of the novel hybrid;
- Screening cells, rather than plants for advantageous characters; and
- Growing plant cells in liquid culture as a source of secondary products.

1.2.2 Bio-control agents

Biological control can be broadly classified into:

- Conventional biocontrol of pest animals, weeds and diseases using the deliberate release of natural enemies, such as predators or parasites, into the environment; and
- The production of bio pesticides derived from organisms, such as insecticides based the bacterium *Bacillus thuringiensis*.

Effective biocontrol needs sufficient understanding of agro-ecological systems so that introduction of biocontrol agents can be successful. It also needs sufficient inoculum of the agent to attain control. Biotechnological techniques, particularly isolation and multiplication under sterile conditions, are important in producing quantities of some biocontrol agents, for example using fungal formulations for weed control or to control crop pathogens and using viruses and nematodes for insect control.

Classical biocontrol was not included in the present research. Classical biocontrol seeks control of a pest at the ecosystem level and is therefore of general benefit to all primary sector producers[1] (Auld, 1998). Classical biocontrol has been practiced for decades and does not necessarily include modern biotechnology.

1.2.3 Enzyme manipulation

Enzymes are proteins that can, at low concentrations, catalyse reactions. They are the basis of biological reactions and are ubiquitous in nature. Basic studies in cell biology have improved knowledge of enzyme properties so that now their activity can be harnessed to perform a number of functions, including some that were previously undertaken using harsh chemicals.

Enzymes are being used internationally in a number of primary industries on farms and in processing in a huge range of activities including feed quality, waste management, food processing, textile manufacture and bleaching of wood pulp.

1.2.4 Marker-assisted selection/breeding

Selection to improve the performance of economically valuable species of animals and plants has been carried out for centuries on the basis of the phenotype or physical appearance of individuals. Marker-assisted selection (MAS) provides the possibility of selecting organisms according to their genotypes or genetic constitution. Genetic linkage maps can be used to locate genes, including those affecting quantitative traits of economic importance in plants or animals. By using molecular markers or identifiable DNA sequences closely linked to particular genes, or located within one or more QTL, information at the DNA-level can be used for early selection of organisms. This allows selection at the genotype level in a similar fashion for genes of major phenotypic effect.

The potential benefits of MAS are greatest for traits that are difficult, time-consuming or expensive to measure or can only be measured after reproduction has been completed (Dreher et al., 2002; Hayes & Goddard, 2003; Moreau, Lemarie, Charcosset, & Gallais, 2000; Tartarini, 2003; Yu, Park, & Poysa, 2000). Mapping and MAS tend to be used mainly in

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[1] In the language of economists, classical biocontrol is a 'public good' (Auld, 1998). It is non-exclusive (specific individuals cannot be excluded from benefiting) and it is non-rival (the benefits that one individual receives are not reduced by the benefits that another individual receives).

species of high economic value and have most potential in clonal breeding programmes, where additional genetic gains can be rapidly multiplied.

1.3 The New Zealand primary sector

The primary sector is an important contributor to the New Zealand economy, both to Gross Domestic Product (GDP) and to export earnings. Together, agriculture and forestry contribute 16 per cent of the country's GDP (Ministry of Agriculture and Forestry (MAF), 2004c). An estimated 53 per cent of New Zealand merchandise exports are agricultural products, and forestry adds another 11 per cent to that number (Ministry of Agriculture and Forestry (MAF), 2004c). Given merchandise exports in 2003 of $28.2 billion (Statistics New Zealand, 2004), seafood's $1.2 billion (Ministry of Fisheries, 2004) accounts for 4.3 per cent of merchandise exports. The total contribution of the primary sector is thus 68 per cent of merchandise exports.

The primary sector in New Zealand is not subsidised (Ministry of Agriculture and Forestry (MAF), 2004c), so that producers are directly tied to international markets. For this reason, exchanges rates can be an important determinant of revenues to the sector, regardless of other trends. This situation is in stark contrast with agriculture in other areas, such as the EU and the US, where New Zealand faces quotas, tariffs and duties on its exports.

What follows is a brief description of several parts of the primary sector in New Zealand. The intent is to provide an indication of the magnitude of production and the relative sizes of different primary commodities.

1.3.1 Dairy

The dairy industry's 12,000 milk suppliers and their 5.11 million dairy cattle produced 1.2 billion kilograms of milksolids in the 2003/04 season (Ministry of Agriculture and Forestry (MAF), 2004c). About four per cent of production was used to produce fresh milk for the domestic market; the other 96 per cent was processed in milk powder, cheese, butter, casein, and other products. The dairy industry is centrally organised, with Fonterra processing 96 per cent of New Zealand's milk. Over 90 per cent of milk products are exported, making the industry highly reliant on international markets. In addition, dairy products accounted for 20.3 per cent of New Zealand's merchandise exports in the year to June 2004, which amounted to $5.826 billion (Statistics New Zealand, 2004).

1.3.2 Beef and veal

According to MAF (2004c), the national beef cattle herd was 4.64 million head in 2004. Production of beef and veal is estimated in Chapter 4 of this report to be $1.30 billion per year. Of this amount, only about three per cent is veal (Ministry of Agriculture and Forestry (MAF), 2004c). Exports were 612,000 tonnes of meat, earning the country $1.92 billion. About one-half of that goes to the US, with South Korea, Japan and Taiwan the next most important export markets.

1.3.3 Sheep

In 2004, New Zealand had 39.7 million head of sheep. Meat production was 107,000 tonnes of mutton and 411,000 tonnes of lamb, carcass weight equivalent (cwe). Exports of mutton were 87,900 tonnes cwe for earnings of $255 million, while exports of lamb were 358,000 tonnes cwe or $1.97 billion. The EU imports about one-half of the total volume of meat exports, paying above average prices for it. The US market is growing, particularly after lifting the tariff rate quota (TRQ) in November 2001.

Eighty per cent of New Zealand wool is produced along with meat from dual-purpose animals. Only about five per cent of the country's wool is fine merino wool from specialty flocks. Production in 2004 was 165,000 tonnes of wool. Of this, 140,000 tonnes were exported for earnings of $740,000 million. The largest market for New Zealand wool is the People's Republic of China (PRC), with the UK and Italy also significant importers.

Statistics on this subsector were taken from MAF (2004c). Total value of production is estimated in Chapter 4 of this report at $2.8 billion.

1.3.4 Forestry

The forestry industry in New Zealand, including pulp and paper product manufacturing, accounted for 3.3 per cent of the New Zealand economy in 2004. Forestry exports represent ten per cent of New Zealand's total merchandise exports and were valued at NZ$3,226 million for the year ended March 2004. Approximately 90 per cent of the commercial forest in New Zealand is radiata pine (Ministry of Foreign Affairs and Trade, 2004)).

Table 1.1 The forestry industry

	2001	2002	2003	2004p
Estimated roundwood removals from New Zealand forests (000 cubic metres)[a] (hectares)[b]	19,287 (46,700)	20,940 (49,400)	22,451 (50,300)	20,888 (n/a)
Area planted (hectares)[c]	76,200	62,200	58,000	n/a
Total Exports ($000)[d]	3,606,005	3,694,742	3,506,017	3,226,272
Total output (GDP in 1995/1996 prices; million dollars))[e]	3,586	3,557	3,880	3,887
-Forestry and logging	*1,396*	*1,488*	*1,568*	*1,505*
-Wood and paper product manufacturing	*2,190*	*2,069*	*2,312*	*2,382*

[a] (Ministry of Agriculture and Forestry (MAF), 2004a)

[b] (Statistics New Zealand, 2005a)

c (Statistics New Zealand, 2005a)

[d] Exports of Forestry Products from New Zealand for Years Ended 30 June
(Ministry of Agriculture and Forestry (MAF), 2004b)

[e] Gross Domestic Product by Industry, 1995/96 prices, year ended 31st of March (Statistics New Zealand, 2005b)

1.3.5 Horticulture

The horticulture subsector, including floriculture, accounted for about $4.5 billion dollars in domestic spending and export revenues in 2002/03 (HortResearch, 2003). Of this total, about $2.1 billion is exported (Ministry of Agriculture and Forestry (MAF), 2003). Total area in horticulture in New Zealand is about 110,000 hectares, spread throughout the country. Major crops by area in 2002 are wine grapes (17,500 ha), apples (12,500 ha), kiwifruit (12,200 ha), potatoes (10,600) and onions (5,680) (Burtt, 2004; Ministry of Agriculture and Forestry (MAF), 2003). The major exports are kiwifruit ($618 million), processed vegetables ($260 million) and wine ($249 million) (Ministry of Agriculture and Forestry (MAF), 2003). The top markets for these exports are the EU, Japan and the US, with Japan an important market for flowers, onions and squash and the UK an important market for wine (HortResearch, 2003). Floriculture accounts for about $40 to $50 million in exports per year, including orchids, callas, sandersonia, and proteacea (Ministry of Agriculture and Forestry (MAF), 2003). Domestic sales of cut flowers are estimated to be $70 million (HortResearch, 2003).

1.3.6 Arable crops

The arable subsector contains a number of different crops. Statistics on production, prices and trends are provided in MAF's *Situation and outlook for New Zealand agriculture and forestry* (2003). The cereal crops of barley, wheat and maize accounted for about 136,000 hectares in 2003/04, with barley accounting for nearly half of that area. Cereal production amounted to about 856,000 tonnes in that year. Small seeds, such as ryegrass and clover seeds, are grown on about 33,000 hectares, and field peas account for another 10,000 hectares of production. A small but growing part of the arable subsector is vegetable seed growing, which earned $25 million in 2003/04. Total exports of arable crops was $111 million, mainly grass seed, field peas, and vegetable seeds. Total production is estimated in Chapter 4 of this report at $389 million.

1.3.7 Seafood

The seafood subsector is the purview of the Ministry of Fisheries, whose information (Ministry of Fisheries, 2004) forms the basis of the following industry description. Being an island nation, New Zealand has a large Exclusive Economic Zone (EEZ) from which to harvest seafood. The 1.3 million square nautical miles in the EEZ provide such economically important species as hoki, mussels, rock lobster, orange roughy, squid and snapper. Total annual harvest is approximately 750,000 tonnes of seafood, of which ten per cent to 15 per cent is produced through aquaculture. The Ministry reports that from 88 per cent to over 90 per cent of the total harvest is exported, depending on prices in export markets. Exports in 2003 were $1.2 billion, down from the $1.5 billion exported in 2002. The main export markets are the EU, the US and Japan. Domestic demand for seafood is a relatively constant $140 million per year. The industry has total direct employment of about 10,000 people, with employment concentrated in certain areas.

1.3.8 Summary of primary sector

The above description is summarised in Table 1.2. Each subsector is described by some indicator of physical production, by an estimate of the value of production, and by an estimate of the value of exports. These values are explained in the descriptions above or in the cost benefit analysis in Chapter 4. The values of production are indicative of the relative sizes of the subsectors, but are not directly comparable. They use data from different time periods between 2002 and 2004, and some are farmgate revenues while others are product sales. Nevertheless, they are useful for understanding the magnitude of the primary sector and its constituent parts.

Table 1.2 New Zealand's primary sector

Subsector	Physical measure of production	Value of production[a] ($ million)	Value of exports[b] ($ million)
Dairy	5.11 million head, 1.2 billion kgs of milksolids	5,300	5,800
Beef and veal	4.64 million head	1,300	1,900
Sheep (meat & wool)	39.7 million head	2,800	3,000
Horticulture	110,000 hectares	4,500	2,100
Forestry	20,888,000 m^3	3,900	3,200
Arable	over 179,000 hectares	389	111
Seafood	750,000 tonnes	1,340	1,200

[a] Figures for each subsector are not directly comparable with each other, but are only representative. See text above for details.

[b] Value of exports can exceed value of production due to processing of raw products.

1.4 Conclusion

The rest of this report is divided into several chapters. The next chapter describes the method for identifying key people in biotechnology and in the primary sector in order to gather information on uses of biotechnology in production. Chapter 3 presents qualitative information from the interviews, information that is important for understanding the impacts of biotechnological innovations but that was not part of the quantitative analysis. The quantitative analysis begins in Chapter 4, which provides estimates of the current economic impact of each innovation. Chapter 5 extends this analysis to include trade impacts, which can influence the prices the New Zealand producers receive for their products. The domestic macro-economic impacts are then analysed in Chapter 6. The final chapter summarises and concludes this report.

Chapter 2
Method: Interviews with Key Informants

2.1 Introduction

This project assessed the economic impact of the current commercial use in the primary sector of biotechnology, broken down into four types. This information is not available in official statistics or from other sources, thus to obtain information on current biotechnology use, it was necessary to talk to people in biotechnology and primary production to get their views, opinions and experiences with biotechnology. They have the knowledge and experience to describe the current usage and impacts. These interviews are the first stage in the assessment of economic impacts of biotechnology.

This chapter therefore describes the method used for the survey. It describes how the industry was scoped and how the key informants were identified. The chapter goes on to describe the economic information that was sought from key informants and the rationale for requesting information. It concludes with a discussion of the interviewing itself.

2.2 Scoping the industry

To obtain as complete a picture as possible of current use of biotechnology, it was important to gather information from a wide pool of informants. Biotechnology is commercialised through the efforts of research scientists, applied scientists, product developers and business people. Thus, this research identified potential key informants across science and industry to get as wide as possible coverage of the use of biotechnology.

The first step in scoping the industry was to identify people and organisations involved in biotechnology and in the primary sector. A very good first source of information was the list of biotechnology firms and organisation that is maintained by New Zealand Trade & Enterprise on the New Zealand Biosphere Website (http://www.biospherenz.com/). This is a list of over 400 people, companies, organisations, and research institutions involved in agribiotechnology and biotechnology. MoRST also provided a list of potential key informants and the organisation to which they belong. These lists, along with Web searches, reviews of reports on the biotechnology sector in New Zealand, and researchers' prior experience in this area formed the basis of the sample. Also added to this list were the key producer organisations in the primary sector. The list was circulated to people in MoRST, MAF, and Treasury to get feedback on its coverage and further people to contact. Finally, as key informants were interviewed, they often suggested other people, companies, or organisations to contact. The result of this process was a comprehensive list of contacts working in biotechnology as it relates to the primary sector, either as producers of biotechnology products or as their users in the primary industries. The full list of contacts contained names of 115 people in 78 organisations.

Broadly speaking, key informants tended to fall into one of three groups. One group could explain the science involved and how the biotechnology contributed in a physical or scientific way. Another group could explain the specific commercial or economic benefit of specific biotechnologies. Often, these were informants involved in commercial firms. The third group provided context or overall industry information.

Over several iterations, this research created a comprehensive list of the primary-sector, commercial applications of the four biotechnologies in New Zealand. Products of biotechnology were identified based on several criteria. This research focused on commercial applications, uses of biotechnology that were used in production agriculture, forestry and fisheries. Products and processes were limited to the four biotechnologies describes above, and medical and human health products were not included in the analysis. Thus, the uses of biotechnology were identified across the primary sector, by the following subsectors:

- Dairy,
- Beef and veal,
- Sheep (meat and wool),
- Forestry,
- Horticulture,
- Arable crops, and
- Seafood.

2.3 Determining farm-gate economic impacts

Once the use of biotechnology throughout the primary sector was scoped and the products and processes of biotechnology were identified, the next step was to determine their value. Researchers conducted interviews of key informants to determine the perceived economic contribution of the identified biotechnologies.

This project is focused on benefits to the primary sector and thus on production impacts. The primary intent of the interviews was to understand the impacts at the level of the primary producer – the farm or similar production unit – and the changes to return at the farmgate. For each product or application the information needed to address four aspects that affect the impact the biotechnologies have on production:

- Technology impact on product and production,
- Adoption pattern,
- Market characteristics, and
- Upstream and downstream impacts.

Each of these aspects is explained below.

2.3.1 Technology impact on product and production

A key factor of interest is whether biotechnology affects the quantity or quality of the primary product. If the biotechnology provides a productivity gain, its use leads to a cost-based competitive advantage. If the effect is on the product attributes, competitive advantage can be based on differentiation (Porter, 1991). The interviews thus sought to gather data on the following:

- Productivity gain ($ per unit of output or per cent change)
- Premium ($ per unit of output or per cent change)

The gains in productivity and/or premiums are of course the result of changes in production. Changes in production can impact in two major ways. Firstly any change will impact on the cost per unit of output through changes in direct variable inputs and yield, and secondly the changes can affect the configuration of input factors (Barney, 1986) and/or the activity structure (Porter, 1991) of the production. Changes in direct variable input, such as fertilisers or veterinary costs, are likely to have their major impacts on a particular step/part in the value system, e.g. on the farm, and thus are more easily obtained and quantified. Changes in resource configuration and/or activity structure are more likely to have larger down- and upstream impacts, as well as structural impacts on the industry. Assessing these types of impacts is more assumptions-based.

Interviews thus raised a number of questions regarding the technologies, as listed below.

- Does the technology affect the use of inputs?
- What will be the technology fee, the cost to producers for using the technology?
- How are capital costs, such as machinery costs, affected? For example, is new machinery required?
- What will be the impact on labour?
- Will changes in labour requirements affect labour availability – with it improve or exacerbate labour bottlenecks?

2.3.2 Adoption pattern

The extent of the economic impact of a biotechnology innovation is directly related to its uptake in the primary sector. Uptake can be influenced by many factors, most notably by expectations of the innovation's profitability. Interviews thus sought to identify uptake rates, such as:

- Percentage of producers or production volume or value using the innovation
- Number of hectares affected by or incorporating the innovation
- Uneven impacts of the innovation over the industry

2.3.3 Characteristics of markets

The relationship between the market and type of technology impact – productivity gains or quality gains – is a major determinant of the economic benefits to New Zealand. Prior research indicates that New Zealand benefits most either from technologies or techniques that affect product attributes or qualities, or from productivity increase that only New Zealand can adopt. Productivity gains may also be necessary for competitive parity in the main commodity markets. In markets where New Zealand has very low market share productivity, gains may be essential. Interviews thus sought to establish New Zealand's position with to respect to the particular application. Key questions were:

- What market share does NZ have, and how might this be affected?
- What are NZ's competitors doing, and what impacts could they have?

- What limits market access in a country: tariffs, quotas, tariff-rate quotas (TRQs), and non-tariff requirements such as technical barriers to trade?
- What are practices overseas for producing these products?

2.3.4 Upstream and downstream impacts

Innovations in production systems can have simple effects, as in the case of substitution of one input for another, or complex effects that entirely change the methods of production. The more complex the effects on production of a specific commodity, the greater the ripple effects, both on upstream suppliers and on downstream purchasers and end-users.

Key informants were surveyed about the impacts of biotechnology products on production processes, with particular attention to these upstream and downstream impacts. Some of the information collected was:

- Do biotechnology products directly substitute for other inputs?
- How has the use of other inputs changed?
- Do production processes need to change in order to use biotechnology products?
- Has the use of biotechnology products led to spontaneous production changes?
- How have purchasers reacted to the use of biotechnology?
- Have purchasers or end-users noticed any difference in the primary product?
- Have there been any market changes or price changes as a result?

2.3.5 Developing the counterfactual

A key consideration in the research was the *counterfactual*. This is the situation that would have prevailed in the absence of the biotechnological innovation. To gather information about the possible counterfactual, key informants were asked how production might occur if the innovation had not been developed. The idea and impact of the counterfactual will be described in more detail in Chapter 4 as part of the methodology for economic valuation. In order to gather the information for developing these counterfactuals, key informants were asked about the following:

- How has biotechnology changed production?
- How would production happen without biotechnology?
- Are there alternative methods of production in use today?
- Are alternative methods possible, and how would they work?

2.4 Survey administration

The considerations described above guided the development of a survey instrument. A further consideration was the necessity of approaching industry and research contacts without preconceived notion of the products and processes in use in the primary sector or their contributions to economic performance. Informants could and did provide unexpected information and insights. The interview format therefore needed to be fairly flexible to allow for a range of responses.

Because this research was as concerned with scoping impacts of biotechnology as it was with gathering specific economic data, the survey was a series of semi-structured interviews. The interviewees are listed in Appendix 1. The survey instrument served as ‘talking points’ to guide interviews, and also served as a reminder to researchers of the main information needed for the later analysis. For this research, it was more important to understand the context of each specific example of biotechnology, where each company was in the process of commercialisation, and how the key informant saw the economic impacts, than it was to fill in boxes on a form. The questionnaire is contained in Appendix 2.

Interviews took place in April, May and June 2005 and took many forms. Some were face-to-face meetings with people who collectively gave many hours of their time to inform the research about their products and their uses of biotechnology. Some were telephone interviews of various lengths, some quite short and others lasting up to an hour. Email was also used to contact people and to provide them with background information. Some key informants also provided answers to research questions via emails, so that entire interviews took place on-line. Many people had pre-prepared documents – articles, reports, brochures, analyses – and generously provided these. All of this information was combined to produce the estimates of economic impact developed below.

Chapter 3
Qualitative Results of Survey

3.1 Introduction

The semi-structured nature of discussion with key informants meant that they provided researchers with much more than the figures used to calculate economic impacts. Many informants were very generous with their time and were only too happy to explain how their innovations were developed, how they have been commercialised in the primary sector, what some of the issues were in development or marketing, and what their plans were for future changes.

To make this information available, this chapter organises and summarises qualitative results from the survey. This discussion establishes the context for the next chapter, which provides the calculations of economic impacts. Although the main goal of this research was establishing the economic value of current commercial applications of selected biotechnologies, these qualitative results form an important part of the research output.

These results and a discussion of them are organised into a three topics. The first topic is a summary of the use of these four biotechnologies in the primary sector, and includes a discussion of an important issue: the nil results. Many times in exploring a technology or a subsector, no commercial benefits had yet been realised. The second topic is commercialisation of biotechnology: what leads to success? Many informants, some with highly successful products and others who were still yet to commercialise the technology, had strong views on this topic. The third topic is the embeddedness of these biotechnologies, which affects both their use and the estimation of economic values.

3.2 Use of the four biotechnologies

The innovations identified in this research affected both the efficiency of production and the qualities of the products produced. Particularly in livestock, the innovations that generated the greatest return were input-oriented. These innovations changed an input to make production better, but left the final product unchanged. Other innovations were output-oriented and changed the final product; these were more common in arable and vegetable crops.

Where there have been product improvements, the value of the improvements is sometimes uncertain. A good example is crop improvements in wheat. Wheat breeding programmes have worked to improve the milling quality of New Zealand wheat. The economic value of these traits and the extent to which the value can be attributed to biotechnology are both uncertain.

The four biotechnologies have had quite different impacts on the primary sector. Clonal propagation/cell manipulation (a set of techniques that are core to plant breeding programmes) has had by far the largest economic impact. However, their impact can only be measured at the level of a crop, rather than on a cultivar-by-cultivar basis. Furthermore, the value of these techniques comes from the steady improvement to primary sector performance over time. The use of biocontrol agents is much more on a case-by-case basis. This is a much newer field, thus represented by specific products in this category. Biocontrol agents are also an additional input to a production system, whereas clonal propagation/cell manipulation change an input – the seed used – but are not itself a separate input. Valuation of biocontrol agents was therefore valued here through a case study approach. Enzyme manipulations are little used in producing raw products, being much more important in transforming raw goods into products for retail sale. In that context, enzyme use is extensive but its valuation sometimes beyond the scope of this project. Finally, marker-assisted breeding is another technology with wide application across the primary sector. However, it has produced few commercial products. Thus, although it is subject of research, the value of this technology so far is represented by a few discrete products.

There are three issues that are treated separately as important issues regarding the use of biotechnology. These are: the nil results, the extent of contributions of biotechnology, and the value of innovations.

3.2.1 Nil results

An important qualitative result of this study was what is referred to here as the nil results. These are biotechnologies which did not currently yield significant commercialised returns and were still under development or yielding only small revenues. This was often to the surprise of not only researchers but also those involved in the sector.

The nil results are important for two reasons. First, this report can be seen as establishing a baseline for the economic impact of the four biotechnologies. Whilst of course those technologies yielding positive returns are vital for this baseline so are those which do not. Future research may be able to use these results as a baseline against which to measure progress towards commercialisation. The second reason that these nil results are important is that they provide important information to the sector as well as policy makers. Many people who seemed to be well informed about the biotechnology sector were not fully aware of which companies had actual sales of commercial products and which were surviving but still had products yet to be commercialised.

Of the four biotechnology types used in this report the most significant giving nil results was marker-assisted breeding. This biotechnology has been described for years as the way of the future, the approach to breeding that will allow precise selection of desirable traits and introduction of new varieties in a fraction of the time that traditional breeding requires. However, key informants only identified three examples of commercialised marker-assisted breeding in the primary sector in New Zealand. Two are for sheep, and only one of these is currently boosting production (the other is too new to have had an impact). The third, a disease-resistant field pea, may be producing benefits in New Zealand, but the scale of the benefits was entirely unclear. For other arable crops, vegetables crops, fruit growing, dairy and meat cattle, etc., marker-assisted breeding has not yet increased production or improved products.

Two subsectors also produced nil results. The seafood industry was not using any of the four biotechnologies in production. In part, this nil result came from the boundaries of the project. The industry used enzymes to produce processed seafood products and also used them to clean equipment, but these uses were not considered directly involved with production. None of the other biotechnologies was applied to the seafood sector. The other subsector was ‘new industries’, a loose category that was expected to contain residual innovations that could not be otherwise categorised. In fact, there were no such innovations. Activities that are typically included under ‘new industries’, such as biofuels, were heavily dependent on technologies and production processes that are not biotechnology.

The intent of this research was to identify and evaluate biotechnological innovations. Researchers thus did not give up searching for examples the first time a key informant said that a biotechnology was not used in a specific subsector. Multiple informants were interviewed for each subsector and each technology, and areas in which nil results were identified were probed even more. Some informants were contacted more than once, just to be certain of the information they had provided. These nil results do not demonstrate a lack of evidence of commercialised products, but rather evidence that commercial products based on these biotechnologies are not in use in certain subsectors.

3.2.2 Extent of contributions of biotechnology

As stated above some of the four biotechnologies have had marginal impacts on primary production. This statement is not meant to disparage the contributions of biotechnology and the obvious gains that have been made, as the following sections will show. However, the qualitative survey results did stress the importance of other factors in increasing returns from the primary sector. These factors include natural resources – land, fresh water, marine environments – in combination with management effort, human labour, and machinery. A significant proportion of the growth in the primary sector has been by adding more of these inputs, as when irrigation is added to land, and by being more efficient in their use, as when information and experience improve farm management. Thus the current use of biotechnologies has tended to make improvements at the margin.

Nowhere is this more apparent than with biocontrol agents. It is perhaps the nature of such products that they contribute only at the margin. It seemed particularly true of the biocontrol agents identified in this research. They seemed to contribute a bit per hectare or a bit to overall production, but in many instances the contribution was hardly measurable.

A further reason for the marginal nature of biotechnology is the volatile nature of primary production. A good example comes from the apple industry. Although the industry uses an integrated pest management programme that makes use of bioinsecticides and biocontrol agents, their impact was overwhelmed by trade patterns, exchange rate fluctuations, and market trends in the industry. Disentangling the impacts of what amounts to a minor input to production from all the other factors affecting the industry was not possible given information available; in any case, these impacts were highly unlikely to be significant.

3.2.3 Value of innovations

In general, few respondents knew about the value of specific biotechnological innovations. For many innovations, it seemed that commercial considerations were minor factors in the process of commercialisation. Biotechnology research appeared to focus on problems that could be solved, rather than examining whether the problems were worth solving from a financial point of view. This was of course not universally true. Many key informants could provide detailed information about production impacts and their values.

As a result of this focus on the technically possible, an innovation might be quite effective against a specific pest or disease. It could be difficult to determine, however, the extent of that pest or disease in New Zealand. The economic benefit might not be immediately clear or readily available, and instead further research was required to uncover exactly what the economic impacts were.

It was also difficult to obtain from respondents what the alternatives were in the absence of the biotechnology, information important to assess correctly the economic value. Again, an innovation might be effective, but consideration was not always given to alternative methods or inputs that could yield similar results. From an economic point of view, allocating resources amongst competing uses is a key consideration. Thus, a central question always is, 'what is the alternative?'

This research bridged these gaps by examining the specific innovations, the economic value of the 'problem' they solved, and the possible alternative solutions.

3.3 Commercialisation of biotechnology

In the interviews with key informants from firms that were selling the products of biotechnology, one of the main topics of discussion was the commercialisation process. Commercialisation was discussed as a difficult, uncertain affair that required proper management; it did not just happen. Because the same ideas came up in several discussions, they are highlighted here.

Many key informants drew distinctions between the fundamental science of biotechnology, biology and agricultural production on the one hand, and commercial application of this knowledge on the other. Fundamental scientific research is increasing knowledge of the biology of plants and animals, often in the context of agriculture. It is also creating technically feasible applications of biotechnology. Although such research expands scientific understanding, it is not the same as creating commercially viable applications of biotechnology.

One element of the difference between the two that was apparent from this research was the tremendous time lag between the initial scientific findings and their eventual commercial applications. In conversation, one person involved with biocontrol agents mentioned that the initial discovery underpinning the Ballance grass grub biocontrol agent was 40 years old. Similarly, the AR1 ryegrass has been on the market for about three years, but it was the result of initial observations about ryegrass staggers that were made in 1980.

Another element that was important in converting the fundamental science into commercialised innovations was the mechanism for delivering the innovation to users. For many innovations, this is a minor issue. Breeding programmes that introduced improved traits into plants still deliver those traits via seeds and seedlings that are similar to the non-improved seeds and seedlings. The biotechnology, in those cases, happens in the background. For other innovations, there is some change to the production process. Providing the innovation in a convenient package is important for successful commercialisation. For example, eco-n from Ravensdown requires specialised equipment for its application. The company charges a per-hectare price for the product that includes application costs. Thus, rather than expecting farmers to obtain new, specialised equipment, the company provides an easy-to-use package.

A further aspect of commercialisation that arose in interviews was the importance of involving commercially-minded people in the process. The technical or scientific performance of an innovation is only one consideration. It is not enough to demonstrate that, for example, a vaccine is effective against a specific pathogen. It is also important to demonstrate the value of the innovation to primary production. For successful commercialisation, end users need to perceive that the innovation will improve the performance of the farm, forest or marine enterprise. 'Selling' the innovation to end users requires that sales and marketing staff are involved in the commercialisation process.

The other side of the commercial transaction is the biotechnology firm's revenues. For the viability of these firms and the continued income stream that can finance further commercialisation, biotechnology firms need to be recompensed appropriately for the innovations they provide. The present research focused on the value of biotechnology innovations to the primary sector. Because this value is net of any direct technology payments (such as increased seed prices or costs of vaccines), this value represents potential revenues for biotechnology firms. If biotechnology firms are to capture enough of the extra value that their innovations produce to remain viable, then they need smart sales and marketing personnel who understand the value proposition of their innovations.

Biotechnological innovations produce extra sales revenue for the primary sector. These extra gross revenues are then split between the firm that provides the innovation and the primary sector itself. This element of innovation produces an important tension between cooperation and proprietary control of the technology. Cooperation between the government, CRIs, innovating firms, and primary producers can lead to impressive gains for the primary sector. Given the expense of research and the long lead times required for commercialisation, cooperation can be invaluable for producing innovations. The gains from an innovation are spread throughout the sector and across all the organisations involved in innovating. Thus, total gains might be large, but gains to any one person or organisation are likely to be proportionally small. Proprietary control of technology, on the other hand, can be quite important for stimulating private firms to pursue innovations. Unless these firms can be assured that they own the rights to the innovations and its profits, they may be unwilling to invest the funds necessary to convert the fundamental science into a commercial product. However, while proprietary control increases the returns to the individual firm, it can ration use of an innovation, limiting its uptake in the primary sector. It can also reduce the net value of an innovation to an individual farmer, forester or fisher. There is thus a fundamental tension between the economic interests of the primary sector and those of biotechnology firms.

This research did not attempt to assess the economic value of proprietary control of technology. First and foremost, the topic was not in the brief for the project. Secondly, the available resources were insufficient for the additional research required to do justice to the topic. Intellectual Property Rights (IPRs) are an important consideration for biotechnology firms and for international trade relations, and there is a significant and complex body of literature considering the impacts of IPRs. The current research focuses on impacts on the primary sector; further research will be required to consider impacts on the producers of biotechnology.

3.4 Embeddedness of biotechnology

A final recurring theme from the interviews was how the four biotechnologies were embedded in primary production. This embeddedness took several specific forms.

One symptom of the embeddedness was that some key informants were unsure of the technical details of the use of biotechnology in producing specific innovations. For example, tissue culture is widely used in plant breeding, but there was no information available on which cultivars had been produced using tissue culture or whether it had been used for specific cultivars or traits. There was even the occasional difference of opinion between key informants over whether biotechnology had been used at all in producing a specific innovation. Thus, some of these techniques are so ubiquitous and even taken for granted that their use is hardly noticed.

Biotechnological innovations do not occur in a vacuum. The environment in which these innovations occur can be divided into the physical environment and the technological environment. The physical environment is an important consideration because the environment factors that currently affect agricultural production are different from the factors that affected production in years past. The pressures from pathogens are different, and biotechnology has bred crops in response to these evolving pressures. In determining the economic value of biotechnology, this research needed to examine how production would occur in the absence of biotechnology. This is not a simple case of taking 40-year-old cultivars and dropping then into the modern environment, however, because the environment has changed. A key question that arose in the research is whether plant breeding could have responded as successfully to evolving pressures if it had not had these biotechnologies.

The other environment in which biotechnology innovations are developed and commercialised is the technological environment. Biotechnology, particular when it is defined as four specific biotechnologies, is one element in a larger picture of technological and scientific development. For example, producing more raw milk on more efficient dairy farms is of little use if that milk cannot be shipped to a processing plant and then exported overseas as butter or milk powder. One specific example that demonstrates the dependence of successful commercialisation of one innovation on a suite of developments is the experience of AgVax with its ToxoVax vaccine. The vaccine reduces the incidence of spontaneous abortion in sheep. AgVax found that the increased use of scanning for sheep increased demand for their product. With scanning, sheep farmers gained information about the number of pregnancies and therefore the expected number of lambs. When farmers discovered that they had fewer live lambs than they expected from scanning results, they had an indication of the incidence of abortions. This information then created greater demand for a product that reduced abortions.

3.5 Conclusion

The discussions with key informants yielded valuable insights beyond the dollars-and-cents information that was required for the economic valuation described in the next chapter. They provided important information on the development of commercialised biotechnological innovations. In particular, they emphasised that individual innovations are the products of long-term, fundamental research. The nil results discussed above can easily be viewed in this context: the fundamental science is being worked out but there is still work to be done before it yields commercial innovations. The scientific success of the research is only one element. Commercialisation is the result of a combination of technology, science, and management producing usable, convenient innovations within the context of an industry or a production system. Furthermore, profiting from commercialisation requires business expertise, such as marketing, sales and farm management, in addition to technological proficiency.

Chapter 4
Quantitative Analysis of Survey Results

4.1 Introduction

This chapter firstly outlines the method used to calculate the economic benefits of the current biotechnology, by sector or case study as appropriate, and then reports the actual calculations of these costs and benefits. A key output of this research is an estimate of the economic contribution of biotechnology to the primary sector in New Zealand. Such an estimate is not readily available from prior research on agricultural productivity or biotechnology. The question of the impact of biotechnology on the primary sector has been examined in several ways, but an estimate of its annual financial contribution to the primary sector has not been made.

The estimates provided here rely on important considerations of the types of impacts that biotechnology can have. As has been recognised elsewhere, different biotechnology applications have different types of impacts. As such, these impacts need to be carefully assessed in order to evaluate their economic benefit to the primary sector. The biotechnologies identified in this research demonstrate some of these different types of impacts. This chapter therefore builds upon Chapter 3 in discussing the different potential impacts, the appropriate methods for determining their economic values and then estimating the net benefit to the primary sector.

The first section of this chapter provides a brief discussion of Cost Benefit Analysis (CBA) methodology and its application in this research. The second section combines information from the interviews of key informants with data from government sources and results of prior research to estimate the economic impacts of specific examples of biotechnology. In the concluding section, the results are summarised and discussed.

4.2 Method: Cost Benefit Analysis

CBA compares the cost and benefits of policies or projects. These may include social, cultural, environmental and economic costs and benefits. This project focused on the economic costs and benefits, but included other types of costs and benefits where appropriate and feasible. It also focused largely on the direct costs and benefits of the biotechnology products. This analysis was based on the assumptions below and those given by respondents. Other impacts, including indirect and induced impacts, are examined in the international trade and macro-economic analyses in Chapters 5 and 6. The stages in a CBA are defined and discussed below.

4.2.1 Stage 1: Definition of impacts

The first stage in any cost-benefit analysis is identifying the options and their impacts. This project relies on a number of sources to identify and estimate the impacts of biotechnology on the primary sector. Ideally when identifying these impacts, information on production inputs and outputs, processes, services, and methods resulting from the four biotechnologies will be included. Some of these will be market impacts, while others may be non-market impacts, such as environmental impacts. However, this information was not always available and use

had to be made of secondary sources or assumptions relating to the impact of the technology, which are described on a case by case basis below.
The next stage in determining the impact of the technology was to assess the alternative option: the scenario in the absence of the biotechnology as the counterfactual. The value of biotechnology in primary production will be measured as the difference between these two options: what is currently being done, and what would have been done had biotechnology not generated the products, processes, services, and methodologies that are currently in use.

Researching the issue of what the industry would do without biotechnology led to interesting discussions with key informants and required close examination of the literature. Information on the counterfactual derived from essentially two sources. The first source was historical: how did production occur before biotechnology was introduced? An interesting example of an historical perspective was potato production. Nearly the whole industry relies on seed potatoes produced through heat treatment and tissue culture and then clonal propagation, a process that provides cleaner, more uniform potato tubers. Whilst the technology has been in use since the early 1980s, there is good information (and personal reminiscences) on earlier production practices from which the counterfactual could be determined. The second source of information for the counterfactual was variation in present-day production. For many products, only some producers use the biotechnological innovations that are profiled below. Other producers do not use the innovations. This enabled good comparisons to be made to demonstrate the impacts of biotechnology.

The counterfactual is important to calculate economic benefits. It is against the counterfactual that the impact of a biotechnology is measured. If a counterfactual contains too high an estimate of productivity or profits, then the impact of the biotechnology application is understated. On the other hand, a low estimate for the counterfactual overstates the impact of the biotechnology. In every case, this research has sought the most realistic picture of production in the absence of these four biotechnologies, based on a review of the literature, analysis of production practices, and the interviews with key informants.

4.2.2 Stage 2: Identification and estimation of impacts

This stage of the analysis takes the information from stage one regarding the physical impacts and calculates the costs and benefits of the technology for the primary sector. Regardless of the types of innovation, the estimation of economic impacts for every biotechnology application had two main considerations:

- What is the impact of biotechnology on production?
- What are the opportunity costs of the resources used in production?

The first question, 'What is the impact of biotechnology on production?' is relatively straightforward. This is the current state, the present method of production. In this study information was primarily obtained from interview participants, who were able to describe production as it happens and the contributions that biotechnology made. This was supplemented with information from product end-users and secondary sources of data, such as data about current production that is included in official statistics and farm-level research.

To estimate the cost to the primary sector of using the biotechnology product ideally requires information on a range of factors. The ERMA report, 'Evaluation of benefits, market access, and demand issues for applications for commercial release of genetically modified organisms' (Kaye-Blake & Saunders, 2003), detailed the direct use costs that should be considered in evaluating new technology. These include technology fees, changes in variable input costs, changes in capital use and costs, impacts on agricultural labour demands, and impacts on use of natural resources such as water. To the extent that they are known and can be assessed or estimated, these cost changes were included in the CBA.

One of the main reasons for pursuing interviews with key informants was to understand exactly how the biotechnology applications that were identified affected production. This is a multi-faceted issue. Innovations can affect the inputs to production or the outputs, and can affect either the quantity or the quality. The economic impact calculations took into account the different types of impacts that biotechnology could have.

One example is AR1 ryegrass, which contains a endophyte that does not cause ryegrass staggers in livestock. The physical seed is identical to seed containing a wild-type endophyte that does cause staggers. It is handled in exactly the same way. The output from pasture using AR1 ryegrass – the meat, milk or wool – is also identical to output from another type of ryegrass. However, the AR1 endophyte improves animal productivity in measurable ways, so that the farmer has more production from the same land area. This is an example of a technology in which the input is improved, but farm-level production system is largely unchanged, as is the physical characteristics of the output.

For an innovation like AR1 ryegrass, the economic calculations focused on the increased cost of the input and the increased amount of output. Calculations of changes to production systems were unnecessary, and considerations of price or marketing changes were also unnecessary.

Another example is the use of clonal propagation to produce improved tubers for floriculture. Larger tubers are more productive and command higher prices. Tubers are both an input to floriculture and an output, so price impacts had to be considered for both sides of the production system. On the input side, larger, clonally propagated tubers cost more. On the output side, they can result in more stems and premium tubers, both of which are export products.

For this sort of innovation, the economic calculation had to account for the increased costs of production as well as the changes to quantity produced and export prices. These calculations were thus more complex.

The second consideration that runs through all of the calculations below is the *opportunity cost* of resources used in production. Opportunity cost is an economic concept that recognises that productive resources have alternative uses. In valuing the costs (and benefits) of the new technology it is the opportunity costs which are relevant, that is, the cost (or benefit) of the next best alternative. This requires information on the counterfactual as discussed in stage one above. It also requires information on the next best use of resources which have been changed in use due to the technology, for example, the cost of alternative treatments or methods for achieving results similar to the results of the biotechnology product. The primary source of this information was the interviews, and this information was supplemented by the literature and secondary sources of data.

The resources used in producing one crop are resources that could have been used in producing another. If biotechnology makes one crop more profitable to produce, that change will pull resources out of other uses. The improvement due to biotechnology is thus the increased returns, *over what the resources could earn in alternative uses or employment*. The improvement is *not*, strictly speaking, simply the value of production.

To capture the opportunity cost of resources used in production, the economic analysis relies on calculations of *gross margin* from the 2004 Financial Budget Manual (Burtt, 2004). This publication contains production budgets for the main agricultural products of New Zealand. Production budgets detail income by source and expenditure by category, and they are widely used in applied economic analysis and practical farm management. The gross margin is the total of income less variable expenditures. Variable expenditures are those that would be affected by increases in production. For example, if a biotechnology increases the amount of a crop that can be harvested per hectare, this increased production also leads to increased costs for harvest labour. Gross margin calculations do not included imputed rent values for land and exclude many fixed costs, such as machinery, capital costs and farmer's labour.

Using gross margins is a good approximation of the increased value of many biotechnologies. The particulars for each biotechnology or each crop may be slightly different, so gross margins will only be an approximation. In addition, the use of gross margin neglects some expenditure, such as land rents, that should be attributed to production. Furthermore, one should expect such fixed assets to increase in value as their products yield more profits. On the other hand, gross margin calculation can understate the impact of a biotechnology. A biotechnology that increases product quality can lead to increased value being produced at the same cost. A simple gross margin calculation can therefore overstate the cost of production. The use of gross margins for this analysis thus has the potential to either understate or overstate the impact of a biotechnology, with no clear expectation of the direction of the impact. However, a key consideration in the economic analysis is evaluating opportunity cost. Gross margin calculations provide a good estimate of opportunity cost in the absence of primary data from the surveys.

The benefits of the biotechnology products were analysed using interviews with key informants as the first source of information. The informants were asked for data regarding the positive impacts of their products in terms of cost savings, improved productivity, enhanced product attributes and increased market premiums (Kaye-Blake & Saunders, 2003). Combined with these primary data were secondary data from the literature, governmental and industry sources to ascertain the contribution of products to overall industry returns. Where necessary, this research also relied on industry estimates of price premiums for differentiated products, such as premiums to organically-produced food, price margins for higher quality designations, and willingness to pay estimates generated by stated preference research.

The research also considered market-level benefits of the biotechnology products, assessing the impacts of differential rates of uptake as well as market trends. Some of the market-level issues previously identified are the intended markets for the commodity, New Zealand's market shares in those countries, the sensitivity of those markets to price changes, and the policies that affect market access (Kaye-Blake & Saunders, 2003). However, the wider economic implications of the uptake of technology are assessed in more detail in Chapter 5 and 6.

By using this information, the CBA estimated the actual first stage net benefits of the biotechnology products from the microeconomic perspective. This initial analysis was based on the assumption of perfectly elastic demand for primary sector products; that is, it assumed that New Zealand could sell as much as it produced without affecting world prices. Following chapters relax this assumption, taking into account New Zealand's relative importance in certain international commodity markets.

4.2.3 Stage 3: Which impacts are relevant?

In collating and assessing the costs and benefits of the biotechnologies, the relevance and significance of the impacts were assessed with a number of criteria, as detailed below.

- Impacts on prices and quantities. Are these impacts large enough to make a difference to producers? Are they large enough to affect the market?
- Impacts on marketed and non-marketed goods and services. Generally the impact on marketed goods and services are covered in a CBA but the coverage of non-marketed effects may require consideration. Assessing their value is often costly and difficult, so it is thus beyond the scope of the proposed research to quantify these impacts. However, where the biotechnology products have been shown to have environmental impacts, these may also be considered in the analysis using secondary sources of estimates of non-market valuations.
- Direct, indirect and induced impacts. The CBA will consider the direct impacts of the products. The indirect and induced impacts will be estimated using secondary data sources.
- Current and future impacts. The proposed research is focussing on currently commercialised biotechnology products. However, in the case of forestry there are cost and benefit streams into the future, which are included as they represent real improvement in capital stock. Thus, in this case future net benefit streams will be discounted to express them in current dollars.
- Certain and uncertain impacts (risk and probability). Because the focus is on current products, the uncertainty surrounding the commercialisation of biotechnology products is not relevant to this study. The main uncertainty in this study is the quality of data and information available from the primary sector. This includes information on uptake rates in the primary sector, interactions between the technologies and the production environments in which they are used, and market conditions. Moreover, the actual costs and benefits do vary according to environmental and market conditions. Whilst the study does undertake to account for this uncertainty through the use of averages there are cases where information is not available on the variability and this is not possible. Discussions with the key informants on this project helped identify key areas of uncertainty. For example, the benefits from a programme to reduce footrot in sheep are greater when climatic conditions are conducive to developing the condition, and conversely are less when conditions are not conducive. Market conditions are another source of uncertainty.

In the course of this research, a few biotechnological innovations were identified but not subsequently valued. There were two reasons not to calculate precise values for them. The first reason was that the innovation was outside the bounds of this research. Some products are clearly the result of biotechnology but did not belong to the categories used in this research. An example is AndroVax, a vaccine from AgVax that enhance sheep fertility. While vaccines are included below, these were included under the heading of 'Biocontrol agents'. As AndroVax is not aimed at controlling a pest, it did not fall into that category.

The second reason is that when estimating the net benefits to the sector particular attention was paid to those biotechnologies which had significant effects. In some cases there were biotechnologies for which information was not available and the small size of their contribution made estimates from secondary sources either impossible or insignificant. Thus there may be cases where specific economic calculations were not made for an innovation which, while successful, did not contribute materially to the primary sector as a whole. The primary sector is worth tens of billions of dollars, and the overall contribution of biotechnology is in the hundreds of millions. This aspect of the research is not intended to impugn any products, processes, or producers.

4.2.4 Stage 4: Discounting of cost and benefit flows

As stated above, the production options may involve both costs and benefits over time, especially with forestry. These may need to be discounted to a net present value (this allows for the fact that generally goods and services available now are more highly valued than those available in the future). For each time period, benefits and costs were assessed and the net benefit determined. The present value of the net benefit was then calculated using a discount rate or a rate of interest. The discounted values of the net benefits for all periods were summed to give a total net present value.

$$CBA = NPV = \sum_t \frac{Benefits_t - Costs_t}{(1+r)^t}$$

NPV = Net Present Value

r = rate of interest (generally the market rate is used here)

t = time period

4.2.5 Stage 5: Apply the net present value test

From the data and information available, it was possible to calculate a Net Present Value (NPV) for the biotechnologies. The NPV Test assesses whether the sum of discounted benefits exceed the sum of discounted costs. If so, the technologies can be shown to be a net improvement to the primary sector in New Zealand, given the information generated in the CBA.

Another use of this test is to determine the relative impacts of different production options. This would be particularly appropriate if there are a number of products or production methods that can achieve similar results. The Cost Benefit ratio is calculated by dividing the discounted benefits by the discounted costs for each project. The resulting ratios are then compared.

4.2.6 The indirect and induced contributions

The above direct contribution of biotechnologies is only part of their total contribution to the New Zealand economy. There are also indirect and induced contributions, which are differentiated below.

1. Direct contributions. These are a result of direct finance and employment injected into the economy.
2. Indirect contributions. These are a result of upstream and downstream finance and employment created to service the biotechnology firms.
3. Induced contributions. These are the effect of the above two contributions on further household spending which generates finance and employment such as increases in the purchases of household goods and services.

Thus, this stage of the analysis calculated the indirect and induced contributions to assess the total impact of the biotechnologies on the economy. To estimate the indirect impacts (for both output and employment) it is usual to include two levels of upstream and downstream effects. The first level is from those who supply the industry directly, such as component suppliers. Ideally this should be estimated from primary data. The second level is the output and employment effect generated by these firms supplying the industry directly. The survey did include questions to try and elicit this first level of indirect impact for output/expenditure by providing data on the inputs into biotech firms by type. However, data were not generally available so secondary sources of data have been used. The indirect and induced contributions are calculated and discussed in Chapter 6.

4.3 Analysis and results

This section reports the results of the cost benefit analysis by product sector or case study as appropriate. As outlined in Chapter 3, the application of the technology varies considerably by type, impact, and coverage. Moreover, the information available also varies considerably as does the availability of secondary sources of data to confirm industry sources or to obtain estimates on its impact. Therefore, in the analysis various assumptions have had to be made. In addition, whilst in some sectors it has been possible to calculate or estimate impacts of technology to the whole sector, in others it has been necessary to rely on case studies. These issues are discussed in more detail below.

4.3.1 Direct impacts: Clonal propagation/cell manipulation

Clonal propagation/cell manipulation is a broad category of biotechnology that encompasses a number of specific techniques, such as tissue culture, protoplast fusion, in vitro cloning, tetraploidy, etc. Not specifically included in this category are genetic manipulation and transgenics, but this is not a material omission as these techniques have not yielded commercial products in New Zealand. The definition of clonal propagation also does not include garden-variety cloning, such as rooting plant cuttings, done without the aid of laboratory facilities.

Of the four biotechnologies in this report, clonal propagation/cell manipulation has contributed the most value to the primary sector. There are several reasons for its relative importance. First, it is a relatively mature, well-established group of techniques. Because it has produced effects over time, those impacts have grown and compounded. Secondly, its impacts are widespread across the primary sector. Finally, it has proved quite important for some products of economic significance to NZ. These factors have all contributed to the importance of clonal propagation and cell manipulation.

These same characteristics do complicate the economic assessment of the value of clonal propagation and cell manipulation. Because it is a widespread technology, some of its impacts need to be estimated at an aggregated level. Also, because some important impacts have been localised – for example in potatoes and floriculture – the exact nature and value of the impacts are commercially sensitive. The following analysis contends with these issues to calculate the contribution of this biotechnology to the primary sector. The sector is divided into five types of crops or production systems for the analysis.

4.3.1.1 Arable crops

Agronomic research on staple crops led to important increases in production in the second half of the 20th century. These increases have been well-documented and studied. Abeledo, Calderini, & Slafer (2002) summarise research on genetic gains in barley. Genetic yield gains in barley vary by study, but they are 0.3 per cent to 0.4 per cent per year for the whole 20th century. Gains achieved in the second half and the last quarter of the century were higher than those in the earlier periods. For example, plant breeding has increased the genetic grain yield by more than 0.5 per cent per year since the 1940s. In the same chapter, Abeledo, et al. (2002) note that genetic gains from wheat have been slightly higher than those for barley, about 0.5 per cent per year. However, it is possible that yield increases have declined over time in New Zealand, as they have in Mexico (Traxler, Falck-Zepeda, Ortiz-Monasterio, & Sayre, 1995) and across developing countries (R. E. Evenson, 2003; R.E. Evenson & Gollin, 2003). For maize, Duvick & Cooper (2004) demonstrated a clear linear trend in yields per hectare since 1930. Interestingly, potential yield per plant had not increased from 1930 to the mid-1990s. Instead, newer varieties performed better for harvest index and under stress and crop density, leading to increased yields per hectare over time. An implication of their linear trend in yields is that the percentage yield increase per year has been falling over time, as the same additional production is added to larger base yields. At total yield of six tonnes per hectare, which was achieved in 1955 according to the regression line and in about 1940 according to the data points, an annual increase of 68 kgs represented a 1.1 per cent increase. Yield in 2000 was estimated to be nine tonnes per hectare, so that 68 kg represented only a 0.76 per cent increase. Importantly, the authors did not separate the genetic yield increase from other factors.

Biotechnology through clonal propagation/cell manipulation has contributed to the genetic component of the increase in yields reported above. However, the exact contribution is not known. The research into gains in yield reviewed above has found that genetic improvements vary by crop and country and over time. Certainly, biotechnology was used to generate some of these gains but it was also reported in interviews and in the literature that some of these gains could have been achieved through traditional breeding. However, there is a view expressed in the literature that the ‘easy gains’ from traditional breeding techniques had already been achieved and that further gains are harder to achieve and thus require more powerful technologies such as biotechnology (Bajaj, 1990). The studies above imply a base crop genetic improvement figure of 0.5 per cent per year in yield for arable crops. In this study, after consultation with key informants, it was assumed that one-half the base crop genetic improvement can be attributed to clonal propagation/cell manipulation. By this assumption, the implicit counterfactual is that crop genetic improvement would have been one-half its current level if clonal propagation/cell manipulation had not been available.

Thus it is estimated that arable crops have been increasing in productivity by 0.25 per cent per year as a result of biotechnology. Writing in 1990, Bajaj (1990) reported that modern biotechnology was increasingly incorporated into breeding programmes during the 1980s. Attributing some value to biotechnology starting from 20 years ago therefore seems appropriate. Compounding the annual gain of 0.25 per cent over a period of 20 years results in an estimate of the total gain from the use of biotechnology. Thus, current production is estimated to be 5.1 per cent greater than it would be in the absence of clonal propagation/cell manipulation. It would be desirable in future economic research to estimate the specific contribution of biotechnology to each commodity, but this figure of 5.1 per cent represents the best estimate with the available data. Table 4.1 presents calculations of the value to New Zealand producers of this increase in yield. This shows that with a 5.1 per cent increase in yield the increase in revenue is nearly $20 million, however to calculate the net returns to NZ the gross margin is used giving net benefits of $8.2 million.

Table 4.1 Economic contribution of clonal propagation/cell manipulation to the arable crop subsector

Arable crops	Area (hectares)	Revenue per hectare[a] ($)	Revenue ($000's)	Current production due to biotechnology from 0.25% annual increase (%)	Increased production ($000's)	Gross margin[a] ($ per $ of revenue)	Value of clonal propagation/cell manipulation ($000's)
Barley[b]	64,700	1,725	111,608	5.1	5,692	0.45	2,561
Field peas[c]	10,000	2,320	23,200	5.1	1,183	0.54	639
Maize[d]	14,166	3,497	49,539	5.1	2,526	0.36	910
Small seeds*[c]	33,000	2,376	78,408	5.1	3,999	0.42	1,679
Veg seeds[c]	3,000		25,000	n/a	n/a	n/a	n/a
Wheat[e]	40,900	2,480	101,432	5.1	5,173	0.47	2,431
Total arable			389,187		18,579		8,220

* Gross margin is the unweighted average of clover, ryegrass, and fescue gross margins.

[a] Burtt, E. (Ed). (2004). *Financial Budget Manual*. Canterbury: Farm Management Group, Lincoln University.

[b] Area data: Ministry of Agriculture and Forestry Website, Total Barley - Area Harvested and Quantity Produced, 2003.

[c] Area data: Ministry of Agriculture and Forestry, (2004), Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF).

[d] Area data: Ministry of Agriculture and Forestry Website, Grain and Seed Crops by Farm Type (ANZSIC), 2002.

[e] Area data: Ministry of Agriculture and Forestry Website, Total Wheat - area harvested and quantity produced, 2004.

4.3.1.2 Floriculture

One example of an industry in which this biotechnology is important is the flower industry. Some firms, such as Multiflora Ltd and Lifetech, are specialists in tissue culture on contract. They reproduce plant matter – bulbs, corms, tubers, and other plant material – for the floriculture industry. The industry then sells cut flowers and bulbs to the consumer. Tissue culture allows for quicker propagation and better form resulting in larger tubers and earlier flowers, resulting in premium prices for growers.

The flower industry can be broken down into several components. One division is between the domestic market and the export market. The domestic market for cut flowers is estimated to be $70 million (HortResearch, 2003), and the export market for cut flowers, live plants, foliage, and bulbs, tubers, and corms totals $76.6 million. MAF suggests that the domestic market is potentially oversupplied and that returns are marginal (Ministry of Agriculture and Forestry (MAF), 2003). This analysis thus concentrates on values in the export market.

In order to calculate impacts on the gross margin, this analysis uses the production budget for export calla lilies (Zantedeschia) (Burtt, 2004) as representative for the whole industry. The ratios and margins were calculated from this production budget, and were then applied to industry earnings as a whole. The industry on average per holding earns a revenue of $16,750 of which when variable inputs are removed leaves a gross margin of $5,221, however it should be stressed here that the gross margin excludes the cost of the tubers which are counted as capital stock. This implies a gross margin ratio to total revenue of 31.2 per cent. If this ratio is applied to the total industry export earnings of $76.6 million then $23.9 million represents the gross margin for the industry.

Given the widespread adoption of the biotechnology in the industry, no actual estimates could be made of the counterfactual. Thus, the study assumed that in the absence of the technology the gross margin would be lower. An average was taken of the lowest gross margin estimate of a loss of $2,921.19 and the current average of (a gain of) $5,221.25, a value of $1,150. This is taken as the counterfactual gross margin, what the flower grower would have earned in the absence of tissue culture-derived plantstock. The gross margin for the total industry, instead of being $23.9 million, would have been $5.26 million. The gross benefit to the industry is the difference between these two figures, or $18.6 million.

This benefit however excludes the cost of the tubers as capital stock which would have been produced using biotechnologies; these would cost more when starting up a floriculture operation. The prices for different-sized tubers are presented in the Farm Budget Manual, and range from $0.70 per tuber to $2.10 per tuber. Given this price spread, one-half the original cost of the tuber stock was ascribed to the improved stock. The cost of the stock for the production budget was estimated as the interest on the capital invested in tuber stock. This was estimated at 7.61 per cent of total income, or $5.83 million for the industry. In the counterfactual, growers would be producing less but also spending less on their tuber stock. This spending was estimated to be $2.91 million less than actual industry spending, and represents the cost of the plant material improved through biotechnology.

The total impact of tissue culture on floriculture was thus estimated to be a benefit of $18.6 million at a cost of $2.91 million, for a net benefit of $15.7 million.

Table 4.2 Economic contribution of clonal propagation/cell manipulation to the floriculture subsector

	With biotechnology	Without biotechnology
Export earnings	$76,600,000	
Gross margin (%)	31.2%	
Gross margin ($)	$23,899,000	$5,264,000
Cost of investment in plantstock	$5,829,000	$2,914,000
Gross margin net of plantstock costs	$18,070,000	$2,350,000
Value of clonal propagation/cell manipulation		$15,720,000

4.3.1.3 Forestry

Clonal propagation is increasingly adopted in commercial radiata pine forests. Trees of a clone are genetically identical and can be improved in both growth and wood quality. For the purpose of this study, a distinction was made between vegetatively propagated trees and clones developed with modern cell technology. The former approach is very common; about a third of all radiata pine planted is derived from cuttings from control pollinated families. These cuttings are taken from a single mother stool plant, perhaps one hundred over a three- to four-year period. When deployed as cuttings in a forest, the common genetic identity of such plants is not tracked and thus can and will be mixed with other genotypes. These trees do not constitute products of clonal forestry as defined in this study.

The first clonal forestry in NZ based on tissue cultures techniques was commercialised in 1986. Nowadays, cloning of radiata pine is not only technically feasible but also practised on a substantial commercial scale. The two techniques used are tissue culture (organogenesis) and somatic embroyogenesis, with the first one being the original and the second one the most commonly used at the time of writing (Sorenson & Shelbourne, 2004).

About nine per cent of the 30 million genetically improved trees sold annually in New Zealand are made up of clonal planting stock. An estimated total of 14.63 million clonal plants have been sold commercially as of 2004 (2.63 million in 2004 alone). The price of a single commercial clone was around $1.08 according to Sorenson & Shelbourne (2004), which was three times that of control-pollinated trees and five times that of open pollinated plants. This cost reflected the higher value of clones as well as the higher cost of production. As of June 2005 the premium paid for a clonal treestocks was 60 cents, according to industry sources.

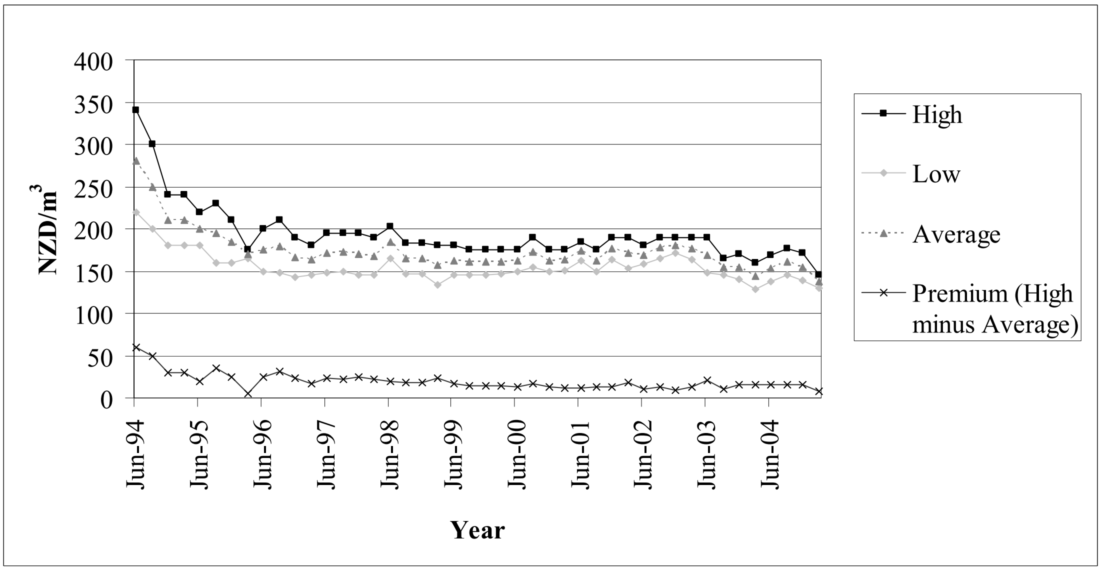
Given that the first commercial clonal forest was planted in 1986 and assuming a 27 year rotation, any clonally propagated trees have yet to be harvested. They thus do not contribute to revenue earned by the New Zealand primary sector. However, there is substantial equity in the 14.63 million clonally propagated trees planted in New Zealand. Given the long investment period in forestry (a 27-year rotation), it is appropriate to value this equity as an unrealised economic contribution of clonally propagated forestry to the New Zealand economy.

The calculations were based on several variables: the initial cost of a clonal tree, the premium at the time of harvest, the estimated number of trees planted each year, and an average post-tax discount rate of 8.3 per cent (Manley, 2003). The cost of management was assumed to be equal to the counterfactual of control pollinated trees. Thus, the only cash flows that differed were the initial cost for a planting and the final premium received for the harvested trees, which are detailed below.

As mentioned above, the initial cost of a planting was in 2004 around \$1.08, which is three times that of control pollinated trees. Thus the additional investment at the time of planting was \$0.72; this figure was used for calculating the impacts of clonal propagation. This cost was slightly more than the current increased cost for a clonal tree of \$0.60, because the appropriate figure was the cost per tree at the time of planting. The lower figure reflected economies of scale for the technology that have only recently taken effect.

The premium at the time of harvest was harder to estimate as there are a number of aspects of clonal forestry that impact on the premium, including better traits and less variance. The best way to estimate the premium was to take the average price of the counterfactual forest, which in this case would be a control pollinated forest, and compare it with a cloned forest block. The graph below shows the quarterly log prices for the quality classification P1, and the high, low, and average prices within that quality classification. A calculated premium is also included in the graph.

Figure 4.1 P.1 quarterly log prices (NZD/tonne)



Source: Ministry of Agriculture and Forestry (MAF) (2005)

There are two important observations about the above figure. The first is that the differences between high, low, and average have been relatively stable for the last five years. The second is that the difference between high and average price serves as an approximation of the premium rewarded to a harvest based on a clonally propagated forest. The table below shows the average premium (high minus average) of the last five years (March 2000 to March 2005) for several different quality classifications. The average premium of the five quality levels in the table below is $14. However, this premium constitutes a best-case average scenario. The range may be from a loss of $100 to a gain of $60 per cubic metre, depending on the success of a specific project. Thus a more conservative average premium, corroborated by industry, of $10 (pre tax) was used in the calculations. A tax rate of 33 per cent was used.

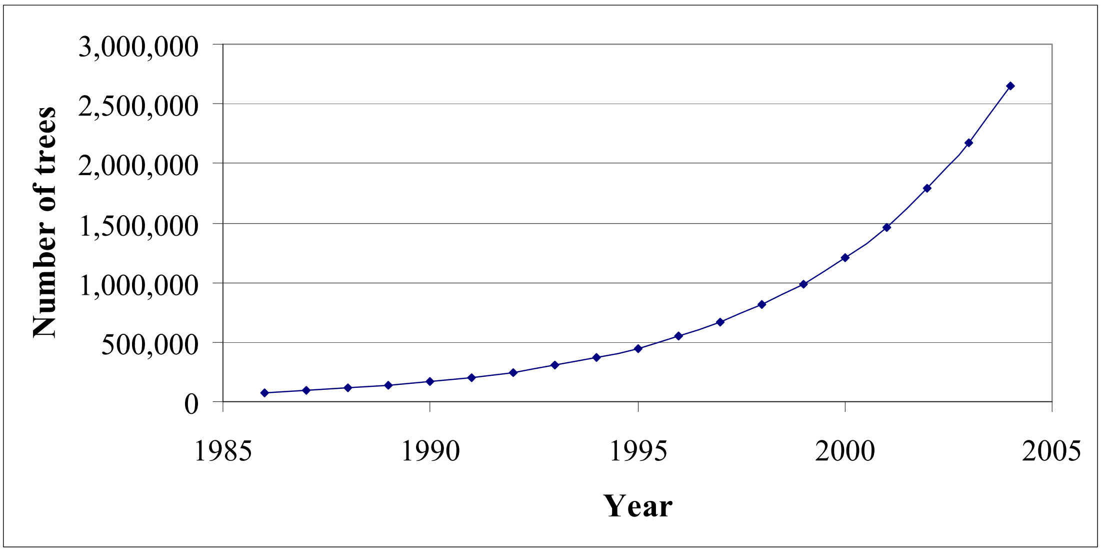
Table 4.3 Premium for high grade logs over average grade

Classification	Five-year average premium (NZD/tonne)
P1	$14
P2	$26
S1	$8
S2	$9
L1 & L2	$11
Total average	**$14**

Source: Ministry of Agriculture and Forestry (MAF) (2005)

The growth in the number of clonal trees planted each year is estimated as a logarithmic curve. The data available were that 14.63 million clonal trees have been planted since 1986 and 2.63 million clonal trees were planted in 2004. A logarithmic curve fit these data well. Further research may be able to determine the exact numbers of clonal trees planted per year. The curve is shown in Figure 4.2.

Figure 4.2 Estimated number of clonal trees planted per year



These data are combined in Table 4.4 to estimate the unrealised capital gain from clonal plantings. This estimated gain is based on the premium calculated above, the logarithmic uptake rate, and an industry-specific discount rate of 8.3 per cent. In addition, the harvest rate is set to 90 per cent, and the each tree provides 2.41 cubic meters of wood, of which 2.06 cubic metres (pruned logs and sawlogs) receive the $10 premium (Forestry Insights, 2005; New Zealand Forest Owners Association, New Zealand Forest Industries Council, & Ministry of Agriculture and Forestry, 2005).

Table 4.4 Economic contribution of clonal propagation/cell manipulation to the forestry subsector

Year	Number of trees planted	NPV of premium per tree	NPV of initial investment per tree	NPV of clonal forestry
1986	76,163	$6.73	-$3.02	$254,292
1987	92,769	$6.22	-$2.79	$285,998
1988	112,996	$5.74	-$2.58	$321,658
1989	137,633	$5.30	-$2.38	$361,765
1990	167,642	$4.90	-$2.20	$406,871
1991	204,194	$4.52	-$2.03	$457,603
1992	248,715	$4.17	-$1.87	$514,659
1993	302,944	$3.85	-$1.73	$578,830
1994	368,996	$3.56	-$1.60	$651,002
1995	449,450	$3.29	-$1.48	$732,172
1996	547,445	$3.03	-$1.36	$823,464
1997	666,807	$2.80	-$1.26	$926,138
1998	812,194	$2.59	-$1.16	$1,041,614
1999	989,281	$2.39	-$1.07	$1,171,489
2000	1,204,979	$2.21	-$0.99	$1,317,557
2001	1,467,706	$2.04	-$0.91	$1,481,837
2002	1,787,717	$1.88	-$0.84	$1,666,601
2003	2,177,501	$1.74	-$0.78	$1,874,403
2004	2,652,272	$1.60	-$0.72	$2,108,114
Total	14,467,403			$16,976,067

4.3.1.4 Horticulture (except floriculture)

Hops

The entire hops industry in New Zealand is based on biotechnology, which has produced triploid hops with good agronomic and brewing qualities. According to information obtained in this research, the hops industry would not exist in New Zealand without biotechnology.

New Zealand Hops Limited provided confidential data that allowed calculation of total farmgate value of production, per hectare gross margins, and total industry gross margins. The total gross margin for the industry was calculated to be $1,919,000. If the entire industry would not exist without biotechnology, then this entire amount could be attributed to biotechnology.

The exact portion of this amount to attribute to biotechnology is a complex matter; unfortunately, there were insufficient resources to devote to the question. One concern is consistency with other parts of this analysis in how clonal propagation/cell manipulation is defined. Some currently commercial cultivars were released in the early- to mid-1970s, before the time period considered in other parts of this research. In addition, although New Zealand hops production is based on triploid cultivars, diploid cultivars are commercially significant in other hops-growing regions. Exactly how the industry could have developed in New Zealand without access to biotechnology is important for developing an appropriate counterfactual, but is also a complex and speculative matter. Given that the estimated industry gross margins were less than two million dollars, and given the information available, the entire amount can be attributed to biotechnology without materially affecting the overall results of the research.

Potatoes

Another crop whose production is significantly improved by tissue culture is potatoes. Tissue culture is used after heat treatment to propagate the initial generations of plants, which are then used to produce seed potatoes. The resulting potatoes are planted to produce the retail crop. Most of New Zealand's seed potatoes are produced by this process, which produces virus-free, uniform seed potatoes and does so more quickly than older methods of propagation. The industry depends to such an extent on tissue culture that one key informant suggested the potato industry would disappear without it, while other informants suggested that production would fall by two-thirds to three-quarters.

There are several benefits to tissue culture (Ovenden, no date; Ovenden, Anderson, Armstrong, & Mitchel, 1985; Ovenden & Martin, 1981). First, the final product is larger and more uniform, attracting a higher price. Secondly, the crop has fewer problems with pathogens, leading to greater productivity. Thirdly, the potato skin is smoother, making the tubers easier to clean and more marketable.

The value of biotechnology to potato production is significant in one sense. From the accounts of key informants, biotechnology allows the industry to exist in its present form. Given the estimated crop volume of 470,000 tonnes (HortResearch, 2003) and a farmgate price for fresh potatoes in 2003 of $300 per tonne (Ministry of Agriculture and Forestry (MAF), 2003), the value of production is significant at $141 million.

It is important to note, however, that gross margins in the potato sector are variable and on average fairly low as a percentage of total revenue. Gross margins for several years are given in Table 4.5. An average of the last five years' gross margins was $1,438.40 per hectare. Aggregating this to the approximately 10,600 hectares in production (HortResearch, 2003), gross margins were $15.2 million, or 10.8 per cent of total revenue.

Table 4.5 Historical gross margins for potatoes

Year	2003	2002	2001	2000	1999
Gross margin per hectare	$4,050	$1,150	$950	<-$57>	$1,099

Source: (Burtt, 2004)

The value of tissue culture could be expressed in two different ways. The first method would be to take three-quarters of total gross margins and value biotechnology at $11.4 million. This would imply a much smaller industry producing a much smaller crop, but still earning profits. The other method would be to assign the industry's entire gross margins to biotechnology, as was suggested by one informant. However, given that there are some growers who do not buy tubers from off-farm and assuming that alternative techniques would have arisen in the absence of biotechnology, this is probably an unrealistic counterfactual. The first approach is a more realistic assessment of the value of biotechnology and is used in this report. Table 4.8 presents the calculations for potatoes along with calculation for other vegetable crops, and follows the discussion of other vegetable crops below.

Assorted horticultural crops

As has already been discussed, the exact impact of clonal propagation/cell manipulation on the horticultural subsector is difficult to determine. This is true for a number of reasons. First, data on so-called 'minor crops' is not nearly as detailed or consistently available as data on more economically important crops. For example, figures on per-hectare productivity of silverbeet were not available. Secondly, each crop and even different cultivars within each crop have been affected by breeding programmes in different ways. In vegetable crops, changes have included greater uniformity in size, form, and harvest date, impacts on size of the marketed portion of the plant, frost hardiness, heat tolerance, pest tolerance, and simple productivity-per-hectare increases. The impacts of these qualitative and quantitative changes are complex to document and catalogue. Thirdly, the extent to which biotechnology was responsible for these changes is difficult to determine. Despite a number of interviews it was not possible to determine whether a specific change was due to biotechnology. Furthermore, knowledge of the specific phenotypic changes is only part of the story. It is also important to know the economic value of those changes – how much more does a farmer receive for broccoli with a mounded, symmetric shape and the right shade of green?

At the same time, it would be disingenuous to suggest that decades of plant tissue and cell manipulation have had no impacts on horticultural crops. The problem simply is knowing the economic value of the changes.

The solution pursued here was to assign a representative value to the use of clonal propagation/cell manipulation in horticulture. This value was based on several pieces of information. For example, these biotechnological techniques have had commercial success in arable crops. Furthermore, clonal propagation/cell manipulation did not appear to have led to commercially successful results in several horticultural crops, such as apples, kiwifruit, and grapes. This finding was based on discussions with key informants, and was confirmed by the literature. For example, commercially viable genetic improvement to apples are difficult because of scientific and marketing challenges (Brown & Maloney, 2003). The calculations of economic value of the contribution of biotechnology thus excluded these crops and focused instead on vegetable crops. Calculations began with data on the number of hectares of vegetable crops in New Zealand from the 2003 Horticulture Monitoring report and then excluded potato acreage, which was treated separately. Gross margin numbers were from Burtt (2004). This publication provided values for certain crops, and these were taken as indicative of the subsector. Finally, the portion of gross margins attributed to biotechnology was calculated at the same rate as in arable crops.

The final calculation of the contribution of clonal propagation/cell manipulation in horticulture was thus the product of hectares in vegetables other than potatoes (Table 4.6), gross margin per hectare (Table 4.7), and per cent contribution of the biotechnology. The figures are provided below.

Table 4.6 Vegetable crop production hectares in New Zealand

District	Vegetable hectares
Northland	1,407
Auckland	4,752
Waikato	5,957
Bay of Plenty	0
Gisborne	4,593
Hawkes Bay	7,484
Manawatu-Wanganui	6,667
Wellington	447
Nelson/Tasman	421
Marlborough	1,976
Canterbury	13,120
Otago	749
Total	47,573
Less, potato area	-10,600
Total, other vegetables	36,973

Source: MAF (2003)

Table 4.7 Gross margins for main crop vegetables

Crop	Hectares	Gross margin by year ($ per hectare)					Average
		1999	2000	2001	2002	2003	
Onions	5,680	3,124	-1,353	1,035	405	5,800	1,802
Cabbage	780	3,223	3,211	3,060	2,380	2,630	2,901
Cauliflower	1,181	3,762	3,672	3,250	2,490	2,750	3,185
Broccoli	1,786	2,677	2,545	-250	840	695	1,301
Lettuce	1,287	2,454	2,673	3,695	2,600	3,010	2,886
Total average (weighted by acreage)							2,081
Total average (unweighted)							2,415

Source: Burtt (2004)

Table 4.8 Economic contribution of clonal propagation/cell manipulation to the horticulture subsector[a]

Horticultural crops	Area (hectares)	Revenue ($000's)	Current production due to biotechnology (%)	Increased production ($000's)	Gross margin ($ per ha)[b]	Value of clonal propagation/cell manipulation ($000's)
Hops	406		100			1,919
Potatoes	10,600	141,000	75.0	141,000	1,438	11,432
Other vegetables	36,973		5.1		2,081	3,924
Total						17,275

[a] Source: see text and tables above.
[b] Burtt (2004)

4.3.1.5 Pasture

The use of tissue culture, protoplast fusion, and other cellular techniques in pasture plant breeding goes back to the 1970s, but with increased uptake in the 1980s (Van Heeswijck, Hutchinson, Kaul, McDonald, & Woodward, 1994). It was unclear exactly when these techniques began to affect the commercially planted pasture varieties. This application of biotechnology has improved forage quality through changes to digestibility, intake rate, and metabolisable energy content (Woodfield & Easton, 2004). Improved animal health has resulted from decreased incidence of ryegrass staggers, fescue toxicosis, bloat, infertility, and nutrient deficiencies (Woodfield & Easton, 2004). For this assessment of the value of clonal propagation/cell manipulation, reduction of ryegrass staggers was excluded; it is considered separately with biocontrol agents.

There were indications in the literature of the genetic gains in pasture plants and their impacts on animal production. Over the last 50 to 60 years, genetic improvements in forage grasses have led to 0.25 per cent to 1.5 per cent annual gains in dry matter yields, while in forage legumes, the gains have been 0.2 per cent to 4.0 per cent (Woodfield, 1999; Woodfield & Easton, 2004). These gains have led to improved animal performance of 0.3 per cent to 1.4 per cent (Woodfield & Easton, 2004) overall, while deselection of a trait that impaired fertility raised annual gains to 2.8 per cent (Woodfield, 1999). A major source of overall gains, especially since 1985, has been in breeding for specific environments (Woodfield, 1999). Sanderson & Leung-Wai ((2005) also examined improved animal performance, and calculated a growth rate in dairy output from 1975 to 2000 of 1.3 per cent per year. Part of this gain was attributed to the 0.5 per cent per year genetic gain in dairy cattle, while the remaining 0.8 per cent was attributed to several factors, including nutritive value of feed.

Using this research as a basis, this analysis attributed a 0.5 per cent annual gain in animal performance to improved forage plant genetics. The implicit counterfactual is thus that the growth rate in dairy output would have been 0.8 per cent per annum without the biotechnology instead of 1.3 per cent with the technology. As with arable crops, it was difficult to determine the portion of that gain that was due to clonal propagation/cell manipulation, although it was clear that such techniques were important. For example, the development of tetraploid ryegrass required biotechnology. This 0.5 per cent annual gain was compounded over a 20-year period to estimate the current benefit to New Zealand pastoral production from this biotechnology. Note that these gains were only applied to ‘improved’ pasturage, that is, pasturage that was sown with improved varieties. Interviews with key informants suggested that approximately 30 per cent to 40 per cent of New Zealand pasturage is ‘improved’. Improvements to pastures affect production in dairy, beef, and sheep subsectors. The economic impact of these improvements are broken out by subsector and presented in Table 4.9.

Table 4.9 Economic contribution of clonal propagation/cell manipulation to pastoral production

Product	Amount of production[a]	Revenue per unit[b]	Revenue ($000's)	Production affected	Current production due to biotechnology from 0.25% annual increase (%)	Increased production ($000's)	Gross margin[c] ($ per $ of revenue)	Value of clonal propagation/cell manipulation ($000's)
Dairy	1,250,000 t	4250	5,312,500	0.35	5.1	94,828	0.79	74,914
Beef and veal	4,644,000 hd	280	1,300,320	0.35	5.1	23,211	0.90	20,890
Sheep farming								
Lamb	434,000 t	3790	1,644,860	0.35	5.1	29,361		
Mutton	113,000 t	2000	226,000	0.35	5.1	4,034		
Wool	173,000 t	5510	953,230	0.35	5.1	17,015		
Total sheep farming			2,824,090			50,410	0.70	35,287
Total pastoral production			9,436,910			168,449		131,091

[a] MAF (2004c). Figures are from 2003 because some 2004 figures in the report are estimates.

[b] For Dairy, this is the 2003/04 payout of $4.25 per kg. For Beef and veal, this is farm income per head of overwintered cattle (Burtt, 2004). For Lamb, Mutton and Wool, prices are average baseline prices (MAF, 2004c).

[c] Burtt, (2004).For Dairy and Beef and veal, gross margin is adjusted to account for the cost of winter feed. Sheep farming gross margins are the weighted average of three budgets (Burtt, 2004). Merino sheep numbers taken from Greer (2005).

4.3.1.6 Summary: Clonal propagation/cell manipulation

This specific biotechnology is the most widely used of the four biotechnologies examined in this report. For decades, it has been used in plant research and breeding. Our approach here has been to examine the scientific and economic literature and combine those findings with information from key informants to estimate the current impact on the primary sector.

Because the technology has been in use for many years and is so widely used – that is, it is a good example of a horizontal enabling technology – the impacts are quite large compared to the other biotechnologies. The findings from each subsector are summarised in Table 4.10. The total contribution of clonal propagation/cell manipulation to the primary sector is estimated to be $189,282,000.

Table 4.10 Summary of economic contributions of clonal propagation/cell manipulation

Subsector	Value of clonal propagation/cell manipulation ($000's)
Dairy	74,914
Beef and veal	20,890
Sheep (meat and wool)	35,287
Forestry	16,976
Horticulture and floriculture	32,995
Arable crops	8,220
Seafood	nil
Total	189,282

4.3.2 Direct impacts: Biocontrol agents

This research identified several specific biocontrol agents in use in New Zealand. They affect or have the potential to affect production across the land-based primary sector. Innovations in this category of biotechnology were assessed on a case-by-case basis. Each of the specific examples identified is discussed in turn below.

4.3.2.1 BVDV vaccines

Bovine virus diarrhoea virus (BVDV) is a disease known to be present in New Zealand cattle herds, but whose exact impacts are uncertain. The potential effects of BVDV are known: abortions, poor foetal development, and failure to thrive. It is also understood that some three-quarters of cattle in New Zealand have been exposed. However, what is uncertain is the number of exposed cattle that have experienced symptoms, and what economic losses are being sustained as a result. Overseas research estimates economic impacts in other national herds of anywhere from less than US$2 million to as high as US$57 million per million calvings, with most estimates falling in the range of US$10 million to US$40 million and clustered in the low end of that range (Houe, 2003). New Zealand research suggests that the value of lost production could be NZ$60 million (Sanderson & Leung-Wai, 2005).

The increased gross margins to New Zealand beef and dairy farmers were estimated to be $772,000 and $2,523,000 respectively, net of control costs, for a total of $3,295,000. This estimate relies on commercially sensitive information from key informants, so the calculations are not included in the main report. These estimates are based on beef and dairy herd estimates from MAF (SONZAF 2004), loss per million calvings of $10 million (Houe, 2003), a NZ$/US$ exchange rate of 0.70, and a combined gross margin of 0.81 for beef and dairy farms.

4.3.2.2 Trichoderma products

Trichoderma is a beneficial, naturally occurring fungus. It has two basic modes of operation; as a bio-fertiliser and/or as a bio-fungicide. In the first mode the Trichoderma fungus stimulates microbial activity around a plants root system, which has a positive effect on plant growth. In the second mode, as a bio-fungicide, Trichoderma protects the roots from harmful deceases by stimulating protective chemicals on the root surface.

Table 4.11 Benefits from the use of Trichoderma[a]

Crop	Application	Benefit
Beetroot	Trichopel R applied into the furrow of at seeding	69% increase in net yield
Propagation media	Trichodry in a series of replicated pots sown with Pea seeds	48% control of Pythium compared to 16% in untreated media
Tomato plants in glasshouse	Trichoflow treatment in entire glasshouse	Increased yield by 103% compared to control and 69% compared to alternative treatment
Grapevine	Nursery grown vines treated with Trichoprotection products	Bacteria present in roots and rootstock decreased by 32-36% Fungal present in the roots decreased by 29% Black goo fungi decreased by 40% Mean root mass increased by 42%
Turf	Trichopel-Turf raked into the surface layer of the seed-bed	Significant decrease in mean disease scores

[a] Source: Agrimm Technologies Limited.

Several products based on Trichoderma have been developed. They have been successfully applied on many different crops; field crops as well as for indoor crops. Table 4.11 above indicates some benefits from the use of Trichoderma.

Although the Trichoderma range of products has proved to be effective in a number of crops, the uptake appears limited. Information collected in the present research suggested that the economic contribution of Trichoderma products to the New Zealand primary sector is below the level of materiality. This value is approximate, because information on exact impacts on the different cropping systems using Trichoderma products were unavailable.

4.3.2.3 ToxoVax

AgVax was formed to commercialise vaccines developed by AgResearch. They have three main products: AndroVax, CampyVax, and ToxoVax. This research estimated the economic contribution of one vaccine, ToxoVax. Estimates of the value of the other two main products are not provided here. AndroVax increases ewe fertility and lambing percentages. Because it is a fertility regulator and not an agent that controls a disease or pest, it is not included in the estimates calculated here. CampyVax is a vaccine against *Campylobacter fetus fetus*, which is considered the leading bacterial cause of abortions in sheep in New Zealand (Fenwick et al., 2000). From the literature, the overall extent of losses due to this organism is unclear; for example, estimates of the number of ovine abortion per year or the per cent of abortions that were bacterial in origin were unavailable. Significantly, Orr (1996) reported that '[s]heep in New Zealand are remarkably disease free' (p. 105). It is also of importance to this valuation of the impact of biotechnology that an earlier vaccine had been available in New Zealand since 1980 (Fenwick et al., 2000), and it would have been the result of older technology. The contribution of CampyVax is thus the difference between control provided by the earlier vaccine (the counterfactual situation) and the improved control that CampyVax seems to offer. The information necessary to calculate the economic contribution of this difference was unavailable, but the presence of an alternative, though less effective, vaccine suggested that the contribution of biotechnology in this instance was fairly low.

Key informants at AgVax were very obliging and provided very useful information on the effects of ToxoVax and the history of its development. The company's Website notes that field trials show an average national increase in lambing of three per cent for vaccinated flocks. The key informants estimate that a large percentage of replacement ewes are vaccinated with ToxoVax. The financial information provided was analysed for consistency with secondary data sources and then used to estimate the contribution that ToxoVax makes to the primary sector. Using financial information from Burtt (2004) and the information from AgVax, both from key informants and the company's Website, the vaccine is estimated to contribute $33,372,000 annually to sheep farmers' gross margins after costs.

4.3.2.4 Ballance

The Ballance Bioshield Grassgrub uses natural soil bacteria to break the population growth cycle for grass grubs. It was developed in a joint venture between Ballance Agri-Nutrients and Celentis.

The product eliminates the need to use chemical pesticides. The product is drilled into the soil, which costs $70-$100 per hectare. Chemical spray methods have an application cost of $70 per hectare. The control agent is active in the soil for up to five years, during which time it introduces bacteria that interfere with the life cycle of grass grubs by causing the grub to stop eating.

The technology has been on the market for ten years (previously under the name Invade) and is currently applied on 2000-3000 hectares per year.

Information on the economic costs and benefits of Bioshield was unavailable for this research. In addition, secondary sources were insufficient to be used for estimations. This product is thus noted as an example of biotechnology but no value for it was estimated.

4.3.2.5 Bt

The bacterium *Bacillus thuringiensis* (Bt) attacks agriculturally important pests, with different subspecies targeting different families of insects. Commercial preparations of Bt are particularly important in integrated pest management (IPM) systems, for organic agriculture, and in MAF's eradication programmes for several exotic moths. Bt products are widely available and commonly used in New Zealand and overseas.

The value of Bt products derives from essentially two sources: in the first place, they allow agricultural production without use of chemical pesticides. This may allow producers to achieve a premium price in the market, such as a premium price for organic produce. The second source of value is the damage to production that is avoided by using the product. In New Zealand's case, this includes the agricultural production that may be saved because MAF's eradication programmes prevent exotic pests from establishing themselves here.

By far, the largest user of Bt in New Zealand is MAF. MAF's own economic impact assessments of the eradication programmes indicate that the value of production that has been saved up to the present by using Bt is quite small. The population models that underlie MAF's reports have very small growths in pest populations in the first years of infestation. It is not until several years after the first appearance of pest species that they begin to have economically significant populations. In addition, the different exotic insects have different impacts on horticulture and forestry. New Zealand forests are not particularly good hosts for several exotic species, so potential economic damages are limited. Some horticultural crops are good hosts to some species, but account for only a percentage of total damages. The net result is that the value of currently avoided damages through the use of Bt is rather small, in the hundreds of thousands of dollars. It should be emphasised, however, that this use of MAF's economic impact assessment does not in any way address the calculations of present value of future damages. Such calculations are outside the scope of the present research.

The rest of the Bt use in New Zealand can be attributed to the organic and IPM producers, who use it throughout horticultural production. Data on its use and impact are unavailable, however. The specific impacts are related to the target insect pests and the crops on which Bt is used, so that its impacts need to be assessed on a crop-by-crop basis over several years. Furthermore, its net impact for organic and IPM producers is related to the potential premium that producers received as well as the cost structure of organic production. This net impact thus also needs to be assessed in the context of both prices and total production costs; unfortunately, data were not available to do this. The economic impact of Bt use in organic agriculture was also deemed economically immaterial in the context of this report because of the relatively small size of the organic sector and the fraction of that production that could be attributed to Bt.

In sum, while Bt is likely to be important both in particular cases and as a preventative measure, its current contribution to New Zealand primary production is likely to be less than one million dollars in total.

4.3.2.6 Ryegrass endophytes

Endophytes are fungi that live within ryegrass plants. Wild-type endophytes that occur naturally in New Zealand pastures have been shown to have harmful effects on grazing animals. The most significant of these effects is the condition called ‘ryegrass staggers’.

As a result of research on the connection between endophytes and ryegrass staggers, AgResearch identified alternative beneficial endophytes and developed technology for inoculating ryegrass cultivars with this novel endophyte. Seed companies currently use this technology to produce AR1 lines of pasture seeds, which now accounts for a significant portion of their seed sales. In the three years since commercial release of this endophyte, annual sales have gone from 800 tonnes to 2,000 tonnes of seed.

Key informants provided good information about the impact of the AR1 endophyte on pastoral production in New Zealand. Although specific estimates varied, the novel endophyte increases production by about $200 per hectare on sheep farms and by $200 to $400 on dairy farms, with the lower figure the more consistent estimate. The increased cost of the seed is about $25 per hectare and a single planting lasts five to ten years. The seed is sown at 20 kg per hectare, so the amount of pasture sown to AR1 ryegrass is 200,000 hectares. Using these figures, Table 4.12 calculates the increased production in dairy and sheep production and the impacts on gross margins. For this calculation, the counterfactual situation was the absence of improved endophytes and the presence of wild-type endophytes. The entire amount of the increased production was thus attributed to this biotechnology. In total, AR1 endophyte seeds are estimated to increase farmers’ gross margins by $25,351,000.

Table 4.12 Economic contribution of AR1 novel endophyte to pastoral production

Product	Revenue[a] ($000's)	Number of AR1 hectares[b]	Impact of AR1 ($/hectare)	Increased production ($000's)	Gross margin[a] ($ per $ of revenue)	Cost of AR1 seed at $25/hectare ($000's)	Value of AR1 ($000's)[c]
Dairy	5,312,500	130,600	$200	26,120	0.79	3,265	17,370
Sheep farming	2,824,090	69,400	$200	13,880	0.70	1,735	7,981
Total	8,136,590	200,000		40,000			25,351

[a] See Table 4.9 for calculations and sources.

[b] AR1 hectares are apportioned to the two subsectors as a function of their revenue.

[c] Value of AR1 is equal to (Increased production * Gross margin) – Cost of AR1 seed.

4.3.2.7 Summary: Biocontrol agents

This review of biocontrol agents in the primary sector has examined the economic impact of several specific products, all of which have impacts on more than one subsector. Interviews with key informant and research on the economic impacts of these biocontrol agents indicate that these estimates include the economically significant examples of biocontrol agents in New Zealand. Given the constraints of time and information, this research did not estimate specific economic impacts for every product identified, but their impacts do not rise to the level of materiality.

Table 4.13 Summary of economic contributions of biocontrol agents

Subsector	Value of biocontrol agents ($000’s)
Dairy	19,893
Beef and veal	772
Sheep (meat and wool)	41,353
Forestry	nil
Horticulture and floriculture	small value
Arable crops	nil
Seafood	nil
Total	62,018

4.3.3 Direct impacts: Enzyme manipulation

Enzyme manipulation has wide use in food processing, turning products from the farm and sea into the products on supermarket shelves. They have much less use, however, in getting products to the farmgate. Most enzyme use was thus excluded by the focus of this project on the primary sector. There may be significant benefits from this technology but their assessment was beyond scope of the project.

This research examined enzyme manipulation in three areas: a product that inhibits nitrification by enzymes in pastures, enzymes in wine production and enzyme use in producing dairy products. The use of enzyme manipulation for these products will be discussed in turn.

4.3.3.1 Eco-n

Dicyandiamide (DCD) is a nitrification inhibitor that slows down the conversion of ammonium to nitrate. It is marketed in New Zealand as ‘eco-n’ by Ravensdown and under a different product name by Ballance. DCD reduces the leaching of nitrates from grazed pastures and also significantly increases pasture production by improving soil nutrient cycles in grazed dairy pastures. Eco-n is a joint development project between Lincoln University and Ravensdown.

Eco-n is applied as a suspension spray in April-May and again in August-September. This covers the periods when most soil drainage (leaching) occurs. Trial results show that eco-n can give a 60 per cent reduction in nitrate leaching, 50 per cent reduction in potassium, calcium and magnesium leaching, and 75 per cent reduction in greenhouse gas emission (nitrous oxide), in addition to a 15 per cent increase in pasture production (Cameron, Di, Moir, Christie, & Pellow, 2005; Di & Cameron, 2004; Ravensdown).

Cameron et al. (2005) provided the following figures which indicate the economic benefits of eco-n application on grazed dairy pastures.

Table 4.14 Per-hectare benefits of eco-n

	10% increase in pasture production	15% increase in pasture production
Increased pasture production	1300 kgDM/ha/yr	1950 kgDM/ha/yr
Additional milksolids	87 kgMS/ha/yr	130 kgMS/ha/yr
Total Gross return	$347 /ha/yr	$520 /ha/yr
Net return	$223 /ha/yr	$396 /ha/yr

Source: Cameron *et al*. (2005)

The calculations were based on a payout of $4.00 per kilogram of milksolids, a conversion rate of 15 kilograms of drymatter per kilogram of milksolids, and a base production of 13,000 kilograms of drymatter per hectare and year.

Dairy farmers with production of 13,000-15,000 kilograms of drymatter per hectare per year can expect results from eco-n application as detailed in Table 4.14. High input farmers, i.e. around 200 kilograms of nitrogen application per hectare and year, will experience a different result as they probably would not be able to increase drymatter production. Instead, they should be able to apply eco-n, reduce their nitrogen inputs and still experience the same level of production (Ravensdown). Thus, it is prudent to use a ten per cent increase in pasture production as an average increase when calculating the benefits to New Zealand, although most scientific results indicate a 15 per cent average production increase (Cameron et al., 2005).

In the summer of 2004, eco-n was applied to approximately 17,000 hectares. With a net return of $223 per hectare and year, the total net return to the industry is $3,791 million. Information on the DCD product marketed by Ballance was unavailable.

4.3.3.2 Dairy enzymes

This research has not estimated a value for enzyme use in the dairy industry. It was clear that enzymes, including ones improved through biotechnology, are used in processing raw milk into dairy products, such as cheese and cheese flavouring. These products amount to billions of dollars of exports for New Zealand per year.

While it was possible to find information about the products in which enzymes are used and somewhat less information about what those enzymes are, it was not possible to obtain economic information on enzyme use. There was an unwillingness on the part of the dairy industry to demonstrate any economic benefit from improved enzymes or any benefit from research into improved methods of processing. There are naturally-occurring enzymes that can be used to produce dairy foods, so the question of economic interest is the benefit that this industry derives from using the products of biotechnology.

The dairy industry is a good candidate for future research, for several reasons. First, it is an important contributor to New Zealand's primary production and exports. Secondly, there are clear alternative methods of production, some that use biotechnological innovations and others that do not. The assessment of the contribution of these innovations should be relatively straightforward. Thirdly, the dairy sector controls millions of dollars of research spending; some of these funds are privately generated while others are from public sources. Further research would therefore have an interest in assessing the value of publicly funded research.

4.3.3.3 Wine enzymes

Enzymes are used in a number of ways in producing wine. They increase the amount of juice extract from pulp and increase the clarity of the wine, amongst other impacts. Information from a key informant suggested the use of enzymes increase the production of wine from grapes by ten per cent over that which could be achieved without enzymes. Notably, one of the enzymes used in beverage processing is itself a product of biotechnology. This is C-fine, a product of the seafood industry (Boase, 2002, 12 April).

The economic valuation of the impact of enzymes assumed that the impact of enzymes was to increase effective wine grape production by ten per cent without increasing the costs of production. That is, using enzymes was like having ten per cent more grapes to crush from the same acreage, without incurring higher cultivation or harvest costs. The following analysis was based on the estimate of a ten per cent of the value of production.

Table 4.15 Value of enzymes to wine grape production

Grapes crushed[a]	166,000 tonnes
Price of bulk wine grapes[b]	$600 per tonne
Impact of enzymes at 10% of production	$9,960,000

[a] SONZAF 2004

[b] Burtt (2004)

4.3.3.4 Forestry

Enzymes do not appear to have commercial application in the forest and logging business but can be used successfully in the pulp and paper industry. Enzyme technology has the potential to increase the quality and quantity of feedstocks for pulp and paper processes, reduce manufacturing costs, and create high-value products. The technologies can also reduce environmental issues related to the industry.

As the pulp and paper industry is very capital-intensive with facilities specific to the tasks, new technology must have significant benefits or fit easily into the existing manufacturing processes. Although many enzymatic applications have been proposed in the scientific literature, commercialised technologies tend to change existing industrial processes as little as possible. Commercial applications include xylanases in prebleaching kraft pulps and various enzymes in recycling paper.

The decision to use enzyme in the production process depends on process economics, and as of writing this report no such situation exists in New Zealand. Consequently, there exists no current commercial application of enzyme technology in the New Zealand pulp and paper industry. However, it is more than likely that we will see some application within approximately the next five years as some processing facilities will reach capacity limits and most likely will include enzyme applications in their expansion plans.

4.3.3.5 Summary: Enzyme manipulation

The following table presents total results from commercial applications of enzyme manipulation. They do exclude the use of biotechnological enzyme in processing dairy foods.

Table 4.16 Summary of economic contributions of enzyme manipulation

Subsector	Value of enzyme manipulations ($000's)
Dairy	3,791
Beef and veal	nil
Sheep (meat and wool)	nil
Forestry	nil
Horticulture and floriculture	9,960
Arable crops	nil
Seafood	nil
Total	13,751

4.3.4 Direct impacts: Marker assisted selection/breeding

In the course of this research, interviews regarding marker-assisted selection/breeding (MAS) were conducted with people in universities, CRIs, and private firms across all sectors. The general message was that it has led to few commercial products to date. In horticulture, MAS is used in the basic science, but it is not clear that it has led to new commercially-available cultivars. The basic science is still quite new and the cost-benefit ratio of using markers is conditional on the quality of the marker, the kind of trait under investigation and the cost of testing. The same is largely true in arable crops and pasture plant breeding. MAS continues to be of interest, but again not commercial.

One innovation produced through MAS was a field pea cultivar. The biotechnology was used to produce the cultivar and definitely led to an improvement. Sales of the seed overseas are apparently yielding a revenue stream for Crop and Food Research. However, the contribution to the primary sector did not appear large enough to warrant more thorough investigation, given that the exact data were not readily available.

4.3.4.1 Livestock

Two commercial products are available in New Zealand: tests for the Inverdale gene and for the footrot gene. Other markers are scientifically established, but not yet commercially available. The Inverdale gene in the ram leads to more-fertile ewes, thus a benefit in the progeny of rams that have been tested. As the test was commercially released only this year, the primary sector will start to see the benefits after two breeding cycles (one for the more-fertile ewes to be born, and a second cycle in which farmers should see greater production).

The footrot gene-marker test is used for selecting footrot-tolerant sheep to breed. Its use results in a reduction of other input costs, such as vaccinations, antibiotics, foot-paring and foot bathing, which are used for the control and prevention of footrot. As it reduces the use of chemicals, the technology may also benefit New Zealand's 'clean and green' image, as well impact positively on market access issues.

A thorough study by Greer (2005) assesses the benefits to the wool industry from adopting the footrot gene-marker test. The study surveyed all commercial merino and mid-micron farmers, and from that the benefits realised in 2003/04 were calculated at $770,000. The report also provides an estimation of future benefits of between four and 6.3 million dollars.

4.3.4.2 Summary: marker-assisted breeding

Marker assisted breeding and selection has been researched for many years, but is only now producing some commercial products. The only product that is now contributing materially to primary production in New Zealand is the test for the footrot gene marker. The only other commercial product appears to be the test for the Inverdale gene, which should begin yielding commercial value in primary production in a year or so.

Table 4.17 Summary of economic contributions of marker assisted selection

Subsector	Value of marker assisted selection ($000's)
Dairy	nil
Beef and veal	nil
Sheep (meat and wool)	770
Forestry	nil
Horticulture and floriculture	nil
Arable crops	nil
Seafood	nil
Total	770

4.3.5 Summary: Direct impacts of four biotechnologies

This research fully investigated the primary sector in New Zealand to produce a list of the innovations produced using the four biotechnologies that are the subject of this report. Each innovation was examined in detail to determine its exact impacts on production and how production would be different in the absence of the innovation. Some innovations were critical to the modern configuration of the industry, while others boosted productivity without changing productive processes. Those innovations adopted by large industries tended to have large absolute impacts, but were not necessarily the most significant as a percentage of output. Finally, this analysis accounted for the opportunity costs of resources used in production by relying on calculations of farmers' gross margins (where appropriate). Table 4.18 provides a summary of impacts.

Table 4.18 Summary of direct impacts of four biotechnologies

Subsector	Value of clonal propagation/cell manipulation ($000's)	Value of biocontrol agents ($000's)	Value of enzyme manipulations ($000's)	Value of marker assisted selection ($000's)	Total ($000's)
Dairy	74,914	19,893	3,791	nil	98,598
Beef and veal	20,890	772	nil	nil	21,662
Sheep (meat and wool)	35,287	41,353	nil	770	77,410
Forestry	16,976	nil	nil	nil	16,976
Horticulture and floriculture	32,995	small value	9,960	nil	42,955
Arable crops	8,220	nil	nil	nil	8,220
Seafood	nil	nil	nil	nil	0
Total	189,282	62,018	13,751	770	265,821

4.4 Non-marketed benefits

The benefits to the primary sector from using biotechnology are not limited to price and profitability impacts. Some impacts of biotechnology are 'public goods'. This term refers to goods that are non-rival and non-excludable. A good is non-rival if one person's use of them does not diminish another person's use. A good is non-excludable if access to the benefits cannot be limited or rationed. Public goods are not bought or sold in private markets, so the value of these goods cannot be determined by examining prices for the goods and quantities traded.

The basic tasks in researching non-marketed benefits are similar to evaluating direct economic benefits. The first step is to identify the specific impacts and estimate the magnitudes of the impacts. These estimates require the expertise of scientists who can provide information about air, water and soil quality impacts and about biological and ecological effects. After those impacts have been quantified, their value can be determined.

The value of non-marketed benefits can be determined in a number of ways. If there is a good that can serve as a proxy for the non-marketed benefit, then price information on the proxy good can be used. In cases in which the non-marketed benefit can be shown to be bundled with other attributes in a marketed good, then the hedonic pricing method can obtain values for the non-marketed good. This is the case in which lack of air pollution effects housing prices, so that the willingness to pay to avoid air pollution is reflected in a price differential between areas with and without air pollution (Smith & Huang, 1995). For some impacts, cleaner production now averts clean-up costs later. Thus, the value of a benefit now can be measured by later expenditures that are averted. Other benefits, such as recreational values, can be determined by the travel cost method. This valuation method determines willingness to pay for the benefits of recreational amenities by looking at the extra costs that people are willing to incur in order to enjoy them (Devlin, Corbett, & Peebles, 1995). Finally, various survey-based methods, such as contingent valuation and choice modelling, determine the value of non-marketed benefits by examining the stated preferences of survey respondents (Bateman et al., 2002). These methods can be used to calculated values for essentially any impacts that can be sufficiently defined and described.

As an example, the possible ways to measure the value of water resources are shown in Table 4.19. The quality and availability of water resources are affected by agricultural production, and can be affected by the use of biotechnology. The appropriate method for determining the value of water resources depends on which aspect of water resources is being valued. Several studies have estimated values for different types of values and different groups of people, as shown in Table 4.20. These studies have used different techniques to estimate the values for non-marketed benefits. Similar research has been done for air quality to determine the willingness to pay for reductions in particulate matter. Studies using the hedonic method are summarised in Smith & Huang (1995).

Table 4.19 Methods for valuing water resources

Issue	Suggested Method
What is the value of irrigation water to agriculture?	Production function
	Hedonic pricing
What is the value of potable water?	Averting expenditure
	Contingent Valuation
What is the recreational value of surface water?	Travel Cost
	Contingent Valuation

Table 4.20 Previous studies estimating the monetary value of water resources

Author	Method	Type of Value	Existing Estimate[a]
Lynch and Weber, 1992	Contingent Valuation	In-stream Water Values, Ashburton Anglers	$50-$161/household/year (NZ$1991)
Lynch and Weber, 1992	Contingent Valuation	In-stream Water Values, Ashburton Non-anglers	$28-$95/ household/year(NZ$1991)
Lynch and Weber, 1992	Contingent Valuation	In-stream Water Values, Ashburton Non-Ashburton	$15-$63/ household/year(NZ$1991)
Sheppard et al., 1992 ; 1993	Contingent Valuation	Improved Water Quality, Lower Waimakariri River	$93-$133/household/year
Faux and Perry, 1999	Hedonic Pricing	Irrigation Water Value, Malheur County, Oregon	$514-$2551/acre depending on class of land (US$1999)
Torell, Libbin & Miller, 1990	Hedonic Pricing	Irrigation Water Value, Ogallala Aquifer, USA	$9.05 acre/foot (1983 US$)-$1.09 acre/foot (1986 US$)
Kerr, Leathers & Sharp, 1983	Travel Cost	Rakaia River Salmon Angling	$20 angler/visit ($NZ 1983)
Fraser, 1989	Travel Cost	Wanganui River Recreation	$104/person/visit ($NZ 1989)
Sanders, Walsh and Loomis, 1990	Comparison Between Travel Cost and Contingent Valuation	Protection of Rivers Rocky Mountains Colorado	Travel cost: $23 ($US 1990) Contingent Valuation: $21-$24 ($US 1990)

Source: adapted from (Devlin et al., 1995).

[a] These values are current and in national currencies. The values can be converted to New Zealand currency with the relevant exchange rate at the time the original study was conducted. To be strictly comparable, the values should be further adjusted for relative purchasing power across the countries concerned.

To determine the value of non-marketed benefits in the present research, the best practice would be to identify specific impacts of a biotechnological innovation and describe the extent and magnitude of each impact. Depending on the impact, one of the above methods would be chosen as the appropriate method for determining the value of the impact. The value of that specific impact would then be accurately and appropriately measured. That value would then be applied to the impact as measured by scientists working on the specific biotechnological innovation.

For nearly all of the innovations described above, very few data on non-marketed benefits were available. The impacts were insufficiently identified or described, the magnitudes of the impacts had not been measured, and appropriate valuations of those impacts were in any event unavailable. The following discussion describes the potential impacts that should be considered and provides one example of an estimated economic value. However, a full picture of non-marketed values awaits further detailed research.

4.4.1 Non-marketed impacts from biotechnology

The biotechnological innovations reviewed above have changed primary production in one of two ways. Many of the innovations have made production more efficient. They have allowed primary producers to have more output per unit of input. A stark example of this increased efficiency is that '30 million ewes in the national flock now produce the weight of lamb meat each year that 70 million produced in the mid-1980s' (Stringleman, 2005). Another example is the change in harvest index in arable crops. While the biomass of arable crops has remained largely constant, more of that biomass is in the grain and less of it is in the stem. Thus, more grain is harvested per hectare. The other type of change has been a shift to less-toxic methods of production. The use of clonal propagation in potatoes or Bt spray for controlling moth pests has replaced other methods of production or control that were more toxic in the environment or to non-target species.

These general categories of changes have had the potential to have several specific impacts. One such potential impact is that environmental pressures from increased production could be less than they might have been. For example, if per-hectare production had not increased, then more area might have been brought into production, including increasing amounts of environmentally sensitive acreage. These environments could have been degraded, with an overall decline in environmental resilience and sustainability.

A biotechnological innovation might also reduce agricultural chemical use. In the case of potatoes, clonal propagation has allowed the production of pathogen-tested, virus-free potatoes. According to key informants, the alternative methods of production rely on agricultural chemical with high toxicity. Plant breeding in other crops has focused on breeding for resistance to pests and diseases, again reducing the amount of pesticide use. Other innovations may have reduced the need for chemical fertilisers.

The follow-up from such changes could be increased biodiversity. Through both a reduction in chemical pesticide use and changes to biocontrol agents, agricultural production could have reduced impacts on non-target species. These species may thus have been able to continue to survive even while agriculture has controlled pest species.

Finally, air, soil and water pollution might have been reduced due to the use of biotechnology. With fewer hectares in production and more efficient use of water and agriculture chemicals, an innovation would have the potential to reduce pollution.

4.4.2 The value of non-marketed benefits

The value of non-marketed benefit from the biological innovations identified in the present research is uncertain. This uncertainty stems from a lack of information in two areas. First, the specific non-market benefits of the innovations were, in many cases, not specified by key informants. Data that would allow calculation of per-hectare reductions in pollution or measured changes to water quality were generally not available. The second source of uncertainty was the value to assign to specific changes even when they were identified.

Clearly, this is an area of future research. The approach to valuing non-marketed benefits needs to be inter-disciplinary, because it requires the expertise of physical scientists to identify and quantify impacts and the expertise of social scientists to determine the values of the impacts to the general public.

An example of how this research might proceed can be provided here. Lincoln University researchers have analysed the specific impacts of eco-n, a product that Ravensdown has commercialised. They have determined that eco-n leads to a 60 per cent reduction in nitrate leaching, a 50 per cent reduction in potassium, calcium and magnesium leaching, and a 75 per cent reduction in emission of the greenhouse gas nitrous oxide (Cameron et al., 2005). The nitrous oxide emission reduction can be evaluated directly as the carbon dioxide equivalent value in carbon credits. One tonne of nitrous oxide has the global warming potential of 310 tonnes of carbon dioxide (IPCC, 2001). The New Zealand government has decided to cap charges at $25 per tonne of carbon dioxide equivalent (New Zealand Climate Change Office, 2002). Nitrous oxide can thus be valued at $7,750 per tonne. Once the impact of eco-n on emissions from a hectare of pasture is calculated, the dollar value of that emission can be calculated. Reduction in nitrate leaching has two impacts: it increases the availability of nitrogen to the pasture plants and it reduces nitrate pollution of water. The availability of nitrogen, once quantified, can be valued at the equivalent cost of urea fertiliser. Next, the impacts of nitrate leaching need to be described, e.g., impacts on the quality of drinking water and impacts on waterways. The value of these impacts can then be determined by using one or more of the valuation methods described above. The impacts of reduced potassium, calcium and magnesium leaching need to be similarly described and valued. With this information on the specific impacts and the values attached to them, the aggregate impact of eco-n could be determined.

It is unfortunate that data were unavailable that would allow the valuation of non-marketed benefits. Key informants were able to provide general descriptions of the sorts of benefits that biotechnological innovations provide. However, measurements of specific benefits were generally unavailable. Where they were available, the benefits were not necessarily specified in a way that could be easily valued. Finally, data on the potential value of properly specified benefits were largely unobtainable.

4.5 Conclusion

This chapter has presented detailed calculations of the direct costs and benefits of commercialised biotechnological innovations in the primary sector. Through the discussions with key informants, this research was able to identify all innovations of commercial importance that rely on any of the four biotechnologies, clonal propagation/cell manipulation, biocontrol agents, enzyme manipulations and marker-assisted selection. Using primary and secondary data sources, the analysis estimated the direct economic value of each innovation to each subsector of the primary sector.

The total estimated net benefit of these innovations to the primary sector was $266 million per year, assuming constant prices. Clonal propagation/cell manipulation represented the largest contributor to that total, by virtual of its widespread and relatively long-term use. Biocontrol agents had a smaller economic impact, and the impact of enzyme manipulation was smaller still. The least-commercialised biotechnology was marker-assisted selection, with only one innovation currently contributing to the economic performance of the primary sector at a value of less than one million dollars.

The contribution of these biotechnologies to the different subsectors is also apparent in these calculations. Dairy production benefited the most from these innovations, even without calculations of the contributions from enzymes used in dairy processing. This result is not surprising, given that dairy production is the largest of the subsectors. Other pastoral agriculture also benefited, with impacts on sheep production larger than those on beef and veal production. The horticulture subsector showed significant benefits, with some crops heavily reliant on biotechnology and other barely affected. The dollar value of impacts in arable crops was relatively small, but this was a function of the size of the subsector. Finally, impacts were relatively small for forestry as only one of the biotechnologies had commercial application, and they were nil for seafood production.

Additional information related to these estimates is provided in Appendix 3 and Appendix 4. Appendix 3 provides a list of the specific innovations identified in this research, with a brief description of each. Appendix 4 provides additional calculations of the economic impacts of biotechnology. This research found that some innovations have had a range of impacts. In this chapter, those ranges are reduced to point estimates. Appendix 4 calculates the impacts based on the ranges identified.

Estimates of the non-economic impacts were not possible. This research found that non-economic benefits have in general not been specified or measured. While there were suggestions in the literature and in discussions with key informants about possible non-economic benefits, such as environmental improvements, there is essentially no information about the exact impacts. Without this information, there can be no measurement of the value of these possible impacts. If non-economic benefits are considered an important contribution of biotechnology, then this is clearly a significant gap in the research.

In addition to providing the above dollar estimates, this research has developed and demonstrated a robust method for identifying innovations and determining their economic contribution. This method can be applied in future research examining the impacts of other biotechnologies or the contributions to other parts of the economy, resulting in directly comparable value estimates.

Chapter 5
Trade Impacts of Biotechnologies

5.1 Introduction

The above estimate of the direct economic impacts of four biotechnologies contains an important assumption. It was assumed for that analysis that the changes in production had no impact on farmgate prices. Biotechnology was shown to increase the production of several important commodities, but no adjustment was made for possible price impacts. This chapter estimates those price impacts.

This trade modelling is an important contribution to the literature on biotechnology. Most research on the trade impacts of biotechnology has had to rely on *ad hoc* assumptions regarding productivity impact due to lack of data. The present research has estimated actual productivity impacts of commercialised biotechnology products. These impacts are then incorporated into a model of international trade. This analysis of trade impacts thus has a stronger factual basis than prior research.

5.2 Theory

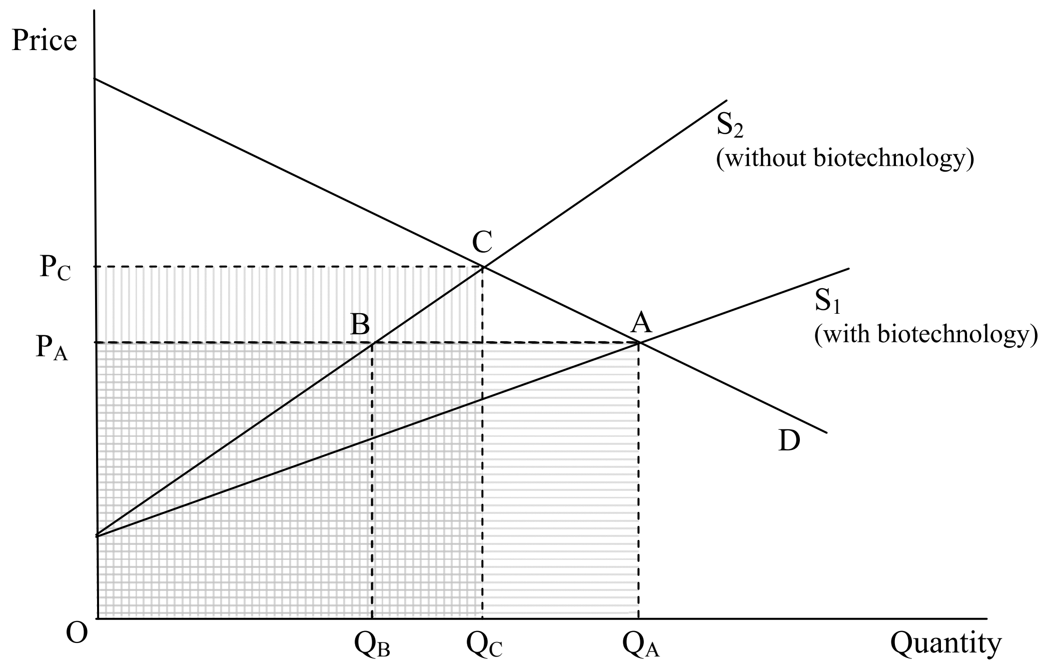
Economic theory explains the relationship between market prices and quantities produced. For those commodities considered 'normal' goods, an increase in the amount produced leads to a reduction of the market price, assuming that preferences for the commodity are unchanged[1]. An important empirical question for this research is whether the increased quantities from New Zealand's primary sector are sufficient to produce a price change. If the quantity that New Zealand produces is small in relation to the world market, then New Zealand is a 'price taker' – it can sell as much or as little as it produces without the market price changing. On the other hand, if New Zealand is a significant producer in relation to the world market, changes in New Zealand production could affect the market price.

The effects of a change in productivity on revenue in New Zealand's primary sector are shown in Figure 5.1. In this figure, the line S_1 indicates current production using biotechnology. The line S_2 indicates production in the absence of biotechnology. This is a backward shift or a shift to the left for the supply line, because production would be more expensive without biotechnology. Demand is indicated by the line *D*. The intersection of S_1 and *D* at point *A* indicates the present market situation, with price P_A and quantity Q_A. Point *B* is the intersection of a price level at P_A and line S_2, production without biotechnology. The economic impact calculated in Chapter 4 assumed a constant price at P_A but an increase in production from Q_B to Q_A. Implicitly, this assumed that New Zealand could not affect international prices. An increase in productivity would therefore inevitably lead to an increase in producer returns.

The results modelled in this chapter are based on a different assumption, which is that New Zealand may be able to affect world prices. A model of international trade was used to model

[1] This study assumes that preferences for the products of the primary sector are unaffected by the use of biotechnology. The innovations identified in this research did not appear to affect consumers' preferences or willingness to pay. Previous research has demonstrated that effects on consumer preferences are an important consideration when evaluating the potential commercial impacts of certain types of biotechnology (Kaye-Blake, Saunders, & Fairweather, 2004; Saunders & Cagatay, 2003; Saunders, Kaye-Blake, & Cagatay, 2003).

Figure 5.1 Impacts of change in productivity



the market situation represented by the intersection of line S_2 and line D at point C. This modelling recognised that changes in the quantity produced and exported can affect prices of primary products. The price level would not be expected to remain at P_A, but would be expected to find a new equilibrium, represented by P_C. The net contribution of biotechnology is the difference in areas of the rectangles $P_A\ A\ Q_A O$ and $P_C\ C\ Q_C O$. Each of these rectangles indicates total revenue to the primary sector, either with biotechnology ($P_A\ A\ Q_A O$) or without ($P_C\ C\ Q_C O$). The difference can be expressed in percentage terms and combined with Chapter 4 calculations to produce a price-adjusted estimate of the impacts of biotechnology. An important consideration with the price-adjusted estimate is that the impact of biotechnology could theoretically be either positive or negative.

Economists distinguish between elastic and inelastic demand for goods. The price elasticity of demand is a measure of the percentage change in price expected from a percentage change in marketed quantities. If demand for a good is price elastic, then a change in the quantity produced leads to a comparatively small change in price. If demand is price-inelastic, then the price change is comparatively large. In general, demand for agricultural commodities is price-inelastic: increasing the quantity supplied has a relatively large impact on the market price. The aggregate impact from increasing the supply of a price-inelastic good is a reduction in total revenues (price multiplied by quantity). This characteristic of some goods has important implications for the New Zealand primary sector, because it means that an increase in productivity can actually cause producer returns to fall.

The basic facts about New Zealand's primary sector suggest that international price impacts need to be analysed. New Zealand is an open economy, so the shifts in international commodity prices are transmitted directly to the farmgate (Kaye-Blake et al., 2003; Ministry of Agriculture and Forestry (MAF), 2004c). Much of New Zealand's primary production is exported, again suggesting that international commodity prices are significant for farmgate prices. Finally, New Zealand represents a significant portion of world trade in some agricultural commodities, so that exporters of those commodities tend to face markets that are relatively price-inelastic. To summarise, the New Zealand primary sector depends to a large extent on exports of price-inelastic commodity products and has little buffer from international price changes. An analysis of trade impacts is therefore important.

5.3 Literature review

There have been several reviews of the literature on biotechnology and international trade, including those in Campbell, et al. (2000); Kaye-Blake, et al (2003); Kaye-Blake & Saunders (2003); Saunders & Cagatay (2003); and Stone, et al. (2002). Trade analyses and these reviews have focused largely on genetically modified crops, and in particular on specific crops rather than the value of the underlying horizontal enabling biotechnologies. They are valuable to the extent that they review findings regarding impacts of productivity gains and consumer willingness to pay for enhanced agricultural products. They also provide indications of robust methodologies for estimating trade impacts.

Trade analysis has found that changes to agricultural productivity have quite different impacts to changes in consumer demand for primary products. Increasing productivity results in greater total social welfare, split between innovators, consumers, and producers. Innovators generally capture significant returns through appropriate licensing and pricing of biotechnological innovations. Consumers usually benefit from increased production: they have more food, fibre, and wood for lower prices. There are exceptions to this generalisation that arise from consumer reactions to genetic modification, but these exceptions are not germane to this research. Producers may or may not benefit from technology that increases agricultural efficiency. The exact impacts depend on the type of technology, its cost, and the final price level after adoption of the technology. By contrast, innovations that create primary products with enhanced consumer-oriented qualities lead to benefits across the board. Innovators can capture returns from the premium products, consumers gain by having better products, and producers benefit from higher prices.

One method for analysing trade impacts is to use a partial equilibrium (PE) model. PE frameworks are ideal for quantifying the effects of changes in agricultural production. This is due to a number of factors, including the level of commodity disaggregation, the ease of traceability of interactions, the transparency of the results, the relatively small size of the models, and the low number of behavioural parameters and the methods used to obtain those parameters (Francois & Hall, 1997; Gaisford & Kerr, 2000; Roningen, 1997; van Beers & van den Bergh, 1996). An extensive programme of trade analysis for New Zealand has been conducted with the Lincoln Trade and Environment Model (LTEM). The LTEM was initially used to simulate various scenarios relating to adoption of GM crops in NZ, including reduced costs of production, premiums for and against GM and bans for GM products in key markets Japan and the EU (Saunders & Cagatay, 2001, 2003). Further modelling work has found that for biotechnology to have positive impacts on revenues to the primary sector, New Zealand must be able to keep productivity benefits for itself and/or the GM product must attract a higher price in world markets (Saunders et al., 2003).

Another method for analysing trade impacts is to use a computable general equilibrium (CGE) model. These models, which can be much larger and more complex, quantify linkages between different parts of the economy. An international trade model would do this for all the sectors and countries in the model. There have been some CGE modelling activities in the Australian context that have relevance to New Zealand. A Productivity Commission Report (Stone et al., 2002) used the GTAP (Global Trade Analysis Project) model to examine potential impacts of GM technology on Australia’s trade in non-wheat grains and oilseeds. The results of the three scenarios in this report demonstrated that very small absolute changes would occur in Australia's import and export flows. Rather, regions with currently significant GM sectors (such as North America) received the most substantial impacts to trade and income. An assumptions critical to their findings is that incompletely-adopting countries (Australia, New Zealand, the EU) have an added regulatory burden that increases supply costs, whereas North America does not. In the present research, the innovations identified have not created any additional regulatory burden on the products of the primary sector. The negative impacts modelled in the Productivity Commission report are therefore not of concern to the present research. Those prior results thus suggest that the price impacts from the biotechnology innovations identified in the present research should be quite small.

For the present research, the preferred method of analysis is a PE model. The ability to considered commodities at a very disaggregated level is a key consideration for modelling the impacts of the biotechnologies in this report. Furthermore, the relative ease and transparency of the modelling make the final impacts easy to understand and interpret. Linkages beyond the agricultural sector are quantified in supplemental ways, with the cost benefit analysis in Chapter 4 and the macro-economic analysis in Chapter 6.

5.4 The trade model

The trade modelling framework is the Lincoln Trade and Environment Model (LTEM); an agricultural multi-country, multi-commodity trade model that uses a PE framework to analyse the impact of changes in agricultural productivity and domestic agricultural and trade policies. The model is based on VORSIM, which evolved from SWOPSIM and its associated trade-database used to conduct analyses during the Uruguay Round of General Agreement on Trade and Tariffs (GATT) negotiations (Roningen, 1986; Roningen, Dixit, Sullivan, & Hart, 1991). It has been used to analyse trade policies, climate change policies, and markets for organically grown, genetically modified, or otherwise differentiated products.

The LTEM embodies all the advantages of PE trade models. An additional strength of the LTEM is its explicit modelling of the dairy sector at a disaggregated level. Because dairy markets are under the influence of various domestic and border policies, explicit modelling of supply and demand behaviour is essential in order to quantify the impacts of productivity changes.

The LTEM includes 19 agricultural commodities (seven crop and 12 livestock products) and 17 countries. The linkages of the agricultural sector with other industries and factor markets are not considered. The commodities included in the model are treated as homogeneous with respect to the country of origin and destination, and with respect to the physical characteristics of the product. Therefore commodities are assumed to be perfect substitutes in consumption in international markets. Importers and exporters are assumed to be indifferent about their trade partners. The nature of the innovations identified and described in Chapter 4 suggests that assuming homogenous products is generally appropriate. The primary products that had quality enhancements through biotechnology are not commodities included in the LTEM.

The LTEM is a synthetic model whose parameters are adopted from the relevant literature. Interdependencies between primary and processed products and/or between substitute/ complementary products are reflected by cross-price elasticities. The model is then used to quantify the price, supply, demand and net trade effects of various policy changes. The model is used to derive the medium- to long-term policy impact in a comparative static fashion. The base year the model works from is 2000. The present research models impacts up to 2005 to determine present price effects.

In the general LTEM framework, there are seven endogenous variables in the structural-form of the equation set for a commodity under each country, made up of six behavioural equations and one economic identity. There are four exogenously determined variables, but the number of exogenous variables in the structural-form equation set for a commodity varies based on cross-price and cross-commodity relationships. The behavioural equations are: (i) domestic supply, (ii) demand, (iii) stocks, (iv) domestic producer price, (v) consumer price, and (vi) trade price. The economic identity is a net trade equation, which is equal to excess supply or demand in the domestic economy. For some products, the number of behavioural equations may change as the total demand is disaggregated into food, feed, and processing industry demand. This is determined endogenously. The equations in the LTEM are presented in Appendix 5.

The results from the quantitative analysis of data from the interviews conducted in the course of this research serve as inputs to the model. They are used to generate estimates of the trade impacts of the biotechnological innovations. The equations and variables in the model are described in an appendix to this report. The next section discusses the model inputs generated for the present analysis.

5.5 Model inputs

The LTEM is used to model different scenarios in the primary sector in New Zealand. These scenarios are described with key inputs, whose values are modified to reflect different situations in the primary sector. The key inputs into the trade model are: the uptake rates of new technologies, the productivity impacts, and the willingness to pay for the products of the primary sector. These are each discussed in turn.

5.5.1 Uptake of biotechnology

One of the major factors affecting the aggregate impacts of an innovation on the primary sector is the proportion of producers who have adopted it. Adoption rates or portion of production using specific biotechnologies were detailed in Chapter 4. Adoption rates were not uniform across innovations or across subsectors. This variability in adoption rates creates difficulties in defining an overall adoption rate for biotechnology.

In the LTEM, the commodities produced are assumed to be homogenous. As a result, it is possible to express the aggregate impact of a biotechnology as a percentage of production. In effect, the increases in production detailed in Chapter 4 are summed and a single shift in production is modelled for each commodity. Because of commodity homogeneity, the production impact is the same regardless of whether they are modelled as technology uptake by specific producers or simple commodity-wide productivity shifts.

This method of modelling biotechnology's impacts does not address the issue of uneven gains in the primary sector from uneven adoption of innovations. However, it would be relatively straightforward to extend the analysis in future research to include these effects.

5.5.2 Productivity increase

The effects of biotechnology on the productivity of the primary sector are simulated with three alternative scenarios. The first scenario is the base case, primary production as it currently happens. This is modelled by using the base data for 2000 and modelling expected production up to 2005. No shifts in productivity are modelled in the first scenario.

The other two scenarios model production in New Zealand in the absence of the biotechnological innovations described in Chapter 4. This absence is modelled as a reduction in primary sector productivity, proportional to the direct impacts quantified above. That is, productivity without biotechnology (S_2 in Figure 5.1) would be less than productivity with biotechnology (S_1 in Figure 5.1). The results from Chapter 4 provided an estimate of the reduction in productivity. The exact production shifts are given in Table 5.1. In this table, the negative signs indicate that production would be lower without biotechnology; this is equivalent to saying that biotechnology has increased production. Demand and supply equations in the LTEM are assumed to have constant elasticity functional form and exogenous shocks to this model arising from biotechnology are assumed to shift demand and supply by a constant percentage of price for all levels of production; in other words, pivotal shifts are assumed. These are similar to the shifts described in Frisvold et al. (2003) in their work on returns to technological advancements.

The two alternative scenarios have one key difference. For the first one, the innovations are removed from the primary sectors of all countries in the model. This scenario examines the impact of an absence of biotechnology with the assumption that all countries have benefited equally from these innovations. For the second scenario, several of the innovations are removed from the primary sector only in New Zealand. This scenario is considered because of the New Zealand-specific application of some innovations. For example, the AR1 endophyte has been extensively adopted in New Zealand, but less extensively adopted elsewhere.

Table 5.1 Trade model scenario inputs

Trade commodity	Change in productivity	Scenario 1 Production systems affected	Scenario 2 Production systems affected
Wheat	- 5.1%	All countries	All countries
Coarse grains	- 5.1%	All countries	All countries
Beef, veal	- 1.9%	All pastoral	NZ only
Sheepmeat	- 3.9%	All pastoral	NZ only
Wool	- 3.9%	All pastoral	NZ only
Milk, raw	- 2.3%	All pastoral	NZ only
Apples	nil	n/a	n/a
Kiwifruit	nil	n/a	n/a

Detailed modelling of the dairy complex is a key strength of the LTEM. In particular, the model separates production into extensive (e.g., pastoral) systems and intensive (e.g., feedlot) systems. This is an important distinction when modelling biotechnological innovations, because several innovations affected only pastoral systems. Feedlot production would not be improved by innovations in pasture quality. In order to reflect the differences among raw milk physical production systems in terms of the differences in nitrogen fertilizer and feed concentrates use, the countries Australia, EU, New Zealand and USA were separated into three regions and supply responses in these regions were modelled explicitly.

The major dairy producing trading blocs were each sub-divided into regions (defined as in Table 5.2) to better reflect internal heterogeneity with respect to dairy production systems and environmental conditions. These divisions were based on observed variation in, for example, yields, stocking rates and drainage characteristics as well as the nitrogen fertilizer and feed concentrate use. The divisions are incorporated into the LTEM through the regional domestic raw milk supply equations. Data on production systems were taken from a number of sources, including farm advisory recommendations, census and survey reports, and field trials.

Table 5.2 Heterogeneity in the dairy production system amongst regions

Region	Production per cow (litres)	Average stocking rate (per ha)	Area (000ha)
EU (15) :			
West EU	5310	2.4	3174.8
East EU	4680	1.8	6639.6
Other EU	4991	2.3	3302.2
Australia:			
Victoria	4715	1.0	1267.9
NSW	4972	0.5	504.0
Rest of Australia	4608	0.5	1046.0
USA:	7238		
California	8439	10.0	149.2
WI, MI, MN, PA, NY	7182	3.0	1251.2
Rest of USA	6770	2.7	1727.8
New Zealand:			
Auckland	3278	2.8	494.6
South Island	3874	2.6	274.8
Rest of NZ	3300	2.0	570.4

5.5.3 Willingness to pay for enhanced products

The LTEM can simulate different willingness to pay for segmented commodity products. For example, an enzyme biotechnology that produces superior meat characteristics should lead to higher export prices for adopting producers. The trade model can incorporate data on the price premium received for the higher-quality meat and determine its impact on the revenues of the adopting producers and the sector as a whole. The modelling of such premiums is similar to the modelling of production impacts.

This capability of the LTEM was not used for the modelling. For several commodities, there were no biotechnological innovations that altered product qualities and led to premium prices. For horticultural products, the interviews with key informants did identify some premium products; however, these products are not included in the LTEM. The main horticultural products in the LTEM, apples and kiwifruit, were not affected by quality-enhancing biotechnologies. Finally, this research did find some evidence of quality improvements in arable crops. Data were not available on the specific changes or their price impacts. Due to lack of data, price premiums could not be modelled for arable crops. Thus, either because there were no enhanced products to model or because data were unavailable, no demand shifts were modelled. This would be an important area for future research, especially once specific quality enhancements could be identified in the primary sector.

5.6 Modelling results

Trade models by their nature produce a range of outputs: consumer and producer prices, quantities produced, quantities traded, and more. The information of importance here is the price change for each commodity as a result of lower production. For each commodity in the model whose production was affected by biotechnology, the difference between the producer price with biotechnology and the producer price in the absence of biotechnology was calculated. These calculations were made for both scenarios. The percentage changes in producer prices are presented in Table 5.3.

Table 5.3 Impacts of productivity shifts

Trade commodity	Change in productivity	Scenario 1 World-wide impacts		Scenario 2 Some NZ-only impacts	
		Change in NZ producer price (%)	Change in NZ producer returns (%)	Change in NZ producer price (%)	Change in NZ producer returns (%)
Wheat	- 5.1%	5.4	3.6	5.5	0.2
Coarse grains	- 5.1%	4.1	1.6	4.3	0.2
Beef, veal	- 1.9%	2.6	0.6	1.0	-2.0
Sheepmeat	- 3.9%	4.6	1.9	1.0	-6.3
Wool	- 3.9%	3.1	-0.6	1.0	-4.1
Milk, raw	- 2.3%	1.8	-1.2	1.1	-1.4

The results in Table 5.3 conform to expectations. Scenario 1 considers the impact of worldwide adoption of biotechnology on the same scale as seen in New Zealand. As the results in Chapter 4 show, if New Zealand producers had not had access to the four biotechnologies, then primary production would currently be lower. When the impact of a worldwide reduction in productivity in the primary sector is modelled, market prices adjust upward in response to the reduction in supply. Trade also adapts to account for the change in productivity. As a result, the net change in producer returns for New Zealand is positive for wheat, coarse grains, beef and veal, and sheepmeat, and negative for wool and dairy.

For Scenario 2, the price impacts are smaller for several commodities, those outside the arable crop subsector. These commodities were modelled as having improvements that applied only to the New Zealand primary sector, so that production in other countries was unaffected. Thus, the absence of biotechnology in New Zealand alone has smaller price impacts on international commodity markets. The net impact on producer returns is essentially nil for wheat and coarse grains and negative for all other commodities.

To calculate the dollar value of net direct impacts, gross impacts from Chapter 4 were adjusted by the changes in producer returns in Table 5.3. The gross margins were then calculated to make the results comparable to those in Chapter 4. Table 5.4 presents the results for Scenario 1, and Table 5.5 presents those for Scenario 2. For these calculations, changes to forestry and horticulture were not included, as they are not included in the trade model.

Table 5.4 Scenario 1: impact of absence of biotechnologies

Subsector	Revenues with biotechnology ($000's)	Change in producer returns (%)	Change in producer returns ($000's)	Gross margin ($ per dollar of revenue)[a]	Net impact of absence of biotechnology ($000's)
Dairy	5,312,500	-1.2	-64,169	0.79	-50,694
Beef and veal	1,300,320	0.6	7,539	0.90	6,785
Sheep (meat and wool) [b]	2,824,090	1.1	29,827	0.70	20,879
Forestry		n/a			n/a
Horticulture and floriculture		n/a			n/a
Arable crops [c]	364,187	2.2	7,856	0.45	3,535
Seafood		n/a			nil
Total					-19,494

[a] Gross margins are taken from various tables in Chapter 4.

[b] The change in producer returns is calculated as the average of the Sheepmeat and Wool impacts in Table 5.3, weighted by the amount of revenue in Lamb, Mutton and Wool in Table 4.8: (1.9% * 1,644,860 + 1.9% * 226,000 + (-0.6%) * 953,230) ÷ 2,824,090 = 1.1%.

[c] Vegetable seeds are not included. The change in producer returns is calculated as the average of the Wheat and Coarse grains change in producer returns in Table 5.3, weighted by the amount of revenue for each arable crop as shown in Table 4.1. The weighted average is equal to 2.2%.

The net, price-adjusted direct economic impact as calculated in Table 5.4 is the reduction in producer returns after variable costs of production that arises from an absence of biotechnologies. This is the reverse view of the situation assessed in Chapter 4. This result suggests that by using the biotechnological innovations identified in this research, and assuming that all other countries had access to the same technology, the New Zealand primary sector had a direct economic benefit of $19 million dollars, excluding forestry and horticulture. By contrast, the direct economic benefit for these subsectors was calculated in Chapter 4 to be $206 million.

Table 5.5 Scenario 2: impact of absence of NZ biotechnologies

Subsector	Revenues with biotechnology ($000's)	Change in producer returns (%)	Change in producer returns ($000's)	Gross margin ($ per dollar of revenue)[a]	Net impact of absence of biotechnology ($000's)
Dairy	5,312,500	-1.4	-73,774	0.79	-58,281
Beef and veal	1,300,320	-2.0	-25,911	0.9	-23,320
Sheep (meat and wool) [b]	2,824,090	-5.5	-156,377	0.7	-109,464
Forestry		n/a			
Horticulture and floriculture		n/a			
Arable crops[c]	364,187	0.2	707	0.45	318
Seafood		n/a			nil
Total					-190,747

[a] Gross margins are taken from various tables in Chapter 4.

[b] The change in producer returns is calculated as the average of the Sheepmeat and Wool impacts in Table 5.3, weighted by the amount of revenue in Lamb, Mutton and Wool in Table 4.8: ((-6.3%) * 1,644,860 + (-6.3%) * 226,000 + (-4.1%) * 953,230) ÷ 2,824,090 = -5.5%.

[c] Vegetable seeds are not included. The change in producer returns is calculated as the average of the Wheat and Coarse grains change in producer returns in Table 5.3, weighted by the amount of revenue for each arable crop as shown in Table 4.1. The weighted average is equal to 0.2%.

The value calculated in Table 5.5 indicates how much lower direct economic impacts in the primary sector would be in the absence of specific biotechnologies. These are New Zealand-specific biotechnologies that increase the productivity of the pasture-based parts of the primary sector. In this scenario, some biotechnologies, such as those in arable crops, were simply not available worldwide. Other biotechnologies were removed only from New Zealand commodity production. These were biotechnological innovations in dairy, meat and wool production. The reduction in direct impacts was $191 million, not including forestry and horticulture. This was very nearly identical to the direct economic benefit for these subsectors in Chapter 4, $206 million.

5.7 Discussion of modelling results

The results from the trade analysis provide important information regarding the impacts of biotechnology. The two scenarios modelled present two different pictures of biotechnology in New Zealand. The first scenario models the primary sector without the innovations identified earlier in this report. Many of these applications of biotechnology, particularly clonal and cell technologies, are widely used. If these biotechnologies had not been developed, then they would not have affected production anywhere in the world. The difference between the world with biotechnology, or the base case, and the world without the identified innovations, is measured by Scenario 1. Considering those sectors that are included in the LTEM, the combination of price and quantity effects, the difference between using and not using biotechnology in New Zealand is $19 million in direct economic impacts.

The second scenario is slightly different. For this modelling, dairy, meat and wool productivity were reduced only in New Zealand (arable crop productivity was reduced for all countries). The second scenario considers a world in which biotechnological innovations with application specifically to New Zealand environments had not been developed. Without these innovations boosting New Zealand production, the primary sector would lose direct economic impacts of $191 million.

The difference between the final figure in Scenario 2, $191 million, and the final figure in Table 4.18, $266 million, stems from two sources. First, only those commodities included in the trade model have trade-adjusted impacts. If forestry and horticulture are removed, the direct impacts in Chapter 4 are $206 million. Secondly, increased production in Chapter 4 assumes that there is no price effect. In the trade analysis, the impact of increased production on world commodity prices is explicitly modelled to determine the net impact on producer returns. For the Beef and veal subsector, the impact in the two different analyses is nearly identical. For the Sheep subsector, the change in the trade analysis is greater than the change in the simple, fixed-price analysis. On the other hand, reducing dairy production in New Zealand does affect world prices in dairy commodities. As a result, the change in the dairy sector is lower in the trade analysis than in the fixed-price analysis. The net effect on the primary sector, taking international price movements into account, is quite small. Individual subsectors do show gains and losses, however.

5.8 Conclusions from trade analysis

The trade analysis demonstrates the net impact of changing productivity. The analysis in the preceding chapter assumed that the price elasticity of demand for agricultural commodities was practically infinite. The New Zealand primary sector was a price-taker on world commodity markets, too small to make a difference. The trade analysis makes some adjustment to this picture. By considering the impact that New Zealand can have on commodity markets, especially in dairy products, it calculated slightly smaller impacts and indicated differences amongst subsectors.

Which of the two trade scenarios more accurately portrays the New Zealand situation is uncertain. Clearly, adopting biotechnology is important. It increases productivity, which either allows New Zealand to have a competitive advantage in certain commodities or keeps the country in line with its rivals. If the former is true, that is, if biotechnology research has produced innovations that preferentially benefit New Zealand, then the contribution of biotechnology is closer to the estimate in Scenario 2. If the latter is true, then the net impact on producer returns of using biotechnology, given that everyone else has adopted it, too, is closer to the estimate in Scenario 1.

Chapter 6
Macroeconomic Impacts of Biotechnologies

6.1 Introduction

Chapters 4 and 5 have estimated the impact on New Zealand's primary sector of the four core biotechnologies considered in this report. This chapter extends that analysis to the macroeconomic level in two steps. First, the chapter considers the contribution of the biotechnologies to the primary sector's recent productivity performance that is recognised as impressive, both compared to the sector's long-term trends and to the performance of other sectors in the economy. Second, the chapter uses the data of Chapters 4 and 5 to calculate indirect and induced impacts of the primary sector effects on the wider macroeconomy.

Two previous analyses have assessed the macroeconomic impacts of biotechnology on the New Zealand economy. The first, submitted to the Royal Commission on Genetic Modification (RCGM) (Stroombergen, 2000), was an economy-wide model of the impacts of GM crops in New Zealand. The consulting firm Infometrics used a computable general equilibrium (CGE) model to simulate the effects of several scenarios. The model essentially calculated the multiplier effects of the given changes but provided little else. Nana (2000) reviewed this RCGM submission and noted that modelling the robustness of the effects or the impacts of closely related scenarios would have provided more useful results.

The other main attempt at macroeconomic analysis was part of a research project for the Ministry for the Environment (MfE) by (Sanderson et al., 2003). The economic research firm Business and Economic Research Limited (BERL) used another CGE model to examine the impact of genetically modified crops on New Zealand. They found that the overall effect on GDP from commercial use of GM organisms in agriculture could be either negative or positive, depending on how consumer reactions affect actual trade and how GM technology affects actual production.

An important lesson from the above research is the importance of accurate and transparent assumptions for modelling. In addition, aggregated macro-economic models are generally insensitive to small-scale changes in primary sector productivity and are insufficiently disaggregated to generate impacts from the biotechnology sectors. With these lessons in mind, the chapter relies on standard multipliers to estimate the macroeconomic impacts of the biotechnology products, which are shown to be relatively small. To provide a context for the multiplier analysis, the following section presents New Zealand Treasury data that highlight the impressive productivity performance of the country's primary sector in the second half of the 1990s.

6.2 Productivity in the Primary Sector

In June 2003, the New Zealand Treasury published a working paper examining productivity in New Zealand between 1988 and 2002 (Black, Guy, & McLellan, 2003). That working paper included analysis at the industry level, noting that important sector trends can be hidden by an aggregate analysis (p. 12, see also Buckle, Haugh, & Thomson, 2001). Their data are presented below in Table 6.1.

Table 6.1 Average multifactor productivity growth by industry

March Years	1988 to 1993 (%)	1993 to 2002 (%)	1988 to 2002 (%)
Primary	-0.52	2.45	1.38
Mining and Quarrying	-1.91	0.72	-0.23
Construction	-4.59	0.25	-1.51
Manufacturing	0.29	-0.16	0.00
Electricity, Gas & Water	1.11	-0.93	-0.21
Transport & Communications	6.75	5.52	5.96
Business & Property Services	-2.54	0.74	-0.44
Personal & Community Services	0.82	1.48	1.24
Retail & Wholesale Trade	-0.38	1.40	0.76
Total	0.09	1.32	0.88

Source: Black, Guy and McLellan (2003), Table 1, p. 8, and Table 4, p. 14.

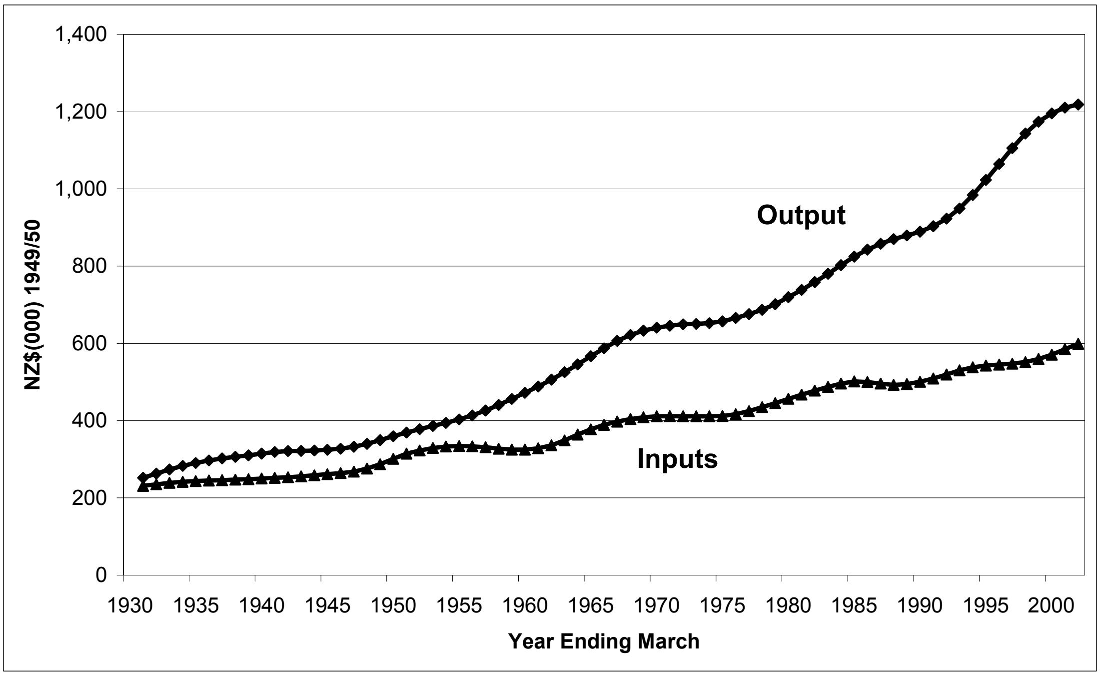
As the Treasury authors observe, 'over the 1988 to 2002 period, the productivity growth of two industries stands out: the Transport, storage and communications industry (average growth of 6.0 per cent per annum) and the Primary industry (average growth of 1.38 per cent per annum)' (Black, et al., 2003, p. 15). In the case of the primary sector, the impressive performance was even more pronounced during the later period of 1993 to 2002, when its annual productivity growth rate of 2.45 per cent was nearly twice as high as the national average (1.32 per cent).

Figure 6.1 and Figure 6.2 on the next page present some preliminary data on long-term trends in the agriculture sector, based on research currently being undertaken within the New Zealand Treasury. We are grateful to Grant Scobie (personal communication, 11 April 2005) for providing these data for this report.

The preliminary dataset contains data for gross agriculture output (defined as gross farming income divided by a farm output price index) from 1926/27 to 2002/03. The last observation showed a very large increase, and so this report has truncated the sample at 2001/02 to avoid this having a disproportionate affect on the Hodrick-Prescott filter used to obtain long-term trends. The dataset also includes a series for the same period on aggregate agriculture inputs, defined as the sum of the farm wage bill, capital services and non-factor inputs. Both series are measured in 1949/50 prices.

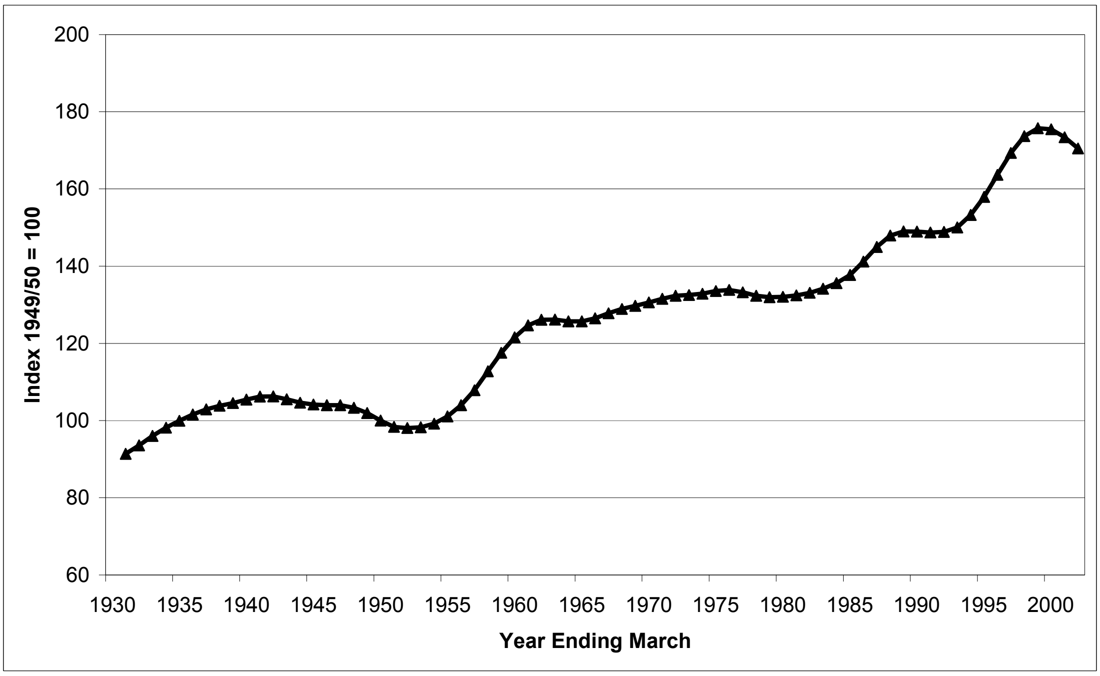
In this study, the authors used the Hodrick-Prescott filter ($\lambda = 7$, as is appropriate for annual data) to obtain long-term trend series for gross output and inputs (Hodrick & Prescott, 1997). These trend series are shown in Figure 6.1. Figure 6.2 shows the implied long-term productivity series, obtained by dividing gross output by inputs, rebased so that 1949/50=100.

Figure 6.1 Trend output and inputs in agriculture, 1929/30 – 2001/02



Source: See text.

Figure 6.2 Trend multifactor productivity in agriculture, 1929/30 – 2001/02



Source: Calculated from Figure 6.2.

Figure 6.2 confirms the impressive productivity growth that took place in agriculture in the second half of the 1990s, comparable to the surge in the late 1950s. This observation would have been further reinforced if the large rise in output recorded for 2002/03 was included in the analysis (so that it is too early to say whether there has been a fall off in trend productivity after the 1998/99 peak shown in Figure 6.2).

Thus the available industry-level productivity data suggest that the primary sector has performed particularly well in recent years, both compared to its long-term trends and to the performance in other sectors of the economy. It is therefore sensible to ask what role biotechnology has played in this recent performance. The value of production calculated for each subsector and presented in Table 1.2, though only representative of the exact output, gives some indication. For example, the dairy output at the farmgate is estimated in Table 1.2 to be $5.3 billion per year. With a gross margin of $0.79 per revenue dollar, the value of total gross margin in dairy is approximately $4.2 billion. The contribution of the four biotechnologies is calculated in Chapter 4 to be $99 million, making the contribution from biotechnology about 2.4 per cent of the gross margin. Similar calculations can be made for beef and veal and for sheep subsectors. They suggest that the contributions of the four biotechnologies to gross margins are 1.9 per cent and 3.9 per cent, respectively. Valuing the contribution of biotechnology to the horticultural subsector generally would be misleading, because it has been key for some crops and relatively unimportant for others. The contribution to forestry would need to be valued in terms of the capital value of all of New Zealand's forests, information that was unavailable for this report. The performance of the arable subsector is directly linked to improvements in plant breeding, which were calculated in Chapter 4 to have led to a 5.1 per cent increase in productivity. Finally, the seafood subsector does not seem to have been affected yet by these biotechnologies.

During the decade 1991/92 to 2001/02, Treasury's preliminary data in Figure 6.1 suggest that trend output in agriculture increased by 14.52 per cent. The contributions of the four biotechnologies to gross margins were no more than about five per cent (leaving aside a few horticultural crops). In this context of the trend output figure, the contributions calculated above suggest that the four biotechnologies considered in this report have played a positive, but not dominant, role in the sector.

6.3 Wider macroeconomic impacts of the direct effects of biotechnology

Chapters 4 and 5 of this report estimated the direct impact of the four biotechnologies on the primary sector. This direct impact is only part of the total contribution to the New Zealand economy; there are also indirect and induced contributions. The three types of impacts are as follows:

1. Direct contributions: the result of direct finance and employment injected into the primary sector by the biotechnology innovations;
2. Indirect contributions: the result of upstream and downstream finance and employment created to service the larger output from the primary sector; and
3. Induced contributions: the result of the above two contributions affecting further household spending, which generates finance and employment such as increases in the purchases of consumption goods and services.

The analysis in this section of the report calculates the indirect and induced contributions to assess the total impact of the biotechnologies on the economy. To estimate the indirect impacts (for both output and employment), it is usual to include two levels of upstream and downstream effects. The first level is from those who supply the primary sector directly. An important element in this first level of impacts is the activity of firms supplying the biotechnological innovations. Ideally this should be estimated from primary data. The second level is the output and employment effect generated by these firms supplying the primary sector directly. The second level includes the economic impacts of the biotechnology firms.

The interviews with key informants did include questions in an attempt to elicit this first level of indirect impact for output/expenditure. Key informants were asked about the inputs to production and how those were affected by innovations. However, data were not generally available so secondary sources of data have been used as described below.

The second level of indirect impact – that is the upstream and downstream expenditure of those firms directly servicing the primary sector – was estimated using secondary sources of data. The secondary sources of data used were the output and value added input/output tables for New Zealand. These tables show the flows in and out of an economy by sector, allowing multipliers to be calculated representing the average upstream and downstream effects by sector, for both output and value added (Butcher, 1999). Finally, the induced impact on output and value added was calculated, again using input/ output tables (Butcher, 1999), and added to the direct and indirect impacts to obtain the total contribution of the biotechnological innovations.

The results of this analysis are presented in subsections 6.3.1 and 6.3.2 based on the assumptions in chapters 4 and 5 respectively.

6.3.1 Constant price analysis

The analysis of Chapter 4 assumed that changes in production had no impact on farmgate prices. The total direct impact of the four biotechnologies on the primary sector was estimated at $265.8 million in current year prices. Table 6.2 presents the multiplied effects of this direct impact as a result of indirect and induced effects as explained above. The total annual contribution of the biotechnologies to the New Zealand macroeconomy under the assumption of no changes in farmgate prices is $453.2 million, with just under two-thirds of this contribution coming from the dairy and sheep subsectors.

Table 6.2 Total annual value-added contribution of the four biotechnologies to the New Zealand economy (current year)

Subsector	Direct impacts ($000's)	Direct + Indirect impacts ($000's)	Direct + Indirect + Induced impacts ($000's)
Dairy	98,598	135,079	167,617
Beef and veal	21,662	30,327	36,392
Sheep (meat and wool)	77,410	110,696	131,597
Forestry	16,976	26,482	29,878
Horticulture	42,955	58,848	73,454
Arable	8,221	12,003	14,305
Total	265,822	373,435	453,243

6.3.2 Trade model analysis

Chapter 5 used the Lincoln Trade and Environment Model (LTEM) to analyse the consequences if changes in productivity led to changes in output prices (see Figure 5.1). The chapter modelled two scenarios. In Scenario 1, it was assumed that the modelled biotechnology innovations were adopted by all countries. In Scenario 2, it was assumed that several of the innovations affected production in New Zealand only. Table 6.3 below presents the calculations associated with Scenario 1, with worldwide absence of the biotechnological innovations. The last row of the table provides the impact without a change in international commodity prices, based on the analysis in chapter 4, *excluding* the impact of forestry and horticulture that were unable to be modelled in chapter 5. Table 6.4 presents the same calculations for Scenario 2. Recall also that Chapter 5 analysed what would happen in the absence of the biotechnologies, so that a minus sign in Tables 6.3 and 6.4 indicates a positive effect of biotechnology.

As would be expected, the total macroeconomic impacts under these assumptions are less than under the assumptions of Chapter 4. The difference is considerable in the case of Scenario 1 (where all countries adopt the biotechnology innovations), reducing the contribution from $349.9 million to $33.1 million. In contrast, if other countries do not adopt the innovations, the effect on New Zealand is relatively small – a drop from $349.9 million to $323.8 million.

Table 6.3 Total annual value-added impact: Scenario 1

Subsector	Direct impacts ($000's)	Direct + Indirect impacts ($000's)	Direct + Indirect + Induced impacts ($000's)
Dairy	-50,694	-69,450	-86,179
Beef and veal	6,785	9,500	11,399
Sheep (meat and wool)	20,879	29,857	35,494
Forestry	n/a	n/a	n/a
Horticulture	n/a	n/a	n/a
Arable	3,535	5,161	6,151
Total	-19,494	-24,933	-33,135
Total at constant prices	-205,891	-288,105	-349,911

Table 6.4 Total annual value-added impact: Scenario 2

Subsector	Direct impacts ($000's)	Direct + Indirect impacts ($000's)	Direct + Indirect + Induced impacts ($000's)
Dairy	-58,281	-79,845	-99,079
Beef and veal	-23,320	-32,648	-39,177
Sheep (meat and wool)	-109,464	-156,533	-186,089
Forestry	n/a	n/a	n/a
Horticulture	n/a	n/a	n/a
Arable	318	464	553
Total	-190,747	-268,562	-323,791
Total at constant prices	-205,891	-288,105	-349,911

6.4 Conclusion

This chapter's macroeconomic analysis relying on multipliers and known flow-on effects has provided a reasonable first estimate of the indirect and induced effects of biotechnology products. Future research could develop a general equilibrium model on the New Zealand economy purpose-built for close examination of the impacts of biotechnological products. In particular, such a model would need a disaggregated agricultural sector and separate sectors for biotechnological research and product development. A large econometric exercise of this type was not possible within the time and resources available for the current project.

The tables in section 6.3 provided estimates of the total macroeconomic impact of the four core biotechnologies ranging from $33.1 million to $453.2 million, depending on assumptions about world trade and the agriculture subsectors included. These figures can be compared to the level of Gross Domestic Product for the year ending March 2004 of $137.8 billion. Thus the largest estimate in this chapter amounts to just under one-third of one per cent of GDP.

The analysis of this chapter contains an important message, however, that should not be overlooked. Comparing the results of Tables 6.3 and 6.4 reveals the large difference that can occur if a biotechnology innovation is not adopted worldwide. This was a frequent comment in interviews for this project: adopting biotechnology innovations in New Zealand has been essential for keeping up with (or ahead of) competing producers in the rest of the world.

Chapter 7
Conclusion

This research assesses the economic impact of the current commercial use in the primary sector of four specific biotechnologies: clonal propagation/cell manipulation, biocontrol agents, enzyme manipulations and marker-assisted selection. By choosing four specific technologies and assessing only commercialised innovations, this research makes two contributions to previous studies of biotechnology use within the primary industries. The first contribution is to calculate actual realised benefits, rather than to make projections about possible future benefits. Secondly, the focus on commercially released technologies meant that issues with regards to possible public perception and potential foreign market access did not cloud the analysis.

The information on the contribution of these four technologies in the primary industries is not readily available in official statistics or from other studies. Thus, to obtain information on current biotechnology use, an extensive survey of scientists and industry people was undertaken. The survey revealed that much biotechnology research has yet to result in commercial products that contribute economic value to primary production in New Zealand. Some parts of the primary sector are essentially unaffected by these biotechnologies. However, there are successful products with a substantial contribution to the sector, as well as a number of commercialised products with more modest impacts.

The detailed cost benefit analysis reveals that the highest contributions come from clonal propagation/cellular manipulation. This specific biotechnology has been commercially used in plant research and breeding for decades, and is a good example of a horizontal enabling technology, a technology with wide application across many industries and innovations. The contribution to the primary sector was estimated to be $189 million; a large part of this value comes from improvements of plant species used in dairy, sheep and beef pastoral agriculture.

Biocontrol agents have a number of products that are applied in a number of different subsectors. Many of these, although successfully used, have yet to reach substantial volumes and materiality in their economic contribution. The total contribution of biocontrol agents was calculated to be $62 million, of which ryegrass endophytes and the ToxoVax vaccine accounted for almost 95 per cent.

Enzyme manipulation had a current contribution of $14 million, excluding the use of biotechnological enzymes in processing dairy foods. The low value reflects this research's focus on the primary industries, thus excluding downstream processing where the main application of enzyme biotechnologies can be found.

Marker-assisted breeding and selection has been researched for many years, but is only now producing some commercial products. The only product that appears to be contributing to primary production in New Zealand is the test for the footrot gene marker, with an estimated contribution of $770,000. The only other commercial product appears to be the test for the Inverdale gene, which should begin yielding commercial value in primary production in a year or so.

The impact of changes in farm gate prices was not accounted for in the analysis of direct impacts. An increase in the amount produced can lead to a reduction of the market price, and an important question is whether the increased quantities from New Zealand's primary sector are sufficient to produce a price change. If the quantity that New Zealand produces is small in relation to the world market, then New Zealand is a 'price taker' – it can sell as much or as little as it produces without the market price changing. On the other hand, if New Zealand is a significant producer in relation to the world market, changes in New Zealand production could affect the market price.

The effect on prices and thus on the net contribution to the NZ economy were assessed with the Lincoln Trade and Environment Model (LTEM). Two basic scenarios were run; the first one has the innovations modelled as adopted by all countries in the model; the second scenario has several innovations modelled as affecting production only in New Zealand. The results indicate a lower contribution by the four technologies than that estimated in the fixed price calculations. In the first scenario the *net impact of absence of biotechnology* was calculated to be -$19 million; for the second scenario the result was -$191 million. The relevant figure from the fixed-price analysis is $206 million, which excludes subsectors not included in the trade analysis. Thus, the first scenario reduces the direct economic impacts to about one-tenth of the original estimate. In the second scenario, the direct economic impacts were again reduced, but were still 90 per cent of the original estimate.

Which of the two trade scenarios more accurately portrays the New Zealand situation is uncertain. Clearly, adopting biotechnology is important. It increases productivity, which either allows New Zealand to have a competitive advantage in certain commodities or keeps the country in line with rival producers. The results do suggest, however, that biotechnologies adopted globally may increase production but may not greatly increase producer returns in the primary sector.

The macroeconomic impact was estimated by calculating the indirect and induced impacts on the New Zealand economy, using the direct impacts described above. Thus the total annual value-added contribution of the four biotechnologies as applied in the primary sector (current year), was calculated to be $453 million, based on the constant price estimate. The two trade scenarios led to estimates of the macroeconomic impact of the absence of biotechnology of $33 million (Scenario 1) and $324 million (Scenario 2), compared to a constant price analysis calculation of $350 million (number reduced by contribution from subsectors not included in the trade analysis).

Analysis of the agricultural sector revealed that the sector has seen significant increases in multifactor productivity over the last ten to 15 years. The productivity increases were much larger than the estimated impacts of the four biotechnologies. In this context of the trend output figure, the impacts of the four biotechnologies considered in this report have had a positive, but not dominant, role in the primary sector.

It is important to recognise the bounds of this research. The research discussed in this report focused specifically on the impacts of four selected biotechnologies on the primary sector. It is difficult to extrapolate from those biotechnologies and sectors to broader conclusions about other biotechnologies or other sectors. Without research specifically examining these other biotechnologies or sectors, the extent of their economic contribution is unknown.

This research does point to areas that would benefit from further investigation. One such area is a survey of biotechnologies and their uses across the whole New Zealand economy. Such a survey would help address the issue of the overall economic impact of biotechnology and the economic impact analysed in the present research relative to the total impact. Some groundwork for such research has been laid here. In addition, existing surveys of biotechnological activity in New Zealand (Miller, 2003; Pink, 2001) and catalogues of biotechnology (e.g., Zaid et al., 1999) would be useful resources for framing future research.

It should also be mentioned that the dairy industry be a good candidate for future research. It is an important industry for New Zealand, and the present research was unable to account fully for the uses and impacts of biotechnology in this industry. The estimates calculated here and further estimates of the impacts of biotechnology could be improved with a better understanding of economic impacts in dairy production. In addition, millions of dollars of research spending, including public monies, are spent on dairy research. It would be interesting to assess the economic benefits from such publicly funded research.

One topic that was found to be little-researched was the non-marketed impacts of biotechnology. The interviews and the literature both suggested that biotechnology could provide numerous non-marketed benefits, especially by reducing the negative environmental impacts of primary sector activities. What appear to be needed are estimates of specific non-marketed impacts, the specific benefits of those impacts, and valuation of those benefits. This lack of information has important policy implications. If biotechnology produces non-marketable benefits, such as pollution reduction that benefits the wider population, then fostering such benefits through public funding is economically appropriate. Without knowing the value of the benefits, however, the appropriate level of funding is unknown.

Another topic that the present research did not include was proprietary control of technology or Intellectual Property Rights (IPRs). There already exists a significant and complex body of literature considering IPRs, and they are an important consideration when assessing economic impacts of biotechnology. It would be valuable to consider the New Zealand situation in light of existing knowledge regarding intellectual property and to investigate potential improvements.

It has been said that to understand the economy, it is sometimes necessary to go and look. The research reported here has taken the ‘go and look’ approach to understanding the economic contribution of biotechnology to New Zealand’s primary sector. The findings are unique, a first attempt to estimate economic impacts in this way, and should thus prove a helpful contribution to understanding the use and development of biotechnology.

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Appendix 1
List of Key Informants

Name	Organisation
Jeremy Absolom	Rissington Breedline Genetics
Jock Allison	Abacus Biotech Limited
Tony Arthur	Ovita Ltd
Ron Beatson	HortResearch
Bruce Belgrave	Grasslanz
Don Bell	Process Developments Ltd
Rod Bennett	Institute of Food Nutrition and Human Health, Massey University
Roy Bickerstaffe	Lincoln University
Andrew Broadwell	BioDiscovery New Zealand Ltd
Mike Butcher	Pipfruit NZ
Keith Cameron	Lincoln University
Garth Carnaby	Canesis (formerly)
John Chang	Canterprise
Andrew Clarke	A2 Corporation
Tony Conner	Crop & Food Research
Matthew Cromey	Crop & Food Research
Rex Dolby	Agro Science Consultancy Services
Sue Finderup	Westland Dairy
Lester Fletcher	AgResearch
Ian Gear	Ministry of Agriculture and Forestry
David Glen	ICPbio Ltd
Stephen Goldson	AgResearch
Warrick Green	Wrightson Research
Jon Hickford	Lincoln University
Lloyd Hickman	Alex McDonald (Merchants) Ltd
Diane Hill	Global Technologies (NZ) Ltd
Kerry Hughes	Alex McDonald (Merchants) Ltd
John S Hunt	Agrimm Technologies Ltd
Trevor Jackson	AgResearch

List of Key Informants (continued)

Name	Organisation
Henry Kaspar	Cawthron Institute
Peter Kettle	Ministry of Agriculture and Forestry
Bruce Kirk	Scios Ltd
Geoffrey Langford	HortResearch
Nigel Larsen	Crop & Food Research
Andrew MacPherson	AgVax Developments Ltd
Sue Marshall	Crop & Food Research
Alan Marshall	Tectra
Morgan McArthur	Ancare NZ Ltd
John McKenzie	Agricom NZ Ltd
Steve McNeil	Canesis
Mike Mensis	Forest Research
Bill Montgomerie	Livestock Improvement Corporation
Ron Pellow	Ravensdown Fertiliser Co-operative Limited
Russel Priest	Meat & Wool
Mike Rockell	Institute of Food Nutrition and Human Health, Massey University
William Rolleston	South Pacific Sera Ltd
Gavin Ross	AgriGenesis Bioscience Ltd
Adrian Russell	Plant Research NZ Ltd
John Scandrett	Botry-Zen Ltd
Alan Seal	HortResearch
Sandra Simpson	Multiflora Labs, Ltd
Charles Sorenson	Horizon2
Richard Spelman	Livestock Improvement Corporation
John Stewart	Grasslanz
Gail Timmerman-Vaughan	Crop & Food Research
Wei Young Wang	P.F. Olsen
Alan White	HortResearch
Phillip Wilcox	Forest Research
Ken Wong	Forest Research

Appendix 2
Survey Instrument

Economics of Biotechnology in Primary Production

Questionnaire for semi-structured interviews of key informants

April - May 2005

AERU

LINCOLN UNIVERSITY
Te Whare Wānaka O Aoraki

This project is assessing the current contribution of biotechnology to the primary sector in New Zealand. We are interviewing people in biotechnology firms and primary industries to gather information.

The biotechnologies of interest for this project are:

- Marker-assisted selection / breeding
- Bio-control agents
- Enzyme manipulations
- Clonal propagation / cell manipulation

We are collecting examples of these biotechnologies from across the primary sector, including:

- Dairy
- Meat and wool
- Forestry
- Horticulture
- Arable crops
- Seafood
- New industries, e.g., biofuels, biomaterials

We appreciate your participation in this project.

This is a joint project of the Agribusiness and Economics Research Unit (AERU), the Commerce Division, and the National Centre for Advanced Bio-Protection Technologies at Lincoln University. It is funded by the Ministry of Research, Science and Technology (MoRST).

Section 1

Identification of key informant

1. Name: ______________________________
2. Organisation: ______________________________
3. Prior organisation (if relevant): ______________________________
4. Contact information: ______________________________

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____

Section 2

Overview of technology use

5. How is biotechnology used in general in your industry or subsector? [*If informant needs prompting, suggest: How has biotechnology affected the methods of production? How has biotechnology affected the products of your industry?*] ______________________________

____

____

6. What role does biotechnology play in your firm's activities? ______________________________

____

Section 3

Specific examples

7. Could we discuss each use of biotechnology in detail? We are looking for examples of production inputs and outputs, processes, services, methods, or environmental impacts from the four biotechnologies. [Use the 'Specific example of biotechnology' sheet to record.]

Key informant: ________________________   Example ____ of ____

Section 3, Question 7: Specific example of biotechnology

Example: ____

Impact (tick one or more)		Biotechnology (tick one or more)
☐ input	☐ service	☐ Marker-assisted selection
☐ output	☐ method	☐ Bio-control agents
☐ process	☐ environmental impact	☐ Enzyme manipulations
		☐ Clonal propagation/cell manipulation

- **Benefits**

Cost savings: ____________________ Output price change: ____________________

Yield increase: ____________________ Other: ____________________

- **Costs**

Technology fee: ____________________ Labour costs: ____________________

Machinery costs: ____________________ Other (finance, land): ____________________

- **Other changes**

Labour use: ____________________ Changes to other inputs: ____________________

Timing changes: ____________________ Other changes: ____________________

- **Uptake rates**

% of producers: ____________________ % w/ impacts: ____________________

% of production: ____________________ Potential uptake?: ____________________

- **Other info:** ____

____

Appendix 3
List of Innovations Identified

Innovation	Type of biotechnology	Description
Plant breeding, arable crops	Clonal propagation/cell manipulation	Studies imply a crop genetic improvement figure of 0.5% per year in yield. It was assumed that one-half the crop genetic improvement can be attributed to clonal propagation/cell manipulation.
Floriculture, contract tissue culture	Clonal propagation/cell manipulation	Tissue culture allows for quicker propagation and better form resulting in larger tubers and earlier flowers, resulting in premium prices for growers.
Forestry, clonal propagation	Clonal propagation/cell manipulation	Tissue culture (organogenesis) and somatic embroyogenesis are used increasingly in commercial radiata pine forests.
Hops	Clonal propagation/cell manipulation	The entire hops industry in New Zealand is based on triploid hops with good agronomic and brewing qualities.
Potatoes	Clonal propagation/cell manipulation	Tissue culture is used after heat treatment to propagate the initial generations of plants, which are then used to produce seed potatoes. Most of New Zealand's seed potatoes are produced by this process, which produces virus-free, uniform seed potatoes and does so more quickly than older methods of propagation.
Plant breeding, horticulture	Clonal propagation/cell manipulation	These techniques are widely used in plant breeding. The exact impact on the horticultural subsector is difficult to determine. This research calculates the impact from gross margins for vegetable crops and the rate of crop genetic improvement found in arable crops.
Plant breeding, pasture plants	Clonal propagation/cell manipulation	The use of tissue culture, protoplast fusion, and other cellular techniques in pasture plant breeding goes back to the 1970s, but with increased uptake in the 1980s. This application of biotechnology has improved forage quality through changes to digestibility, intake rate, and metabolisable energy content

List of Innovations Identified (continued)

Innovation	Type of biotechnology	Description
BVDV vaccines	Biocontrol agents	The potential effects of Bovine virus diarrhoea virus (BVDV) are abortions, poor foetal development, and failure to thrive. Estimated economic impacts in other national herds are US$2 million to US$57 million per million calvings, with most estimates falling in the range of US$10 million to US$40 million.
Trichoderma products	Biocontrol agents	Trichoderma is a beneficial, naturally occurring fungus. It has two basic modes of operation; as a bio-fertiliser and/or as a bio-fungicide.
ToxoVax (AgVax)	Biocontrol agents	This is a vaccine against toxoplasmosis, which causes abortions in sheep. Field trials show an average national increase in lambing of 3% for vaccinated flocks.
Bioshield Grassgrub (Balance)	Biocontrol agents	The Ballance Bioshield Grassgrub uses natural soil bacteria to break the population growth cycle for grass grubs. The product eliminates the need to use chemical pesticides.
Bt preparations	Biocontrol agents	The bacterium *Bacillus thuringiensis* (Bt) attacks agriculturally important pests. Commercial preparations of Bt are particularly important in integrated pest management (IPM) systems, for organic agriculture, and in MAF's eradication programmes for several exotic moths.
Ryegrass endophytes	Biocontrol agents	Wild-type endophytes in New Zealand pastures have been shown to have harmful effects on grazing animals. AgResearch identified alternative beneficial endophytes and developed technology for inoculating ryegrass cultivars with this novel endophyte.
eco-n (Ravensdown)	Enzyme manipulation	eco-n is made from DCD, a nitrification inhibitor that slows down the conversion of ammonium to nitrate. Both Ballance and Ravensdown have commercial DCD products. DCD reduces the leaching of nitrates from grazed pastures and also significantly increases pasture production by improving soil nutrient cycles in grazed dairy pastures.

List of Innovations Identified (continued)

Innovation	Type of biotechnology	Description
Dairy enzymes	Enzyme manipulation	This research has not estimated a value for enzyme use in the dairy. It is clear that enzymes, including ones improved through biotechnology, are used in processing raw milk into dairy products, such as cheese and cheese flavouring.
Wine enzymes	Enzyme manipulation	Enzymes are used in a number of ways in producing wine. They increase the amount of juice extract from pulp and increase the clarity of the wine, amongst other impacts.
Forestry enzymes	Enzyme manipulation	Enzymes have no commercial application in the forest and logging business, but are used in other countries. Enzyme technology can increase the quality and quantity of feedstocks for pulp and paper processes, reduce manufacturing costs, and create high-value products.
Footrot gene marker test	Marker-assisted selection	The footrot gene-marker test is used for selecting footrot-tolerant sheep to breed. Its use results in a reduction of other input costs, such as vaccinations, antibiotics, foot-paring and foot bathing. It also reduces the use of chemicals.
Inverdale gene marker test	Marker-assisted selection	The Inverdale gene in the ram leads to more-fertile ewes, thus a benefit in the progeny of rams that have been tested. As the test was commercially released only this year, the primary sector will start to see the benefits after two breeding cycles.

Appendix 4
Quantitative impacts: a range of values

This appendix presents quantitative values based on the discussion and calculations in Chapter 4. The values presented here indicate a range of possible economic values of impacts from biotechnology innovation, whereas the earlier values represented the best point estimates of economic impacts. This appendix presents the direct economic impacts by subsector or innovation, as in Chapter 4. The indirect and induced impacts from the range of values are also presented.

Detailed tables are provided only for those biotechnological innovations for which a range of values were indicated. For some of the innovations, there was little uncertainty about the value to be estimated. The values for those innovations were the same as in Chapter 4. The summary table in this appendix uses the point values in Chapter 4 or the range of values from this appendix, as appropriate.

In the course of this research, it was suggested that the uncertainty of the economic impacts could be parameterised and modelled. Modelling impacts in this way would allow calculation of mean impacts and confidence intervals. This would be a valid approach to investigating the uncertainty of these estimates and a useful extension of this research. Due to time constraints, such a modelling exercise was not attempted. Beyond the simple mechanics of the work, modelling would require careful consideration of the parameters to use for describing the uncertain variables.

Table A4.1 calculates a range of values for the impact of clonal propagation/cell manipulation in arable crops. The exact contribution of the biotechnology to crop productivity was uncertain. Several estimates of total productivity growth in agricultural were available, as discussed above. The contribution of crop genetic improvement (CGI) was somewhat uncertain, although the general figure of one-half of total productivity growth was cited (Rubenstein, Heisey, Shoemaker, Sullivan, & Frisvold, 2005). The extent to which genetic improvement relies on biotechnology was also uncertain, and did not appear to have been a topic of research in the published literature. The assumption in Chapter 4 was that approximately one-half of CGI depends on biotechnology. For this appendix, the economic impact was recalculated as a range, with the low end assuming that one-quarter of CGI depended on biotechnology and the high end replicating the Chapter 4 calculations.

Table A4.1. Economic contribution of clonal propagation/cell manipulation to the arable crop subsector

Arable crops	Area (hectares)	Revenue per hectare[a] ($)	Revenue ($000)	Current production due to biotechnology (%)		Increased production ($000's)		Gross margin[a] ($ per $ of revenue)	Value of clonal propagation/cell manipulation ($000's)	
				0.125% p.a.	0.25% p.a.	0.125% p.a.	0.25% p.a.		0.125% p.a.	0.25% p.a.
Barley[b]	64,700	1,725	111,608	2.5	5.1	2,790	5,692	0.45	1,256	2,561
Field peas[c]	10,000	2,320	23,200	2.5	5.1	580	1,183	0.54	313.2	639
Maize[d]	14,166	3,497	49,539	2.5	5.1	1,238	2,526	0.36	445.851	910
Small seeds[c]	33,000	2,376	78,408	2.5	5.1	1,960	3,999	0.42	823.284	1,679
Veg seeds[c]	3,000		25,000	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Wheat[e]	40,900	2,480	101,432	2.5	5.1	2,536	5,173	0.47	1,192	2,431
Total arable			389,187			9,105	18,574		4,030	8,220

[a] Burtt (2004).

[b] Area data: Ministry of Agriculture and Forestry Website, Total Barley - Area Harvested and Quantity Produced (2003).

[c] Area data: MAF (2004c). Gross margins for small seeds is the unweighted average of clover, ryegrass, and fescue gross margins.

[d] Area data: Ministry of Agriculture and Forestry Website, Grain and Seed Crops by Farm Type (ANZSIC), (2002

[e] Area data: Ministry of Agriculture and Forestry Website, Total Wheat - area harvested and quantity produced, (2004).

The exact impacts of clonal propagation in forestry were also uncertain. They were very sensitive to the variables used in calculating the unrealised capital gain. A range of possible values of clonal forests could be calculated using the extremes of uncertain and/or variable input variables. By varying rotation, initial investment, premium, and the discount rate as per table below, the value ranged from a loss of $20.5 million to a gain of $69 million.

Table A4.2. Economic contribution of clonal propagation/cell manipulation to forestry

	Minimum gain	Maximum gain
Rotation (years)	30	27
Initial investment ($)	1	0.6
Pre tax premium ($/m^3)	0	20
Discount rate (%)	9.5	7.0
NPV of clonal forestry ($000)	-20,507	69,031

The impacts of clonal propagation/cell manipulation in horticulture were also likely to take a range of values. The estimate for hops is included here as a point estimate, as the information gathered in this research suggested that the entire industry depended on biotechnology. The estimate for potatoes took a range of values, as key informants could only estimate the possible impact of the loss of tissue culture on the industry. For other vegetables, a range of values was calculated using the same impacts estimated in the section on arable crops. The calculations are presented in Table A4.3.

Table A4.4 presents similar calculations for pasture-based production. The calculations were based on the information in Chapter 4 and the range of biotechnology impacts discussed above in the context of arable crops.

The impact of biocontrol agents was also the subject of some uncertainty. Table A4.5 provides estimates for the range of impacts that have been observed with the AR1 endophyte ryegrass. Although the information provided by key informants suggested that the $200 per hectare figure used in Chapter 4 was a consistent and robust value of the benefit, there were indications that benefits could be higher. These higher figures are included in Table A4.5.

Table A4.3. Economic contribution of clonal propagation/cell manipulation to the horticulture subsector[a]

Horticultural crops	Area (hectares)	Revenue ($000's)	Current production due to biotechnology (%)		Increased production ($000's)		Gross margin ($ per hectare)	Value of clonal propagation/cell manipulation ($000's)	
			Low	High	Low	High		Low	High
Hops								1,919	1,919
Potatoes	10,600	141,000	66.7	75	94,000	141,000	1,438	10,162	11,432
Other vegetables	36,973		2.5	5.1			2,081	1,924	3,924
Total								14,005	17,275

[a] Sources: see text and tables above.

Table A4.4. Economic contribution of clonal propagation/cell manipulation to pastoral production

Product	Amount of production[a]	Revenue per unit[b]	Revenue ($000's)	Production affected	Current production due to biotechnology (%)		Increased production ($000's)		Gross margin[c] ($ per $ of revenue)	Value of clonal propagation/cell manipulation ($000's)	
					0.125% p.a.	0.25% p.a.	0.125% p.a.	0.25% p.a.		0.125% p.a.	0.25% p.a.
Dairy	1,250,000 t	4250	5,312,500	0.35	2.5	5.1	46,484	94,828	0.79	36,723	74,914
Beef and veal	4,644,000 hd	280	1,300,320	0.35	2.5	5.1	11,378	23,211	0.90	10,240	20,890
Sheep farming											
Lamb	434,000 t	3790	1,644,860	0.35	2.5	5.1	14,393	29,361			
Mutton	113,000 t	2000	226,000	0.35	2.5	5.1	1,978	4,034			
Wool	173,000 t	5510	953,230	0.35	2.5	5.1	8,341	17,015			
Total sheep farming			2,824,090				24,711	50,410	0.70	17,298	35,287
Total pastoral production			9,436,910				82,573	168,449		64,260	131,091

[a] MAF (2004c). Figures are from 2003 because some 2004 figures in the report are estimates.

[b] For Dairy, this is the 2003/04 payout of $4.25 per kg. For Beef and veal, this is farm income per head of overwintered cattle (Burtt, 2004). For Lamb, Mutton and Wool, prices are average baseline prices (MAF, 2004c).

[c] Burtt (2004). For Dairy and Beef and veal, gross margin is adjusted to account for the cost of winter feed. Sheep farming gross margins are the weighted average of three budgets (Burtt, 2004). Merino sheep numbers taken from Greer (2005).

Table A4.5. Economic contribution of AR1 novel endophyte to pastoral production

Product	Revenue[a] ($000's)	Percentage of AR1 hectares[b] (%)	Number of AR1 hectares	Impact of AR1 ($/hectare)		Increased production ($000's)		Gross margin[a] ($ per $ of revenue)	Value of AR1 ($000's)	
				Low	High	Low	High		Low	High
Dairy	5,312,500	65.3	130,600	$200	$400	26,120	52,240	0.79	20,635	41,270
Sheep farming	2,824,090	34.7	69,400	$200	$220	13,880	15,268	0.70	9,716	10,688
Total	8,136,590	100.0	200,000			40,000	67,508		30,351	51,958

[a] See Table A4.4 for calculations and sources.

[b] Percentage of AR1 hectares is calculated as the subsector revenue divided by total Dairy and Sheep farming revenue.

The economic value of Bovine virus diarrhoea virus (BVDV) was unknown because the exact losses due to the disease are uncertain. Houe (2003) provided values from a range of studies. The values clustered around the point estimate of US$10 million per million calvings, but Houe (2003) indicated that the range is US$10 million to $40 million. Table A4.6 presents the results of calculations of the impact of BVDV vaccines. The underlying calculations are confidential, but were based on beef and dairy herd estimates from MAF (MAF, 2004c), losses per million calvings of $10 million and $40 million (Houe, 2003), a NZ$/US$ exchange rate of 0.70, and a combined gross margin of 0.81 for beef and dairy farms.

Table A4.6. Economic contribution of BVDV vaccines

Product	Revenue	Value of BVDV vaccines ($000)	
	($000's)	low	high
Dairy	5,312,500	2,523	16,118
Beef and veal	1,300,320	772	4562
Total	6,612,820	3,295	20,680

The last biotechnological innovation for which a range of impacts was calculated is eco-n, the DCD nitrification inhibitor. As discussed in Chapter 4, scientific research suggested that the product could have a range of impacts. The point estimate above assumed the conservative value from the following table. However, the higher per-hectare findings could also be used to generate a higher benefit estimate, as shown in Table A4.7.

Table A4.7. Benefits of eco-n

	10% increase in pasture production	15% increase in pasture production
Increased pasture production	1300 kgDM/ha/yr	1950 kgDM/ha/yr
Additional milksolids	87 kgMS/ha/yr	130 kgMS/ha/yr
Total Gross return	$347 /ha/yr	$520 /ha/yr
Net return per hectare	$223 /ha/yr	$396 /ha/yr
Number of hectares	17,000 ha	17,000 ha
Total benefits	$3,791,000	$6,732,000

The total range of benefits from the biotechnological innovations identified in this research is presented in Table A4.8.

The final table in this appendix, Table A4.9, presents the range of direct, indirect and induced economic impacts from these biotechnologies. They were calculated as in Chapter 6, using the range of direct impacts presented in this appendix. These calculations suggested that the range of total economic impacts from the use of these innovations, including the upstream and downstream impacts, and changes to household income and employment, was from $261 million to $616 million.

Table A4.8. Summary of range of direct impacts of four biotechnologies

Subsector	Value of clonal propagation/cell manipulation ($000's)	Value of biocontrol agents ($000's)	Value of enzyme manipulations ($000's)	Value of marker assisted selection ($000's)	Total ($000's)
Dairy	36,723 - 74,914	19,893 - 54,123	3,791 - 6,732	nil - nil	60,407 - 135,769
Beef and veal	10,240 - 20,890	772 - 4,562	nil - nil	nil - nil	11,012 - 25,452
Sheep (meat and wool)	17,298 - 35,287	41,353 - 42,325	nil - nil	770 - 770	59,421 - 78,382
Forestry	-20,507 - 69,031	nil - nil	nil - nil	nil - nil	-20,507 - 69,031
Horticulture and floriculture	29,725 - 32,995	small value - small value	9,960 - 9,960	nil - nil	39,685 - 42,955
Arable crops	4,030 - 8,220	nil - nil	nil - nil	nil - nil	4,030 - 8,220
Seafood	nil - nil	nil - nil	nil - nil	nil - nil	nil - nil
Total	77,509 - 241,337	62,018 - 101,009	13,751 - 16,692	770 - 770	154,048 - 359,808

Table A4.9. Range of total annual value-added contribution of the four biotechnologies to the New Zealand economy (current year)

Subsector	Direct impacts ($000's)	Direct + Indirect impacts ($000's)	Direct + Indirect + Induced impacts ($000's)
Dairy	60,407 - 135,769	82,757 - 186,003	102,692 - 230,808
Beef and veal	11,012 - 25,452	15,417 - 35,633	18,500 - 42,759
Sheepmeat and wool	59,421 - 78,382	84,972 - 112,086	101,016 - 133,249
Forestry	-20,507 - 69,031	-31,991 - 107,687	-36,093 - 121,496
Horticulture	39,685 - 42,955	54,368 - 58,848	67,862 - 73,454
Arable	4,030 - 8,220	5,884 - 12,002	7,012 - 14,303
Total	154,048 - 359,809	211,407 - 512,259	260,989 - 616,069

Appendix 5
The Lincoln Trade and Environment Model

This appendix provides a detailed description of the Lincoln Trade and Environment Model (LTEM). Included in this description are the equations in the model, the method of determining prices and quantities, and the parameters in the base data for the model.

Behavioural Equations in the LTEM

Each country in the LTEM has its own set of behavioural equations for each commodity. In general there are six behavioural equations and one economic identity for each commodity in each country, i.e. there are seven endogenous variables in the structural-form of the equation set. These behavioural equations are domestic supply, demand, stocks, domestic producer and consumer prices and a trade price equation. The economic identity is the net trade equation, representing the excess supply or demand in each country. There is some variation between countries and commodities based on the levels of disaggregation. The following section explains the functional form and variable specification for each of the behavioural equations.

Domestic Supply

The type of supply equation used in the LTEM is known as a directly estimated partial supply response model (Colman, 1983). The equation is a function of own- and cross-prices, with an *ad hoc* theoretical background. The equations use the Cobb-Douglas (CD) constant elasticity functional form, specified at the level of the variables. The supply equations for each of the types of commodities are presented below:

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} \prod_j pp_{jt}^{\alpha_j} \quad ; \qquad \alpha_1 > 0,\ \alpha_j < 0 \qquad 1$$

Livestock Products

Meat: Beef and Veal, Sheepmeat, Pig Meat

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} \prod_j \prod_k pp_{jt}^{\alpha_j} pc_{kt}^{\alpha_k} \quad ; \qquad \alpha_1 > 0,\ \alpha_j < 0,\ \alpha_k < 0 \qquad 2$$

Dairy: Raw Milk

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} \prod_j \prod_k pp_{jt}^{\alpha_j} pc_{kt}^{\alpha_k} \quad ; \qquad \alpha_1 > 0,\ \alpha_j < 0,\ \alpha_k < 0 \qquad 3$$

*Dairy: Liquid Milk, Butter, Cheese, Whole Milk Powder, Skim Milk Powde*r

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} qs_{RMt}^{\alpha_{RM}} \prod_j pp_{jt}^{\alpha_j} \quad ; \qquad \alpha_1 > 0,\ \alpha_{RM} > 0,\ \alpha_j < 0 \qquad 4$$

Poultry: Eggs and Poultry Meat

$$qs_{it} = \alpha_0 pp_{it}^{\alpha_1} \prod_j \prod_k pp_{jt}^{\alpha_j} pc_{kt}^{\alpha_k} \quad ; \qquad \alpha_1 > 0 \text{, } \alpha_j < 0 \text{, } \alpha_k < 0 \qquad 5$$

Variables and Parameters:

i: *own commodity*

j: *substitutes*

k: *feed products*

qs: *domestic supply*

pp: *producer price*

pc: *consumer price*

In the LTEM, the supply and demand responses in the dairy sector are modelled explicitly, as the sector is affected by various domestic and border policies in world markets.

Domestic Demand

Demand is simulated in the LTEM using a uniform CD aggregate domestic demand function, again for each country and commodity. The demand relationship is derived from the consumers' utility maximisation behaviour under perfect competition assumption. Demand is therefore specified as a function of the own- and substitute prices, per capita income and the population growth rate. Income and population are exogenous to the model. The demand equations for the main groups of commodities are shown below:

Crops

Wheat and Coarse Grains

$$qd_{i,fot} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3} \prod_j pc_{jt}^{\beta_j} \quad ; \qquad \beta_1 < 0 \text{, } \beta_2 > 0 \text{, } \beta_3 > 0 \text{, } \beta_j > 0 \qquad 6$$

$$qd_{i,fet} = \beta_0 pc_{it}^{\beta_1} \prod_j \prod_q pc_{jt}^{\beta_j} qs_{qt}^{\beta_q} \quad ; \qquad \beta_1 < 0 \text{, } \beta_j > 0 \text{, } \beta_q > 0 \qquad 7$$

Oils and Oilseeds

$$qd_{i,fot} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3} \prod_j pc_{jt}^{\beta_j} \quad ; \qquad \beta_1 < 0 \text{, } \beta_2 > 0 \text{, } \beta_3 > 0 \text{, } \beta_j > 0 \qquad 8$$

$$qd_{i,fet} = \beta_0 pc_{it}^{\beta_1} \prod_j \prod_q pc_{jt}^{\beta_j} qs_{qt}^{\beta_q} \quad ; \qquad \beta_1 < 0 \text{, } \beta_j > 0 \text{, } \beta_q > 0 \qquad 9$$

$$qd_{OS,prt} = \beta_0 pc_{OSt}^{\beta_{OS}} \prod_r pp_{rt}^{\beta_r} \quad ; \qquad \beta_{OS} < 0 \text{, } \beta_r > 0 \qquad 10$$

Sugar and Rice

$$qd_{i,fot} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop_t^{\beta_3} \quad ; \qquad \beta_1 < 0 \text{, } \beta_2 > 0 \text{, } \beta_3 > 0 \qquad 11$$

Livestock Products

Meat: Beef and Veal, Sheepmeat, Pig Meat

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j} ; \qquad \beta_1 < 0,\ \beta_2 > 0,\ \beta_3 > 0,\ \beta_j > 0 \qquad 12$$

Dairy: Liquid Milk, Butter, Cheese, Skim Milk Powder, Whole Milk Powder

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j} ; \qquad \beta_1 < 0,\ \beta_2 > 0,\ \beta_3 > 0,\ \beta_j > 0 \qquad 13$$

Poultry: Eggs, Poultry Meat

$$qd_{it} = \beta_0 pc_{it}^{\beta_1} pinc_t^{\beta_2} pop^{\beta_3} \prod_j pc_{jt}^{\beta_j} ; \qquad \beta_1 < 0,\ \beta_2 > 0,\ \beta_3 > 0,\ \beta_j > 0 \qquad 14$$

Variables and Parameters:

i: *own commodity*

j: *substitutes*

pc: *consumer price*

pinc: *per capita income*

pop: *population*

pp_r: *producer price of oilmeals and oil*

qd_{fe}: *domestic feed demand*

qd_{fo}: *domestic food demand*

qd_{OS}: *domestic processing demand for oilseeds*

qs_q: *domestic supply of meat, poultry products and raw milk*

Stocks

Stocks are modelled using the theory of inventory demand (FAPRI, 1989). The main motive for the stock demand is transaction rather than speculation. The equations are shown below:

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$qe_{it} = \varphi_0 qs_{it}^{\varphi_1} ; \qquad \varphi_1 > 0 \qquad 15$$

$$qe_{it} = \varphi_i qd_{it}^{\varphi_1} ; \qquad \varphi_1 > 0 \qquad 16$$

Variables and Parameters:

i: *own commodity*

qd: *domestic demand (can be food, feed or processing)*

qe: *stocks*

qs: *domestic supply*

Net Trade

As mentioned previously, net trade in the LTEM is an economic identity based on the difference between domestic supply and the sum of various demand amounts as well as stocks. Stocks are incorporated as a change from the previous year. The net trade equations are shown below:

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$qt_{it} = qs_{it} - (qd_{i,fot} + qd_{i,fet} + qd_{i,prt}) - (\Delta qe_{it}) \quad 17$$

Variables and Parameters:

i: *own commodity*

qd_{fe}: *domestic feed demand*

qd_{fo}: *domestic food demand*

qt: *quantity traded*

Raw milk is not traded as its supply is assumed to be completely exhausted in the production of the other dairy products.

Prices

Domestic consumer and producer prices in the LTEM are determined by the world trade prices for each commodity, as well as the domestic and border policies applied in each country. Equations 19 and 20 illustrate this price transmission mechanism. The trade price of a commodity is determined by the world market price of that commodity, as shown in equation 18. Producer and consumer support and subsidy measures are incorporated into the price equations through the use of commodity based price wedge variables, which differentiate the domestic and trade prices of each commodity. These variables may include per unit direct payments, inputs subsidies, general services expenditures and other market subsidy payments to producers, as well as a consumer market subsidy, as shown in equations 21 and 22. These policies are all calculated per tonne of production and consumption, following the concept of producer and consumer subsidy equivalents (PSE and CSEs) (Cahill & Legg, 1990).

Crops

Wheat and Coarse Grains, Oils and Oilseeds, Sugar and Rice

Livestock Products

Meat, Dairy, Poultry

$$pt_{it} = \left(\frac{WDp_{it}}{ex}\right)^{\varepsilon_{\tau}} \quad (18)$$

$$pp_{it} = pt_{it} + tp_{it} + tc_{t} \; ; \qquad tc = 0 \quad (19)$$

$$pc_{it} = pt_{it} + tc_{it} + tc_{t} \; ; \qquad tc = 0 \quad (20)$$

$$pp_{it} = (pt_{it} + tp_{it} + sd_{it} + si_{it} + sg_{it} + sm_{it}) \quad (21)$$

$$pc_{it} = pt_{it} + tc_{it} + cm_{it} \quad (22)$$

Variables and Parameters:

i: *own commodity*

cm: *consumer market subsidy*

ex: *exchange rate*

pc: *consumer price*

pp: *producer price*

pt: *trade price*

sd: *direct payments*

sg: *general services expenditure*

si: *input subsidy*

sm: *other producer market subsidy*

tc_i: *export subsidies*

tc: *transportation costs*

tp_i: *import tariffs*

WD_p: *world price*

The model works by simulating the commodity-based clearing price in world markets on the domestic quantities and prices, which may or may not be under the effect of policy changes, in each country. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market-clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market, by using a non-linear optimisation algorithm (Newton's global or search algorithm).

All prices in the LTEM are in US dollars, removing any exchange rate effects.

Supply and Demand Side Parameters:

Table A5.1. Supply Side Parameters: Own- and Cross-Price Elasticities

Country	*Producer Price*				*Consumer Price*			
Commodity	*Raw Milk*	*Beef and Veal*	*Sheepmeat*	*Wool*	*Wheat*	*Coarse Grains*	*Oil Seeds*	*Oil Meals*
Raw Milk								
Australia	0.50	-0.04	-0.01	-0.01	-0.10	-0.13		-0.02
EU (15)	0.50	0.11			-0.11	-0.20		-0.09
New Zealand	0.80	0.06			-0.04	-0.52	-0.01	-0.09
USA	0.40	0.05			-0.01	-0.19	-0.01	-0.04

Country	*Producer Price*					
Commodity	*Liquid Milk*	*Raw Milk*	*Butter*	*Cheese*	*Skim Milk P.*	*Whole Milk P.*
Liquid Milk						
Australia	0.50	-0.17	-0.03	-0.05	-0.03	-0.02
EU (15)	0.50	-0.12	-0.05	-0.10	-0.01	-0.02
New Zealand	0.50	-0.06	-0.08	-0.07		-0.08
USA	0.30	-0.04	-0.01	-0.03	-0.01	
Butter						
Australia	-0.07	-0.24	0.80	-0.40	0.30	-0.19
EU (15)	-0.07	-0.23	0.59	-0.12	0.06	-0.03
New Zealand	-0.01	-0.03	0.15		0.10	
USA	-0.07	-0.25	0.74	-0.29	0.10	-0.03
Cheese						
Australia	-0.04	0.07	-0.12	0.44	-0.15	
EU (15)	-0.03	0.01	-0.03	0.29	-0.01	-0.02
New Zealand	-0.01	0.05	-0.01	0.17		
USA	-0.02	0.06	-0.03	0.26	-0.04	-0.02
Skim Milk Powder						
Australia	-0.07	-0.24	0.80	-0.40	0.30	-0.19
EU (15)	-0.07	-0.23	0.59	-0.12	0.06	-0.03
New Zealand	-0.01	-0.03	0.15		0.10	
USA	-0.07	-0.25	0.74	-0.29	0.10	-0.03
Whole Milk Powder						
Australia	-0.08	-0.30	-0.25	-0.02	-0.07	0.91
EU (15)	-0.14	-0.32	-0.12	-0.40		1.18
New Zealand	-0.01	0.06				0.16
USA	-0.22		-0.31	-1.54		2.29

Table A5.2. Demand Side Parameters: Own-, Cross-Price and Income Elasticities

Country / *Commodity*	*Producer Price* *Liquid Milk*	*Butter*	*Cheese*	*Skim Milk P.*	*Whole Milk P.*	*Income*
Liquid Milk						
Australia	-0.23				0.01	-0.03
EU (15)	-0.50			0.01		0.05
New Zealand	-0.20					0.09
USA	-0.30	0.01	0.02	0.01		-0.01
Butter						
Australia		-0.45	0.05	0.01		0.24
EU (15)		-0.48	0.05	0.01		0.30
New Zealand		-0.45	0.01			0.19
USA	0.06	-0.70	0.01	0.01		0.10
Cheese						
Australia		0.01	-0.40			0.31
EU (15)		0.01	-0.45			0.35
New Zealand		0.01	-0.45			0.42
USA	0.01		-0.55			0.40
Skim Milk Powder						
Australia	0.02	0.01		-0.45	0.04	-0.04
EU (15)	0.02	0.03	0.02	-0.40	0.03	0.30
New Zealand				-0.40		0.18
USA	0.03	0.01	0.03	-0.55	0.01	0.35
Whole Milk Powder						
Australia	0.07			0.05	-0.45	-0.04
EU (15)	0.01		0.04	0.10	-0.50	0.30
New Zealand	0.05			0.02	-0.45	0.18
USA	0.08			0.15	-0.70	0.38