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**Fostering Innovation in a Small Open Economy:
The Case of the New Zealand Biotechnology Sector**

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Abstract

The New Zealand Biotechnology sector is worthy of study for several reasons. While there is a large and growing international literature on economic aspects of biotechnology innovation these studies concentrate on the United States and Europe. The New Zealand biotechnology sector may be expected to develop along a different trajectory as a consequence of a markedly different set of initial and framework conditions. Government has indicated a strong interest in fostering innovation and aims to concentrate on selected areas where New Zealand may be able to develop a new comparative advantage. One such area is biotechnology, which would build on New Zealand's existing comparative advantage in the primary sector (dairy, forestry, meat, wool and horticulture). This paper describes the preliminary results of an ongoing study that aims to fill some of the gaps in our knowledge of innovation processes in New Zealand while using the international literature as a benchmark. The paper focuses on the drivers of innovation in the biotechnology sector; the role of networks and other linkages; the role of government and industry, the role of human and venture capital, and data from patenting.

Keywords

innovation; innovation system; biotechnology; patents; New Zealand

JEL Classification

L65, L66, O31, O32, O38

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1. Introduction

Modern biotechnology has the potential to transform large parts of the global economy and to have a major impact on the way we live. Its birth is usually traced back to the development of the recombinant DNA technique in 1973 and hybridoma technology in 1975 (Orsenigo, 1989, p. 37). The rapid pace and widespread impact of developments in biotechnology since that time has often been referred to as the biotechnological revolution. This has a number of features which make it quite distinct from the traditional model of technological revolutions¹:

First, whereas the traditional model is derived largely from the study of radical shifts in *engineering knowledge* ..., the revolution in molecular biology represented a shift in the *scientific* knowledge base of an industry. Second, despite the sweeping nature of the molecular revolution, incumbent pharmaceutical companies have not been swept away by new entrants. Third, and relatedly the relationship between incumbents and entrants has entailed not only competition but also cooperation and the establishment of complex interactions between firms (Henderson, Orsenigo and Pisano, 1999, p. 268).

Eliasson and Eliasson (1997, p. 141) add that:

biotechnology originated in academia and therefore corresponds to the ideal concept of a science-based industry, ...new discoveries ... are almost always the result of a combination of different clusters of scientific know-how: in chemistry, molecular biology, cell biology, physiology, and toxicology, pharmacology... [and] failed experiments are a significant part of the total development costs in the industry.

It is also interesting because of its markedly different effects on industry structure in different parts of the world. This contrasts with the standard view of scientific advance as creating a 'free good', which is universally available.

There is a large and growing international literature on economic aspects of biotechnology innovation. Carlsson (1997) and his co-workers used the concept of technological systems to analyse the development, diffusion and utilization of technology in various fields of economic activity including the "pharmaceutical and biotechnological competence bloc" (Eliasson and Eliasson, 1997). Orsenigo (1989), McKelvey (1996), and others described and explained the emergence and development of the biotechnology industry within an evolutionary framework. Zucker and Darby (1996) and their co-workers produced a range of detailed studies on factors influencing the development of the modern biotechnology industry in the United States and Japan. They focussed particularly on the first 10 to 15 years of the biotech revolution when innovations were characterized by naturally excludable knowledge in the hands of only a few star scientists. They found that generation of biotech knowledge in a specific location was the principle determinant of the growth of the biotech industry in that area.

¹ Some consider biotechnology to be the third revolution – the industrial and information technology (computer) revolutions being the first two. Biotechnology may also be viewed as a 'technoeconomic paradigm' e.g. steam power, electric power and computer technology

1.1 Aims of this Paper

Our empirical knowledge of innovation processes and knowledge flows in New Zealand is embryonic. New Zealand has not undertaken innovation surveys comparable to those implemented in Europe and the OECD under the Community Innovation Survey (CIS), National Innovation System (OECD) and other projects. This paper describes the preliminary results of an ongoing study that aims to fill some of the gaps in our knowledge of innovation processes in New Zealand while using the international literature as a benchmark. The study will describe and analyse the innovation system for biotechnology in New Zealand focussing on the major actors (firms, research organisations, universities, government, overseas linkages) and the linkages among them (knowledge flows, financial flows, links with suppliers and customers, other linkages).

This paper is divided into five sections. Section 2 describes New Zealand's National System of Innovation, including a review of the effects of recent science reforms and the strength of the science base. Section 3 describes New Zealand's biotechnology based sectors and the role of private industry, research organisations and the universities. Some of the factors affecting innovation in biotechnology in New Zealand are reviewed in Section 4. The paper closes with some concluding remarks on the current state of the biotechnology sector in New Zealand.

The New Zealand Biotechnology sector is worthy of study for several reasons. While there is a large and growing international literature on economic aspects of biotechnology innovation, these studies concentrate on the United States and Europe and little has been written on New Zealand or similar countries e.g. Australia. The New Zealand biotechnology sector may be expected to develop along a different trajectory as a consequence of a markedly different set of initial and framework conditions². New Zealand has a small open economy, which has been modified by an extensive set of institutional and economic reforms including transformation of the national science and technology system towards a more market driven model. Government has indicated a strong interest in fostering innovation and aims to concentrate on selected areas where New Zealand may be able to develop a new comparative advantage. One such area is biotechnology, which would build on New Zealand's existing comparative advantage in the primary sector (dairy, forestry, meat, wool and horticulture).

1.2 The Systems of Innovation Framework

The current study uses the Systems of Innovation (SI) literature (Freeman, 1987; Lundvall, 1992; Nelson, 1993) as a theoretical framework. Central to this concept is the idea that the overall innovation performance of an economy depends not so much on how specific organisations perform but on how well they interact with each other. Systems of innovation have been analysed at several levels ranging from enterprise specific innovation systems, to local, national, regional and global systems of innovation. In focussing on a particular sector within the SI approach, this paper follows Metcalfe who explains the concept of sectoral innovation systems:

² framework conditions of national, institutional and structural factors set the rules and range of opportunities for innovation (OECD, 1997, p. 31)

as a convenient middle ground which recognises that not all the influences on technical progress lie within the firm, and that an economy wide, aggregate, approach can make little sense of the diverse conditions in which different kinds of knowledge are accumulated (1998, p. 2).

He suggests “the fundamental source of growth is innovation at the level of the firm and that it is this which underpins structural change within and between economic sectors”. He argues that there are major differences in the technical progress functions³ of different sectors that shape the overall pattern of growth. As a result the principal focus of empirical investigation should be at the sectoral level. Pavitt’s (1984) paper on sectoral patterns of technical change was an important precursor while the formal appearance of the Sectoral Innovation System (SIS) approach is generally traced back to Breschi and Malerba. They defined it as:

that system (group) of firms active in developing and making a sector’s products and in generating and utilizing a sector’s technologies. Such a system of firms is related ... through processes of interaction and cooperation in artefact-technology development and through processes of competition and selection in innovative and market activities (1997, p. 131).

Carlsson and Stankiewicz (1991) had earlier developed the alternative concept of the Technological System (TS) as a network of vertically and horizontally connected agents and organisations; somewhat different to the SIS approach where the central actors are private firms and the focus is on competitive relationships among firms. The TS research theme led by Bo Carlsson was developed under a five-year research programme on Sweden’s Technological Systems and Future Development Potential. The programme includes theoretical studies of technological systems as well as empirical studies of factory automation (Carlsson, 1995), electronics and computers, pharmaceuticals and powder technology (Carlsson, 1997); it provides an invaluable resource into theoretical and empirical aspects of the technological system approach.

Country specific factors in the development of the biotechnology industry have been extensively investigated often within a SI framework e.g. in Canada, Japan and Germany (Fransman and Tanaka, 1995; Arundel and Rose, 1999; Momma and Sharp, 1999). Less work has been published on smaller or less developed economies with the exception of Fontes and Novais (1998) on Portugal, Rickne (1999) on Sweden and various authors (Janszen and Deganaars, 1998; van Geenhuizen, 1999) on the Netherlands.

1.3 Definition of Biotechnology

The term biotechnology was coined in 1919 by Karl Ereky, a Hungarian engineer “to refer to the science and the methods that permit products to be produced from raw materials with the aid of living organisms” (OECD, 1999a). For reasons explained above, the economics literature has tended to focus on modern biotechnology defined by McKelvey as: “biological activities dependent on controlled changes to genes, and thereby intimately coupled to scientific fields such as molecular biology and biochemistry and to genetic engineering and gene therapy...” (1996, p. 81). Other authors have used a slightly wider definition; for example Orsenigo (1989, p. 61) based his analysis of patenting on the OTAF/SPRU database technical code

³ Other authors use the term ‘technological regime’ which would appear to be a very similar concept.

Bioengineering “this includes both genetic engineering and other ‘second generation’ biotechnology activities⁴...” while Eliasson and Eliasson state that:

the biotech field is thought of as consisting of three or four sub-areas: (1) recombinant DNA technology, (2) use of antibodies including phage display, and (3) protein engineering. Sometimes also: fermentation and volume production of (generic) biological substances are defined as a separate biotech area. (Eliasson and Eliasson, 1997, p. 145).

This study uses a narrow definition of modern biotechnology which broadly corresponds with the above work by Orsenigo and Eliasson. Data on activities in the fourth area (fermentation and volume production of biological substances) is presented where appropriate. The New Zealand Biotechnology Survey 1998/99 (Statistics New Zealand, 2000) uses a classification system adapted from the Canadian Biotechnology Survey. This has been used to classify biotechnology activities into modern biotechnology (narrow definition) and biotechnology (broader definition through four main categories (see Table 1).

Although the term ‘biotechnology sector’ is used in the title of this paper it would be more precise to talk about biotechnology-based sectors since as Saviotti (1998, p. 19) points out:

biotechnology is not an industrial sector, but a set of techniques for the manipulation of living organisms which comprises several disciplines which provide scientific foundations for such techniques. Both the techniques and the scientific disciplines are used for a wide variety of applications, ranging from pharmaceuticals and agriculture to the environment. It is thus appropriate to talk about biotechnology-based sectors.

⁴ these include enzymes *per se*, immobilised enzymes, starch-hydrolysates, amino acids and tissue culture.

Table 1: Classification of Biotechnology Categories

	Main Category	Sub Categories
Modern Biotechnology <i>Narrow Definition</i>	DNA Based Technology	Genetic engineering, Gene Probes Bio-informatics, Genomics Pharmacogenetics, Gene Therapy Rational Drug Design DNA Sequencing, Synthesis, Amplification
	Biochemistry or Immunochemistry based	Vaccines, Immune Stimulants Drug Design and Delivery Combinatorial Chemistry, Diagnostic Tests Peptide/Protein Synthesis and Sequencing Cell Receptors and Cell Signalling Bio-Sensing, Pheromones Molecular Modelling, Structural Biology Antigens, Antibodies, Microbiology, Biomaterials
Biotechnology <i>Broad Definition</i>	Bio Processing ⁵	Cell, Tissue and Embryo Culture Cell, Tissue and Embryo Manipulation Somatic Embryo genesis Fermentation, Bio processing, Bio transformation Bio leaching, Bio pulping, Bio bleaching Bio desulphurisation, Bio pesticide Manufacturing Extraction, concentration, purification, separation Natural Products Chemistry, Bio filtration, Bio indicators, Microbio inoculants, Bio Sensing
	Environmental Biotechnology	Bio augmentation, Bio reactors Biological Gas Cleaning Bio remediation, Phyto remediation

Note: The classification of main and sub categories in this table has been adapted from the New Zealand Biotechnology Survey 1998/99.

⁵ Excludes Classical/traditional breeding which was included in this category by Statistics New Zealand. Includes only those firms that use more sophisticated scientific and engineering principles for extraction, concentration, purification, separation and natural products chemistry. Firms using less sophisticated, traditional processes are classified as natural product producers and are not included in the biotechnology sector.

2. New Zealand's National System of Innovation

New Zealanders like to think of themselves as innovative people who can fix anything with a piece of No. 8 fencing wire⁶. This kind of innovation enabled many enterprises to develop and prosper while making do with local resources but seems to be less suited to competing in the global economy. Engelbrecht and Darroch (1999) used a range of indicators to measure innovation, knowledge absorption and diffusion and compared the performance of New Zealand with other OECD economies. Overall they concluded that “New Zealand continues to have a weak NIS⁷, despite the major changes to its research, science and technology sector since the late 1980s, and despite its openness to foreign direct investment”.

Table 2: Selected Indicators of Innovation System Performance

Indicator of:	<i>Potential to Produce Knowledge</i>	<i>Inflows of Technology</i>	<i>Absorptive Capacity</i>		<i>Evidence of Diffusion Taking Place</i>
Indicator:	GERD ⁸ as % of GDP	FDI Inflows as % of GDP	University Graduates as % of Population ⁹	Science Graduates as % of University Graduates	High and Medium Tech. Manufacturing as % of Total
All 18 Countries	2.03	1.57	0.35	23.4	43.2
G7	2.14	0.95	0.43	21.3	50.8
Small Countries ¹⁰	1.99	2.01	0.28	24.9	37.4
Australia	1.62	1.55	0.60	18.5	38.1
New Zealand	0.98	4.21	0.41	14.5	24.8

Note: All of the above data is drawn from Engelbrecht and Darroch (1999) and relates mainly to OECD data for 1996 from various sources.

Table 2 summarises results for four out of the 14 main indicators used in their study. New Zealand consistently scored below Australia and below the average for G7 and other small, high-income OECD countries. New Zealand had the poorest record of all 18 countries for potential to produce knowledge. The high level of FDI inflows and strong imports of manufactured goods mean that there should be plenty of opportunities for knowledge to flow into the country. However it had the lowest number of science graduates¹¹ of the 18 sample countries and was ranked lowest on indicators of whether diffusion had actually taken place.

⁶ the gauge of wire most commonly used on farm fences.

⁷ National Innovation System

⁸ Government Expenditure on Research and Development

⁹ i.e. the number of students graduating in 1996 as a % of the total population.

¹⁰ Austria, Belgium, Denmark, Finland, Ireland, Netherlands, NZ, Norway, Sweden, Switzerland

¹¹ See Clark and Pavlovich (1999, p. 5) for anecdotal evidence on the shortage of science graduates.

Several of the weaknesses in New Zealand's innovation system have been public knowledge for over a decade; for example Bollard et al. (1987) reported on the 1984 Probine report which found that New Zealand's R&D profile was affected by: the small scale of the economy and of most manufacturing firms; problems of isolation; problems of balancing applied and basic research and the limited number of scientists.

2.1 The Science Reforms

Problems such as these and an economy wide programme of economic reform led to a series of major changes to the organisation of science funding starting in 1991. The 66-year old Department of Scientific and Industrial Research (DSIR) was dissolved and replaced by a system of nine Crown Research Institutes (CRI's) which operate as commercial companies with their own boards and two government ministers as shareholders. They must attain 'profit' targets - surpluses of 'private' earnings over expenses - set by the government, which are then retained for investment. The purchasing of science is carried out by the Foundation for Research Science and Technology (FRST) which distributes the Public Good Science Fund (PGSF).

The rationale for the reorganisation has commonly been characterised as the application of agency theory which suggests a split between the purchaser of science (now FRST), and the providers (now CRI's and others). However Upton who was the Minister at the time states that "the science reforms... were not a case of applying a theory to a sector. Rather particular outcomes were sought which the machinery of state sector reform ably aided and abetted" (Upton, 1995 p. 2). More recent science sector reforms have aimed to foster networks and increase the flow of knowledge between researchers, industry and business. An extensive foresight process was intended to focus science spending on specific science outcomes and various other initiatives have been announced to support innovative New Zealanders.

Whatever the original rationale, the big question now is whether the reforms have done any good. Jacobsen (1991, p. 35) suggested that "the changes in science policy to date have encouraged more efficient use of research resources". Pockley (1998) provides anecdotal evidence both for and against the reforms, while Simpson and Craig (1997, p. 75) state that "there is mounting anecdotal evidence to suggest that both the quality and quantity of the science [the CRI's] are producing is on the rise". Alston et al (1998, p. 30) are concerned over the possible effects of reform in New Zealand and other developed countries. They highlight two potentially serious adverse effects; the removal of long-term guarantees of employment may reduce incentives for competent and gifted individuals to embark on research careers; and the shift in research resources towards agribusiness and food processing research which may have reduced the rate of return to public research investments.

Overall, it is too early to give a definitive answer to 'the big question' and in any case the necessary data collection and analysis has not been undertaken. All of the authors cited above base their views on theory or anecdotal evidence rather than on any representative quantitative analysis. There are bound to be substantial lags in the transformation process so the indicators collated by Engelbrecht and Darroch would not be expected to show the impact of the reforms. It has been claimed that the policy changes of the last decade have established a NIS in New Zealand which is unique amongst OECD countries (Winsley and Hammond, 1997, p. 277). The jury is still out

on whether this NIS will foster innovation and assist New Zealand to compete in world markets.

2.2 *The Science Base*

The strength of New Zealand's science base is an important determinant of the effectiveness of the National Innovation System and should also provides a strong indication of the degree (if any) of New Zealand's advantage in the area of biotechnology.

New Zealand came first in a comparative study¹² of the number of papers published per 100 scientists in 1993 and 1995 (Walker and Liu, 1998, p. 28). Biology and clinical medicine were found to account for more than half of New Zealand's scientific research papers. Overall performance was evaluated in both quantitative and qualitative terms by using relative publication ratio¹³ as a proxy measure for quantity and relative citation rate¹⁴ as a proxy for quality. While publication ratios in biology and clinical medicine were well above the world average; a possible indicator of advantage in these areas, citation ratios were slightly below the world average.

Cole and Phelan's (1999) investigation into the scientific productivity of nations found that New Zealand has a high output of scientific papers relative to the size of its economy. In a study of 43 countries New Zealand ranked seventh ahead of the UK, Canada, Australia the USA and Japan. They then used the number of highly cited papers¹⁵ as an indicator for the level of production of scientific knowledge. By this measure New Zealand's science base is slightly below average both relative to G7 and to other small developed countries. They found that the strongest correlate of high-quality papers published per capita is the number of research scientists per capita. This is consistent with the fact that New Zealand also has a below average number of scientists.

Further data on the relative quantity and quality of New Zealand science publishing is available from the ISI database for 1994-98 (Institute for Scientific Information, 2000). New Zealand authors wrote 0.56% of all 1994-98 science and social science papers on the database. New Zealand papers were heavily concentrated in areas such as agricultural, plant and animal sciences, geosciences, ecology and environmental sciences. The citation impact¹⁶ of New Zealand papers in these areas was within 10% of the world average. Papers in pharmacology were frequently cited with a relative impact of +72%, while citations in microbiology and molecular biology, biology and biochemistry were all below average. Data from the SCI¹⁷ database for 1980-1995 paints a similar picture.

¹² compared to a reference group of countries comprising Australia, Denmark, Finland, Ireland, Norway and Sweden.

¹³ Relative Publication Ratio is the ratio between a country's papers in a field as a percentage of total country papers, and the percentage of world papers in that field.

¹⁴ Relative Citation Rate is the average citation for New Zealand papers in a field relative to the average citation rate for all papers in the Science Citation Index.

¹⁵ Based on the number of papers published in 1987 which received 40 or more citations by the Science Citation Index between 1987 and 1991.

¹⁶ this is the same as Relative Citation Rate (see above)

¹⁷ Unpublished data provided by the Ministry of Research, Science and Technology

Berridge (1999) analysed New Zealand science publications using the science citation index database¹⁸. Total New Zealand publications as a percentage of total world publications fluctuated between 1990 and 1995, and increased from 1996-99, mostly attributable to more publications by universities. He also found that:

relative to world publications, non-university publications declined by 3.5% per year over the 1990-96 period and appear to have stabilised since. Interestingly publications with Ag in their institutional title increased steadily 1990-99, both as total publications and as a percentage of total world publications.

He concluded that “science restructuring has had some deleterious effects on science performance in non-university science institutions as measured by international publications” and that publications in the agricultural and medical fields have run counter to these trends and increased.

Overall, New Zealand’s science base is relatively small (compared to G7 and small OECD countries) and is heavily skewed towards certain areas (e.g. biology, clinical medicine and agriculture). New Zealand scientists have a high productivity (measured by papers per scientist) but New Zealand science is not highly cited internationally except in a handful of specialist areas e.g. pharmacology.

3. Biotechnology in New Zealand

Despite the small size of its economy and of its science base New Zealand has had a significant role in the biotechnology revolution. New Zealand contributed to the birth of modern biotechnology through the first description of the structure of DNA by a New Zealand biophysicist, Dr Maurice Wilkins who was later jointly awarded the Nobel Prize with Crick and Watson (New Zealand Trade Development Board, 2000, p. 2)

Much of New Zealand’s work builds on national strengths in agricultural and primary industry production and research. But there are also a number of new enterprises at the forefront of research in health and in intellectual property. Recent examples cited by BIOTENZ (1998) include:

- Breeding of transgenic crops with virus and insect resistance.
- Clonal afforestation through the development of micro propagation techniques to select superior tree variants for large scale forestry.
- Genetic manipulation of flower colour.
- The world's first enteric bacteria-based bio insecticide, for the control of grass grubs.
- Test kits using monoclonal antibodies for residues in plant and animal tissue.
- A project to map the sheep genome - The world's first sheep genetically engineered for increased wool production.
- The world's first recombinant livestock vaccine, to combat sheep measles.

Most modern biotechnology activities in NZ are concentrated in universities and CRI’s and a small number of private sector companies e.g. Genesis (Probe,

¹⁸ the ISI web of Science, Science Citation Index Database

ViaLactia). The government has been estimated to spend around NZ\$100m a year¹⁹ on biotechnology-related research ranging from genomics to processing of natural products” (Rolleston, 1999, p. 46). Genesis has invested NZ\$41 million in research since its inception in 1994 while CRI’s and companies such as Auckland UniServices have also been successful in generating research revenue from outside the government sector. Nonetheless it must be recognised that New Zealand’s total expenditure on biotechnology research is very small by global standards. Total public and private R&D expenditure in 1998 would not have exceeded NZ\$150 million²⁰ – around 1% of the R&D expenditure by the 330 public biotech companies tracked by Ernst & Young (1999b) in their annual survey of the international biotech industry.

Few innovations or processes in modern biotechnology have reached the stage of being commercialised for example the CEO of a large research institute indicated that “most of our work is in the early discovery or experimental stage where we are genetically engineering animals to get proof of function²¹”. Genesis Research and Development is perhaps closest to achieving income from a new biotechnology product – it received FDA clearance to start phase II Psoriasis clinical trials in January 2000; one of over 300 biotech products now in phase II or phase III trials...(Ernst & Young, 1999b, p. 35).

A study was conducted by Tradenz in 1994 to investigate the foreign exchange earning potential of the pharmaceutical and biotechnology industry. Taking a relatively broad definition of biotechnology it was concluded that total turnover was around NZ\$330 million with foreign exchange receipts of around NZ\$137 million (around 0.7% of total merchandise exports). Industry estimates of growth rates for different categories of firm ranged from 16 to 25% per annum. These figures exclude traditional areas such as dairy and other food production e.g. New Zealand Dairy Exports of NZ\$4.6 billion in 1998/9. If biotechnology in traditional food applications (Cheese, yoghurt, beer) and natural health products including deer velvet are added BIOTENZ estimate that the industry could have a turnover of NZ\$7-11 billion by 2010²².

Little hard data on the size and activities of modern biotechnology firms in New Zealand is available; this will be rectified by the present study and a survey of organisations involved in biotechnology which will be conducted by Statistics New Zealand in the current year. However a preliminary analysis of the New Zealand modern biotechnology sector has been carried out using a database of firms and research organisations built up from website information on the members of the New Zealand Biotechnology Association and BIOTENZ and from a search of New Zealand newspapers, magazines, journals and the NZBA newsletter. All organisations

¹⁹ Total spending on ‘the Science Envelope’ for 1999/2000 is estimated at NZ\$586 million (Ministry of Research Science and Technology, 1999, p. 7). New Zealand’s 1999 GDP was NZ\$98.9 billion.

²⁰ Ernst & Young (1999a) estimated Australian total R&D expenditure on biotechnology in 1998/99 to be A\$491 million (NZ\$614 million) 52% being government funded. On a population basis Australia would be expected to spend five times as much as NZ. However the estimate for New Zealand is for a broader definition of biotechnology and so is not comparable.

²¹ Interview A, 11 April 2000

²² Based on 2.5% p.a. annual growth GDP would be around NZ\$130 billion – so this would be around 7% of GDP.

described by Kennedy and Davies in their description of “The Impact of Biotechnology on New Zealand Industry 1984 - 1994” (1994) were also categorised and included in the database, with information being updated where possible. An outline of the New Zealand’s biotechnology sector based on this analysis is presented as Table 3.

It may be seen that the modern biotechnology sector consists of approximately 40 organisations (20 private companies, 2 trade organisations, 11 research organisations and 7 universities) employing of the order of 1250 people. A further 40 firms are involved in various kinds of bio processing activity and employ over 500 people in ‘biotech based activities’. Table 3 also includes 30 firms involved in the production of natural products or nutraceuticals that are members of NZBA or BIOTENZ.

Table 3: An Outline of the New Zealand Biotechnology Sector

		Private Sector Firms	Producer Boards	Research Organisations	Universities
DNA Based <i>e.g. genetic engineering, genomics, bio-informatics</i>	# Organisations # Employees Examples	10 300 <i>Genesis, PPL Therapeutics, Fletcher Challenge</i>	2 (+?) ? <i>New Zealand Dairy Board – ViaLactia, Wool Board</i>	11 450 <i>AgResearch, HortResearch, Mallaghan Institute</i>	7 150 <i>Auckland, Otago, Massey, Waikato, Lincoln</i>
Biochemistry/ Immunochemisry <i>e.g. vaccines, protein synthesis, antigens, antibodies</i>	# Organisations # Employees Examples	10 350 <i>Immuno-Chemical Products Ltd</i>	<i>See above (most of these are also involved in biochemistry/immuno chemistry based activities).</i>		
Bio processing <i>e.g. fermentation, cell & tissue culture, bio pesticides</i>	# Organisations # Employees Examples	40 550 <i>Tatua, NZ Pharmaceuticals</i>			
Environmental Biotechnology <i>e.g. bio augmentation, bio-remediation</i>	# Organisations # Employees Examples	2 (+?) 25 <i>Waste Solutions Ltd</i>			
Natural Products and Nutraceuticals	# Organisations Examples	30++ <i>Herb Farm, Zeal Extracts Ltd</i>	<i>Note: data in this category is for NZBA and BIOTENZ members only.</i>		

Note: Data in this table should be regarded as preliminary. Estimates for number of organisations in each category have been rounded. Estimates for number of employees ‘in biotech’ are from NZBA data base and other sources. Organisations above the bold line fall under the modern biotechnology sector.

3.1 Trade and other Organisations Concerned with Biotechnology

Since biotechnology cuts across a range of industries there are several different trade organisations with a strong interest in the subject ranging from agricultural (dairy, meat, deer and wool) and horticultural (pip fruit, citrus growers, kiwi fruit) through to medical e.g. Health Research Council. The New Zealand Biotechnology Association (NZBA) provides a broad forum to represent the interests of “those concerned with biotechnology in New Zealand²³”. It uses an amended version of the OECD

²³ Objectives of the NZBA at <http://www.biotech.org.nz/objectives.htm>

definition²⁴ of traditional biotechnology “the application of scientific and engineering principles to the processing of material by biological agents and the processing of biological materials to improve the quality of life” and so includes a range of companies which produce or sell natural products, nutraceuticals and dietary supplements. Their web site lists 90 members in their on-line directory; including manufacturers, processors, distributors, consultants and research organisations. They publish a quarterly newsletter and hold an annual conference.

BIOTENZ is a group of leading New Zealand providers of biotechnology and pharmaceutical products and services. BIOTENZ is supported by Tradenz, the New Zealand Government's export promotion arm²⁵. The BIOTENZ website lists 38 members, many of whom are also members of NZBA. A number of organisations have also been active in setting up the Life Sciences Network which is an attempt to bring together companies involved in biotechnology²⁶. The Independent Biotechnology Advisory Council (IBAC) was established in 1999 with the objective of stimulating dialogue and enhancing public understanding about biotechnology. It will also provide independent advice to government on environmental, economic, ethical, social and health aspects of biotechnology²⁷. The council's work has, at least for the next year been somewhat overtaken by the appointment in April of a Royal Commission on Genetic Modification which will:

inquire into and report on the strategic options available to enable New Zealand to address genetic information now and in the future. The Royal Commission may also recommend any changes in the current legislative, regulatory, policy or institutional arrangements for addressing genetic modification technologies and products in New Zealand (Royal Society of New Zealand, 2000b).

3.2 *Private Sector Modern Biotechnology Firms*

New Zealand has very few ‘classic’ biotech firms based on the development and commercialisation of intellectual property. By far the largest is Genesis Research and Development, which focuses on the generation of EST²⁸ databases from microbes plants and animals and searching for genes of economic importance. Genesis has over 90 employees and a rapidly expanding intellectual property portfolio²⁹. Genesis has partnerships with Fletcher Challenge and Carter Holt Harvey³⁰; large forestry companies which have invested heavily in biotechnology in New Zealand. Fletchers has been involved in commercial production of cloned pine trees through somatic embryo-genesis for several years. Carters followed the more difficult organo-genesis route and is now ready to start trials of genetically modified trees. Both companies took leading roles in promoting biotechnology research in association with the Forestry Research Institute³¹. As a result this is now an area where New Zealand based firms and scientists are at the forefront of technology; Arborgen the world's leading forestry biotechnology company is a joint venture between two huge US

²⁴ See Bull (1982)

²⁵ BIOTENZ web page at <http://www.biotenz.org.nz/>

²⁶ Interview A, 11 April 2000

²⁷ IBAC web page at <http://www.ibac.org.nz/terms.htm>

²⁸ Expressed Sequence Tag – single pass sequence files of an organisms expressed genome.

²⁹ 11 patents issued, 3 granted, 80 applications (interview, 5 April 2000)

³⁰ through it's parent International Paper

³¹ interview D, 1 May 2000

companies (International Paper and Westvaco Corporation) and three New Zealand companies (Fletcher Challenge Forests, Genesis and Carter Holt Harvey).

Other firms are involved in research and trials towards use of genetically modified organisms e.g. PPL Therapeutics which has a flock of genetically modified sheep which will be used to produce a human protein for treatment of cystic fibrosis and New Zealand King Salmon which is researching growth-enhanced salmon using genetic manipulation techniques (NZBA, 1999). Another company is involved in genetic improvement in plants and “is best known for its success in developing novel coloured varieties of cut flowers”(NZPA, 2000b). Multinational agricultural biotechnology companies e.g. Pioneer and Monsanto are represented in New Zealand although no genetically modified crops have progressed beyond field trials.

Production of vaccines, antigens, antibodies and associated technologies is an area where New Zealand is relatively strong e.g. Immuno-Chemical Products Ltd which manufactures and markets embryo transfer chemicals, hygiene test systems and biochemicals. There are also a number of pharmaceutical firms with local research and production facilities which are involved in the biotechnology sector to some degree; for example Bomac a producer of animal health products has provided funding to enable a multi-million dollar expansion of Massey University’s Institute of Veterinary & Biomedical Science (Leech, 1999).

A number of small biotechnology companies are either university spin-offs or have other strong university links. Auckland UniServices has probably the strongest record in establishing such companies:

Based on the work of a team led by Professor Peter Gluckman at the University of Auckland Medical School, Auckland UniServices has established a spin off company, NeuronZ Ltd, that is pioneering a revolutionary therapy for rescuing brain cells damaged by injury and stroke. Another UniServices company, Physiome, a joint project with Oxford and Johns Hopkins Universities based in New Jersey, is developing world-first technology for computer modelling of human organs. (New Zealand Trade Development Board, 2000, p. 3)

Other companies have strong links with, or are owned by other New Zealand universities particularly Lincoln, Massey, Otago and Waikato.

3.3 Private Sector Bio Processing Firms

New Zealand also has a large group of bio processing firms that might be included in a broader definition of the biotechnology sector. These range from sophisticated operations e.g. manufacture of purified protein and bioactive peptide fractions from milk to simple extraction of raw materials from natural products e.g. essential oils. The more sophisticated firms are mainly involved in extraction of high value products either from milk or from animal by-products. Some firms were founded to take advantage of a ready supply of animal by-products but have grown to the extent where they import most of their raw materials (and find that imported products are cheaper than those available on the domestic market).

None of the traditional biotech firms interviewed to date had any plans to move into modern biotechnology – indeed some are already competing against products produced using GM organisms and use their ‘natural’ production methods to gain marketing advantage.

3.4 *Producer Boards and Trade Organisations*

There have been some major initiatives recently to investigate how New Zealand's primary industries should react to, or participate in the biotechnology revolution. Both the wool and dairy boards have recently completed reviews with the assistance of outside consultants. The sheep industry is reported to have acquired "a very good base for driving forward in biotechnology [that was] ... totally driven by scientists ... irrespective of what the industry thought they needed"³².

Early in 1999 the New Zealand Dairy Board (NZDB) announced that it would boost its research spending by up to NZ\$150 million over the next five years to investigate the potential of biotechnology (NZPA, 2000a). This followed a comprehensive investigation by an industry wide team including AgResearch (New Zealand's largest CRI) and outside consultants which concluded "that an opportunity existed for New Zealand to lead the world in dairy biotechnology and that the potential benefits could be in the region of one billion dollars" (NZDB, 1999). The investment is to be concentrated into three main areas: forage biotechnology, marker assisted selection and transgenics.

Research into ryegrass and white clover will use biotechnology to increase the productivity of New Zealand's pasture based dairy production system. The ability to accurately assess genotype will accelerate the rate of genetic gain in the national dairy herd. Research into cloning and transgenics "will position the New Zealand dairy industry to take advantage of these technologies if it so wishes" (Marshall, 2000, p. 171). The industry's investment in biotechnology and the associated intellectual property is to be managed by a wholly owned NZDB subsidiary called ViaLactia. It is reported that ViaLactia will be a relatively small company which will outsource R&D from leading research organisations both in New Zealand and overseas. ViaLactia recently announced its first major outside research contract - with Celera Genomics:

ViaLactia Biosciences New Zealand Ltd, a subsidiary of the Dairy Board, has signed an agreement with Celera Genomics of Rockville in the United States which will enable more rapid improvement of the national dairy herd, particularly through better sire selection...This pilot project will sequence around 10 percent of bovine genes and will be a forerunner of a much larger project involving a greater number of target genes. An early output from the project will be the identification of 'gene markers' for livestock selection. The availability of these markers will enable the use of DNA profiling to identify milk production and other traits in individual animals and thus facilitate more precise natural selection for breeding (Royal Society of New Zealand, 2000a).

3.5 *Research Organisations*

Several of New Zealand's Crown Research Institutes (CRI's) are taking a leading role in biotechnology research. "The largest CRI, AgResearch has five research campuses, over 1100 staff, of whom nearly 200 have PhDs and an annual research budget of NZ\$90 million (New Zealand Trade Development Board, 2000, p. 4).

AgResearch operates a molecular biology unit in conjunction with the University of Otago which is building genetic maps for sheep and identifying DNA markers for disease resistance, reproduction, wool quality, meat quality and other desired characteristics. The unit also "owns and operates the international databases for sheep

³² Interview F, 8 April 2000

and deer genes. The sheep map contains 100,000 genes that may find expression in new protein products and services” (Mazoyer, 1999, p. 6).

AgResearch is also working on development of transgenic livestock (L’Huillier, 2000, p. 186) and has applied to the New Zealand Environmental Risk Management Authority (ERMA) to undertake genetic modification studies for potential applications in therapeutics and functional foods. “This work has two ultimate applications... firstly for the possible development of a new treatment for multiple sclerosis; and secondly, to modify milk composition to make it richer in casein or reduce its content of beta-lactoglobulin” (AgResearch, 1999, p. 9).

The CRI’s also have a number of spin-off companies which handle their biotechnology products e.g. AgVax which manufactures toxoplasma³³ and other vaccines; and Genomnz which uses genetic identification technology to identify parentage and characteristics of animals.

3.6 Universities

New Zealand universities have been active in various aspects of modern biotechnology. Massey University began the first undergraduate degree course in 1967 and has a strong record in several areas including structural biology. In 1978 Baker succeeded in solving the 3D structure of actinidin, an enzyme from kiwi fruit “even today with more than 1000 protein structures solved this remains one of the ‘best’ structures in the protein database and it enabled a great deal of new information to be uncovered about how protein structures are built and stabilised (Baker, 1998, p. 12)”. Researchers at Massey University went on to solve the structure of lactoferrin. “This established international credibility and enabled the build up of the critical mass of researchers that is essential to build up a vigorous research programme” (Baker, 1998, p. 13). Professor Baker now heads the Laboratory for Structural Biology at the University of Auckland that comprises some 25 researchers, including 3 academic staff and 12 Postdoctoral fellows (Farrell, 1999, p. 6).

The University of Auckland Medical School is another centre of research excellence which has led to the creation of several spin-off companies³⁴. Jim Watson was head of the Department of Molecular Medicine before he used his understanding of signalling molecules³⁵ to found Genesis Research and Development. Researchers at the University of Waikato have strong links with the forestry industry and are working on a joint project to develop and commercialise bio control products for use against sapstain³⁶. The university also owns Pacific Enzymes which works on the “isolation of novel thermophilic organisms which express industrially useful enzymes and the cloning of their respective genes”³⁷.

The University of Otago runs a Molecular Biology Unit in conjunction with AgResearch which works on molecular tools for genome analysis and is an

³³ toxoplasma infections are a key cause of abortion in sheep (New Zealand Trade Development Board, 2000, p. 12)

³⁴ See Auckland UniServices in the section above on Private Modern Biotechnology Companies

³⁵ Interview E, 5 April 2000

³⁶ Sapstain is caused by a specific fungi which invades radiata pine causing revenue losses estimated at NZ\$100 million p.a.

³⁷ NZBA web pages: <http://www.biotech.org.nz/dir/pacificenzymes.htm>

international leader in the application of sheep and deer gene maps for agricultural and biomedical research³⁸. A Lincoln University spin-off company has developed a biosensor that uses whole microorganisms to “slash the time needed for environmental testing of pollutants in waste water from five days to an hour” (Birss, 2000).

The examples outlined above illustrate the existence of several pockets of excellence in the university sector. While a number of these have been associated with the creation of spin-off companies, there is no sign that New Zealand is likely to experience anything like the surge of biotech start-up activity that was experienced in the United States.

3.7 *Data from Patenting*

The use of data from patenting as an indicator of innovative activity has been well established for many years³⁹. There is also a rapidly increasing literature in the biotechnology area based on analysis of patents (Joly and Looze, 1996; Malo and Geuna, 1999; Foltz, Barham and Kim, 2000; McMillan, Narin and Deeds, 2000).

A preliminary analysis of New Zealand patenting activity in biotechnology was carried out using international applications published in the Patent Cooperation Treaty (PCT) Electronic Gazette⁴⁰. The PCT provides for the filing of an international application to have the same effect as a national application in each of the contracted states designated in the application (OECD, 1994, p. 19); it thus provides a useful measure of international patenting activity. Use of applications data provides a more immediate picture, since it can take up to five years from the first application for a patent to be granted⁴¹.

Methodology based on Engelbrecht and Darroch (1999) was used to compare New Zealand’s rate of patenting with G7 and a reference group of high-income OECD countries (see Table 4). For the purposes of this analysis modern biotechnology was taken to be synonymous with the International Patent Class C12N, while a ‘Broad Definition’ of biotechnology included a number of other classes detailed below⁴².

New Zealand’s rate of modern biotech patent applications at 8 per million of population is below the average for the G7 (13.6) and for a reference group of small developed OECD economies (15.4); these results are essentially unchanged when the broader definition of biotechnology is used. Patent application rates range from a high of 44 for Denmark to a low of 1.4 for Italy. Overall New Zealand ranks twelfth out of 18 with a patenting rate slightly above that found in France, Germany and Japan. However New Zealand’s performance is disappointing compared to other small countries with strong primary industries that it might hope to emulate e.g. Denmark (44.1), Netherlands (16.6), Australia (12.1).

³⁸ University of Otago web pages: http://www.otago.ac.nz/research/centres/units/res_unit_molecular_biol.html

³⁹ See Griliches (1990) for an excellent survey.

⁴⁰ Web page: <http://pctgazette.wipo.int/>

⁴¹ Lead times for patent application procedures are summarised in OECD (1994, p. 27).

⁴² Includes A01G, A01H, A01N, C12M, C12N, C12P, C12Q – defined as ‘General Biotechnology’ by Joly and de Looze (1996).

Table 4: New Zealand and OECD Patenting Rates in Biotechnology

	<i>PCT Patent Applications (1 Jan 1997 – 15 May, 2000) per million population</i>	
	C12N Modern Biotechnology	Broad Definition
All 18 Countries	13.8	22.5
G7	13.6	22.2
Small Countries ⁴³	15.4	25.7
Australia	12.1	19.1
New Zealand	8.0	15.7

Table 5 breaks down New Zealand patent applications by organisational type. While the results are broadly consistent with the relative size of the different groups (see Table 3), they also indicate a higher rate of patenting by universities and private companies compared to Crown Research Institutes. Genesis and its partner Fletchers dominate private sector patenting; they were responsible for 37% of all PCT applications under patent class C12N.

Table 5: Breakdown of New Zealand PCT Patent Applications 1997-2000

International Patent Class	C12N	Broad Definition
No of Patent Applications	30	59
No of Different Applicants	24	46
Total NZ Applicants	35	69
Breakdown of NZ Applicants:		
Private companies and individuals	63%	62%
<i>of which Genesis, Fletchers & subsidiaries</i>	37%	20%
Crown Research Institutes	17%	20%
Universities (including associated companies)	17%	12%
Producer Boards	3%	6%
Total NZ Applicants	100%	100%

⁴³ Austria, Belgium, Denmark, Finland, Ireland, Netherlands, NZ, Norway, Sweden, Switzerland

4. Factors Affecting Innovation

4.1 *The Innovation System for Biotechnology*

The OECD's Oslo Manual (1997, p. 31) lays out a useful framework that allows us to relate science investment to all the other factors that may affect innovation. It describes four categories of factors relating to innovation:

- the *framework conditions* of national institutional and structural factors
e.g. economic, financial and educational setting and the rules and range of opportunities for innovation
- the *science and engineering base*
the accumulated knowledge and the science and technology institutions which underpin innovation
- *transfer factors*
which strongly influence linkages and flows of information etc which are essential to innovation
- the *innovation dynamo*
dynamic factors shaping innovation at the level of the firm

In other words, science investment is only one of a large number of factors that affect the rate of innovation. Even the best managed science investment may have poor outcomes if other aspects of the innovation policy terrain are in poor shape e.g. if there is a shortage of appropriately trained staff; if the economic climate discourages innovation; or if the network of institutions firms and organisations does not have a system of linkages which encourages the effective dissemination of results.

The heading of this section begs the question as to whether New Zealand does have a network of institutions firms and organisations, *an innovation system*, which encourages the effective dissemination of results. The system, if it exists, is dominated by crown research institutes and universities which rely on the government for the majority of their funding. Research and teaching in biotechnology is carried out in seven of New Zealand's eight universities. Biotechnology research is also carried out at eight of the country's nine Crown Research Institutes⁴⁴. Indeed this spread of activity has been argued to be a serious waste of resources by some who believe that it would be more efficient to concentrate biotech research into a smaller number of sites.

Data from interviews with biotech industry representatives carried out as part of this study provide little evidence for the existence of a well functioning innovation system for biotechnology. Private firms did not place high importance on strong linkages with CRI's and universities. Universities and CRI's do not generally have particularly strong linkages; indeed the relationship is often more one of competition for scarce research funding. Nor is there much movement of staff between CRI's, universities and the private sector. Turnover at the CRI HortResearch was reported to be 3-5% per annum "there were limited cross-CRI transfers and just a few people moving on to universities or polytechnics" (Clark, Pavlovich et al., 1999, p. 6).

⁴⁴ this under represents the geographic spread of biotech research since most CRI's are spread over several different campuses.

Some private firms placed little emphasis on linkages in development of biotechnology innovation; others found few organisations worth linking with (perhaps because the modern biotechnology sector in New Zealand is so small) – and so concentrated on developing strategic alliances and joint ventures with overseas partners. Others felt that CRI's and universities have little to offer them:

they operate on a completely different time horizon ... the difference between commercial reality and university and government research is so wide that most people cannot understand that what they are doing never actually achieves a desired outcome (interview C, 30 March 2000).

This view is supported by another biotech CEO quoted in Mazoyer (1999): “NZ does not have a broad range of public research agencies that are well inter-linked. There may not be much cross-over into industry – in fact the public research system seems to operate in a sector of its own”. Opinion is divided as to whether it is the public research agencies which don't meet the needs of the private sector⁴⁵ or the private sector which has a limited ability to apply the results of publicly funded R&D or to evaluate opportunities (Winsley, Couchman and Gilbertson, 1998, p. 61). It is not surprising then, that Mazoyer goes on to conclude that “commercialisation is sometimes hindered by a lack of interaction between the science sector and manufacturers ... [and that] more effective learning interactions and networking between scientists, public and private investors and users need to be encouraged” (1999, pp. 6-7).

Modern biotechnology activity in New Zealand may perhaps be better described through the idea of ‘islands of excellence’⁴⁶. Leading edge work is carried out in a number of areas; but these islands of excellence tend to collaborate strongly with a small number of other organisations rather than being strongly connected to any wider innovation system. A good example is provided by the forestry industry where a small number of leading companies collaborated with the Forest Research Institute to promote research into forest biotechnology. Carters were able to develop the ability to genetically transform pine trees using a company scientist, a recent graduate with an MSc in biotechnology and email contact with a colleague in Canada⁴⁷. The innovation system for forestry biotechnology in New Zealand is now concentrated on the biotech company Arborgen and its shareholders.

Similarly Genesis was founded using intellectual property from the University of Auckland and has strong partnerships with two CRI's, the New Zealand Dairy Board and six overseas companies. However Genesis can probably be best characterised as being part of the international innovation system for biotechnology rather than having particularly strong links with many New Zealand based institutions.

4.2 *Framework Conditions for Innovation*

Many of those interviewed for this study had serious concerns about New Zealand's framework conditions for innovation. They focussed particularly on “the lack of a pro-business environment, national attitudes to entrepreneurs and risk takers and the regulatory framework which has made New Zealand an expensive country in which to do business”. One interviewee cited the recent increase in the top rate of income tax

⁴⁵ see also Frater, Stuart, Rose and Andrews (1995, p. 179)

⁴⁶ also the title of a 1993 report by the New Zealand Institute of Economic Research

⁴⁷ interview D, 1 May 2000

as an example of negative attitudes to business that has harmed their ability to recruit scientists internationally. He also expressed the opinion that “we don’t like people being enterprising, we don’t admire people being rich [and]... if we don’t have an admiration for people taking risks and being successful then we won’t have innovation in biotechnology⁴⁸ .

Work on genetically modified and new organisms in New Zealand is controlled by the Hazardous Substances and New Organisms (HSNO) Act 1996 which aims to “protect the environment, and the health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms” (Environmental Risk Management Authority, 1999). Serious concerns have been expressed both about the degree of control and the associated delays: “it can take 18 months to get approval from ERMA to do a piece of research ... by the time you get approval to do it, it is a whole new world, literally”⁴⁹. The University of Otago recently fell foul of ERMA regulations on “a very low risk project that in any other country would not require the approval of a regulatory authority” (Cassie, 2000).

Firms involved in extracting high value products from animals also commented that various regulations administered by the Ministry of Agriculture and Forestry (MAF) increased their costs and put them at a competitive disadvantage when exporting. A new Animal Products Act which came into effect in 1999 regulates the production and processing of animal material and products in order “to protect human and animal health and facilitate overseas market access”⁵⁰. Hopefully this Act will reduce these problems and prove to be less prescriptive.

On the positive side; research costs are estimated to be 40% below international levels (New Zealand Trade Development Board, 2000, p. 4). This and New Zealand’s rigorous border controls and relatively disease free status have been pushed heavily by BIOTENZ and the New Zealand Trade Development Board in an attempt to increase overseas funding of biotechnology activities in New Zealand.

Unfortunately these low research costs are a double-edged sword when it comes to attracting overseas talent and retaining top New Zealand scientists as illustrated by the following quotes from Petersen and a CRI manager:

We were recruiting a plant breeder. We had a very good candidate from the US who we brought out here. We paid for him to come out. We said we don’t want you to come just for an interview, come for a week. You need to find out about us and we need to find out about you. He was our preferred candidate. We offered him between \$5,000 - \$10,000 more per annum starting salary. So we really wanted this person. But he converted his dollars back and said “No” (Clark, Pavlovich et al., 1999, p. 5).

Petersen (1998) was initially the only scientist working on DNA chemistry in the Southern Hemisphere. DSIR encourage his research even though it was clear that any possible applications were years off ... Petersen makes some excellent points on how internationally competitive research should be supported in New Zealand:

If we want our research to be internationally competitive, then our graduates have to trained to international standards and be given internationally-equivalent

⁴⁸ interview E, 5 April, 2000

⁴⁹ interview A, 11 April 2000

⁵⁰ MAF web site: <http://www.maf.govt.nz/animalproducts/>

research opportunities. Yet this makes them susceptible to offers from other countries and, and if we want them to stay in New Zealand or return to New Zealand after their post-doctoral training, we are going to have to do that extra bit to make them want to make their long-term careers in their own country (Petersen, 1998, p. 7).

4.3 *Government Policy*

Over the six years from 1984 to 1991 New Zealand engaged in “one of the most radical market liberalisation programmes initiated anywhere in the world” (Massey, 1995, p. xii), “transforming New Zealand from the most to the least regulated economy in the OECD” (Hazeldine, 1998, p. 1).

Interest rate controls were removed, agricultural subsidies were phased out, New Zealand moved to a floating exchange rate regime, monetary policy was given a single statutory objective of maintaining price stability, detailed industrial and occupational regulations were replaced with a generic commitment to competitive markets, import quotas and tariffs were eliminated or reduced, public sector management was reformed, trading departments were converted into State-owned enterprises with a clear commercial focus, and a programme of selling State assets was commenced (Dalziel, 1999, p. 1).

These non-interventionist, free market policies continued to dominate the New Zealand political scene until the election of a new Labour government in 1999. There have been neither large-scale policy interventions designed to increase R&D spending nor major funding initiatives to promote biotechnology. Indeed government and industry only seem to have started taking a close interest in biotechnology in the last three to four years⁵¹.

There are now signs of a more interventionist approach to science policy. As part of the most recent round of policy adjustments New Zealand’s Foundation for Research, Science and Technology (FRST) has developed a series of Strategic Portfolio Outlines (SPO’s), which will guide its investments. Investment in biotechnology falls under the Advanced Biological Enterprises SPO which aims to:

generate wealth for New Zealand by assisting the migration of the country’s economy into new and emerging markets. To do so, this SPO will seek to develop a coordinated and focused approach to establishing a vibrant biotechnology-based sector (Foundation For Research Science and Technology, 2000, p. 1)

The document goes on to describe “principles and behaviours to be encouraged” which include⁵²:

- the need for a targeted, rapid and flexible investment system by Government;
- the development of an entrepreneurial spirit;
- partnerships and linkages between stakeholders;
- increase global linkages to exploit New Zealand’s competitive advantage; and
- enhanced integration and leadership among sector groups and along value chains.

New Zealand’s approach has contrasted strongly with some of its regional trading partners. In Australia, the federal government established two new agencies “to ensure Australia realises the potential gains being offered by biotechnology”⁵³. The

⁵¹ Interview F, 8 April, 2000

⁵² See FRST web page: <http://www.frst.govt.nz/public/foresight/spo/ABE.htm>

⁵³ See Biotechnology Australia web page: <http://www.isr.gov.au/ba>

Singapore Government has a strategy 'to position Singapore as the strategic hub for the pharmaceutical, biotechnology and health care industry in Asia' while Taiwan aims to develop into 'an Asia-Pacific R&D Center' and 'an Asia-Pacific Manufacturing Center for high-tech products'. Taiwan currently spends NZ\$200 million per year on biotech and is increasing its technology budget by 10-15% per year (Rolleston, 1999, p. 43).

There is a significant level of dissatisfaction with government policy towards research, science and technology in New Zealand. Comments such as "I don't think science management in New Zealand has been a great success" and "put money into the private sector not FRST"⁵⁴ are frequently heard. A more specific criticism is that "the science reforms produced an over-emphasis on incremental innovation or technology and undermined the science base, leaving less time for research from which big new ideas could emerge" (quoted in Mazoyer, 1999, p. 9).

A "focus on small projects focussed on individuals has taken away the ability of CRI's to build future science capabilities"⁵⁵. This is supported by Petersen (1998, p. 10) who suggests "there must be some mechanism that allows scientist to be kept on the payroll while alternative funding routes are worked out". There is a serious brain drain of students completing PhD's "because they are not prepared to spend the rest of their lives living from hand to mouth on short-term contracts".

The impact of funding constraints is commented on by Baker (1998, p. 15) " I consider it a tragedy that New Zealand has no agency that can fund major equipment. It severely limits our ability to take advantage of the new opportunities in the current biological revolution".

On a more positive note some interviewees found that government programmes to encourage technology transfer were useful. They attributed low uptake of these programmes to company culture and short termism. Others said accountability requirements in using TBG, PGSF and GRIF are excessive (Mazoyer, 1999, p. 10).

4.4 *R&D Funding*

It has been well known for some years that New Zealand's expenditure on R&D is low relative to other OECD members. In 1996 New Zealand's gross expenditure on R&D (GERD) was 0.98% compared to 2% or over for G7 and a group of small OECD countries (Engelbrecht and Darroch, 1999). Spending by New Zealand industry, as a % of GDP was 0.26% in 1995, far below the OECD average of 1.46% (OECD, 1999b, p. 131). While no comprehensive data is available on R&D expenditure on biotechnology, it may be logical to assume that "if New Zealand is bad at doing R&D generally it would [expect to be] a whole lot worse in the biotech area"⁵⁶.

One factor that would be expected to affect the level of R&D expenditure by industry is the tax and incentive regime. In a recent review of the evidence on the effects of fiscal incentives for R&D, Hall and Van Reenen (2000, p. 449) concluded that "in the

⁵⁴ interview F, 8 April 2000 and interview E, 5 April 2000

⁵⁵ interview A, 11 April 2000

⁵⁶ interview B, 5 April 2000

current (imperfect) state of knowledge ... a dollar in tax credit for R&D stimulates a dollar of additional R&D”.

All OECD countries except New Zealand have special tax schemes for R&D expenditures such as immediate write-off and various types of tax credit, indeed New Zealand comes bottom of an OECD league table of the amount of tax subsidy for R&D (OECD, 1999b, p. 135). In New Zealand, private sector expenditure of one dollar costs companies \$1.13 after tax and compliance are included. This compares to 89 cents in Australia, 83 cents in Canada and 69 cents in Spain.

It has also been suggested that differences in national tax regimes may significantly bias reported levels of R&D expenditure. The negative treatment of such expenditures in New Zealand encourages under-reporting⁵⁷ while the favourable treatment in other countries encourages widespread over-reporting.

Industry views appear to be somewhat polarised on whether the tax treatment of R&D spending has had a major effect on the level of expenditure in the private sector. Some large players saw this as a key influence: “the 150% tax rebate meant that you could do research for free in Australia and make money out of it ... it was a pretty favourable regime – nothing like that here”⁵⁸. Others were more sceptical: “I have not seen results that suggest support of R&D delivers real commercial benefits”⁵⁹.

Difficulties in obtaining venture capital may also constrain start-up or expanding biotech firms in New Zealand. Until recently no venture capital appeared to be available for biotechnology and companies relied on traditional methods of funding. Recently Morel Bank and Direct Capital partners have provided funds to the industry, the former being listed in the NZBA Biotechnology Directory (Hynes, 1999, p. 26). Auckland UniServices has also helped to establish a seed fund with starting capital of around NZ\$15 million; it will establish in on-going research in the high-tech area, with the caveat that it should direct half its funding to matters arising out of the University of Auckland (Lee, 2000).

5. Summary and Conclusions

New Zealand has some ‘islands of excellence’ where world-leading biotechnology R&D is carried out and despite its small size has played a significant role in the biotechnology revolution. While most biotech activities build on existing strengths in primary industry (e.g. forestry, deer and sheep) there are also examples of innovative research in health and the creation of intellectual property.

New Zealand’s gross expenditure on R&D and number of science graduates was the lowest in a group of 18 OECD countries. New Zealand’s small science base is heavily skewed towards certain areas e.g. biology, clinical medicine and agriculture. New Zealand scientists have a high productivity (measured by papers per scientist) but

⁵⁷ see Rolleston (1999, p. 45)

⁵⁸ Interview B, 5 April, 2000

⁵⁹ Interview C, 30 March, 2000

New Zealand science is not highly cited internationally except in a handful of specialist areas e.g. pharmacology.

The modern biotechnology 'sector' is small; consisting of around 40 organisations employing approximately 1250 people. A further 40 firms carry out various kinds of bio processing activity and employ over 500 people in 'biotech based activities'. New Zealand's rate of modern biotech patent applications is below average for the G7 and for a reference group of small developed OECD economies. Overall New Zealand ranks twelfth out of 18 with a patenting rate slightly above that found in France, Germany and Japan. However New Zealand's performance is disappointing compared to other small countries with strong primary industries that it might hope to emulate e.g. Denmark, Netherlands and Australia.

The factors that seem to have encouraged the emergence of world-leading research are diverse ranging from strong basic science in medical research and science push in sheep genomics, to industry pull in the case of forest biotechnology. Growth in these and other biotech-based sectors may be constrained by the poor performance of New Zealand's National System of Innovation. The system is dominated by Crown Research Institutes and universities which rely on government for the majority of their funding. Leading edge work is carried out in certain areas, but this tends to involve links with a small number of organisations rather than strong connections to any wider system of innovation. There have been major changes to research, science and technology policy since the late 80's, but it remains to be seen whether these will result in improved performance.

There is a significant level of industry discontent with government policy and the framework conditions for innovation, particularly "the lack of a pro-business environment, national attitudes to entrepreneurs and risk takers and the regulatory framework which has made New Zealand an expensive country in which to do business". On the positive side; research costs are estimated to be 40% below international levels. This and New Zealand's rigorous border controls and relatively disease free status have been pushed heavily in an attempt to increase overseas funding of biotechnology activities in New Zealand.

The New Zealand Government has not taken leadership in fostering innovation in the biotech sector. Indeed government and industry only seem to have taken a close interest in biotechnology in the last three to four years. New Zealand has not made the kinds of large investment seen in Australia and some of its regional trading partners. Instead it has concentrated on science sector reforms and a free market oriented approach. New Zealand has the potential to demonstrate a new model for the development of a biotech industry based on comparative advantage in primary industry and some other niche areas. The jury is still out on whether New Zealand's innovation environment will allow that potential to be achieved.

References

- AgResearch (1999) *Annual Report 1999*, New Zealand Pastoral Agricultural Research Institute, Hamilton.
- Alston, J. M., P. G. Pardey and V. H. Smith (1998) 'Financing Agricultural R&D in Rich Countries: What's Happening and Why', *Australian Journal of Agricultural and Resource Economics*, Forthcoming March, .
- Arundel, A. and A. Rose (1999) 'The Diffusion of Environmental Biotechnology in Canada: Adoption Strategies and Cost Offsets', *Technovation*, 19(9) September, pp.551-560.
- Baker, E. (1998) 'Structural Biology - A Personal Account of its Development and Prospects in New Zealand', *NZ Science Review*, 55(3) pp.11-16.
- Berridge, M. (1999) 'Effects of Science Restructuring Receive Little Attention', *Laboratory News*, June, .
- BIOTENZ (1998) *BIOTENZ Promotional Brochure*, Auckland.
- Birss, N. (2000, 25 April). Lincoln Scientists Develop Biosensor. *The Christchurch Press*, pp. 13.
- Bollard, A., D. Harper and M. Theron (1987) 'Research and Development in New Zealand: A Public Policy Framework',
- Breschi, S. and F. Malerba. (1997). Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics and Spatial Boundaries, *Systems of Innovation: Technologies, Institutions and Organisations* . London: Pinter.
- Bull, A., G. Holt and M. Lilly (1982) *Biotechnology: International Trends and Perspectives*, OECD, Paris.
- Carlsson, B. (ed) (1995) *Technological Systems and Economic Performance: The Case of Factory Automation*, Economics of Science, Technology and Innovation, Dordrecht: Kluwer.
- Carlsson, B. (ed) (1997) *Technological Systems and Industrial Dynamics*, Economics of Science, Technology and Innovation, Dordrecht: Kluwer.
- Carlsson, B. and R. Stankiewicz (1991) 'On the Nature, Function, and Composition of Technological Systems', *Journal of Evolutionary Economics*, 1(2) pp.93-118.
- Cassie, F. (2000, April 14). University GM Research 'Can of Worms'. *NZ Education Review*, pp. 1.
- Clark, D. N., K. Pavlovich and B. Simpson (1999) 'The Horticulture and Food Research Institute of New Zealand Ltd',
- Cole, S. and T. J. Phelan (1999) 'The Scientific Productivity of Nations', *Minerva*, 37 pp.1-23.
- Dalziel, P. (1999) 'New Zealand's Economic Reform Programme was a Failure', July.
- Eliasson, G. and Å. Eliasson. (1997). The Pharmaceutical and Biotechnological Competence Bloc and the Development of Losec, *Technological Systems and Industrial Dynamics* (Vol. 10,). Dordrecht: Kluwer.
- Engelbrecht, H.-J. and J. Darroch (1999) 'A Comparative Macro-Level Assessment of New Zealand's National Innovation System', *Prometheus*, 17(3) September, pp.283-298.
- Environmental Risk Management Authority (1999) *Briefing for the Incoming Government*, ER-BR-01-1 11/99, Environmental Risk Management Authority, Wellington.
- Ernst & Young (1999a) *Australian Biotechnology Report 1999*, Ernst & Young, Canberra.
- Ernst & Young (1999b) *Bridging the Gap: Ernst & Young's 13th Biotechnology Industry Annual Report*, Ernst & Young, Palo Alto, California.
- Farrell, R. (1999) *Pacific GEM Proposal*, University of Waikato, Hamilton.
- Foltz, J., B. Barham and K. Kim (2000) 'Universities and Agricultural Biotechnology Patents Production', *Agribusiness*, 16(1) pp.82-95.
- Fontes, M. and A. Q. Novais (1998) 'The Conditions for the Development of a Biotechnology Industry in Portugal: The impact of Country Specific Factors', *Technological Analysis & Strategic Management*, 10(4) .
- Foundation For Research Science and Technology (2000) *Strategic Portfolio Outline: Advance Biological Enterprises*, Foundation for Research, Science and Technology, Wellington.
- Fransman, M. and S. Tanaka. (1995). The Strengths and Weaknesses of the Japanese Innovation System in Biotechnology, *The Biotechnology Revolution?* (pp. 431-483). Oxford: Blackwell.
- Frater, P., G. Stuart, D. Rose and G. Andrews (1995) *The New Zealand Innovation Environment*, The Berl Foundation, Wellington.
- Freeman, C. (1987) *Technology and Economic Performance: Lessons from Japan*, Pinter.

- Griliches, Z. (1990) 'Patent Statistics as Economic Indicators: A Survey', *Journal of Economic Literature*, 28(4) December, pp.1661-1707.
- Hall, B. and J. V. Reenen (2000) 'How Effective are Fiscal Incentives for R&D? A Review of the Evidence', *Research Policy*, 29(4-5) April, pp.449-469.
- Hazeldine, T. (1998) *Taking New Zealand Seriously: The Economics of Decency*, Harper Collins.
- Henderson, R., L. Orsenigo and G. P. Pisano. (1999). The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions Among Scientific Institutional, and Organisational Change, *The Sources of Industrial Leadership* (pp. 267-311): Cambridge University Press.
- Hynes, N. (1999) *Strategic Alliances and the New Zealand Biotechnology Industry*, Commerce Division, Lincoln University, Lincoln, New Zealand.
- Institute for Scientific Information (2000) *National Science Indicators on Diskette, 1981-98*, Institute for Scientific Information,
- Jacobsen, V. (1991) 'Contestable Funding: A New Deal for Research and Development in New Zealand', *CIS Policy Monographs 19*,
- Janszen, F. and G. Deganaars (1998) 'A Dynamic Analysis of the Relations Between the Structure and the Process of National Systems of Innovation Using Computer Simulation: The Case of the Dutch Biotechnological Sector', *Research Policy*, 27(1) May, pp.37-54.
- Joly, P.-B. and M.-A. d. Looze (1996) 'An Analysis of Innovation Strategies and Industrial Differentiation Through Patent Applications: The Case of Plant Biotechnology', *Research Policy*, 25(7) October, pp.1027-1045.
- Kennedy, M. J. and R. J. Davies (1994) *The Impact of Biotechnology on New Zealand Industry 1984-1994*, SIR Publishing.
- Lee, Y. H. (2000, 6 March). New Fund Aims to Commercialise University Research. *New Zealand Herald*.
- Leech, W. (1999,). Funding Partnership Links Bomac's Business Acumen, Massey Academia. *Dairy Exporter*, pp. 4.
- L'Huillier, P. (2000) *Genetic Modification of Livestock for the Production of Therapeutics and Designer Foods*, Dairy Farmers' Conference, Rotorua, New Zealand.
- Lundvall, B. (ed) (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers.
- Malo, S. and A. Geuna (1999) 'Science-Technology Linkages in an Emerging Research Platform: The Case of Combinatorial Chemistry and Biology', *SPRU Electronic Working Paper No 37*, August.
- Marshall, K. R. (2000) *Biosciences: An Explanation of Why the New Zealand Dairy Industry is Investing in Research*, Dairy Farmers' Conference, Rotorua, New Zealand.
- Massey, P. (1995) *New Zealand: Market Liberalization in a Developed Economy*, London: Macmillan.
- Mazoyer, P. (1999) *A Study of the Innovation System for Biotechnology in New Zealand*, Report No. 1072, Ministry of Research, Science and Technology, Wellington.
- McKelvey, M. (1996) *Evolutionary Innovations: The Business of Biotechnology*, Oxford: Oxford University Press.
- McMillan, G. S., F. Narin and D. L. Deeds (2000) 'An Analysis of the Critical Role of Public Science in Innovation: the Case of Biotechnology', *Research Policy*, 29(1) January, pp.1-8.
- Metcalfe, J. S. (1998) 'Innovation Systems and Endogenous Growth Theory',
- Ministry of Research Science and Technology (1999) *Briefing for Incoming Minister of Research, Science and Technology*, Ministry of Research, Science and Technology, Wellington.
- Momma, S. and M. Sharp (1999) 'Developments in New Biotechnology Firms in Germany', *Technovation*, 19(5) February, pp.267-282.
- Nelson, R. R. (ed) (1993) *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press.
- New Zealand Trade Development Board (2000) *Back to the Future New Zealand's Biotechnology Industry*, New Zealand Trade Development Board, Auckland.
- NZBA (1999) 'King Salmon', *New Zealand Biotechnology Association Newsletter*, 43 .
- NZDB. (1999, 12 October). Dairy Industry Must Embrace Biotechnology. *Press Release*.
- NZPA. (2000a, 28 April). Dairy Board in Genetics Deals with US. *The Dominion*, pp. 6.
- NZPA. (2000b,). NuFarm Buys up Biotech Company. *The Dominion*, pp. 20.
- OECD (1994) *The Measurement of Scientific and Technological Activities. Using Patent Data as Science and Technology Indicators: Patent Manual 1994*, OECD, Paris.
- OECD (1997) *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, Revised Edition (1997), OECD, Paris.

- OECD (1999a) *Modern Biotechnology and the OECD*, OECD, Paris.
- OECD (1999b) *OECD Science, Technology and Industry Scoreboard 1999 Benchmarking Knowledge-Based Economies*, OECD, Paris.
- Orsenigo, L. (1989) *The Emergence of Biotechnology*, New York: St Martin's Press.
- Pavitt, K. (1984) 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', *Research Policy*, 13(6) pp.343-373.
- Petersen, G. (1998) 'Science in New Zealand Beyond 2000. Have we Lost the Plot?', *NZ Science Review*, 55(3) pp.4-10.
- Pockley, P. (1998) 'New Zealand puts its Science to Profit', *Nature*, 391 January 29, pp.426-427.
- Rickne, A. (1999). The Growth of New Technology-Based Firms: The Case of Biomaterials in Sweden, Massachusetts and Ohio, *New Technological Systems in the Bio Industries: An International Study* .
- Rolleston, W. (1999) *Leveraging the Biology Revolution*, Opportunities for Collaboration between Business, CRI's and Tertiary Institutions, Auckland: Royal Society of New Zealand.
- Royal Society of New Zealand (2000a) 'New Zealand Dairy Board Subsidiary Moves to Process Genetic Data', *Royal Society Alert*, 124 5 May, .
- Royal Society of New Zealand (2000b) 'Royal Commission on Genetic Modification', *Royal Society Alert*, 122 18 April 2000, pp.1-14.
- Saviotti, P. P. (1998). Industrial Structure and the Dynamics of Knowledge Generation in Biotechnology, *Biotechnology and Competitive Advantage : Europe's Firms and the US Challenge* (pp. 19-43). Cheltenham, UK: Edward Elgar.
- Simpson, B. and J. Craig (1997) 'A Policy for Science Innovation: The New Zealand Experience', *Science and Public Policy*, 24(2) April, pp.70-78.
- Statistics New Zealand (2000) *Biotechnology Survey 1998/99*, Statistics New Zealand, Wellington.
- Tradenz (1994) 'The Foreign Exchange Earning Potential of the Pharmaceutical and Biotechnology Industry in New Zealand', *New Zealand Biotechnology Association Newsletter*, 25 December, pp.44-55.
- Upton, S. (1995) 'Contracting in the Science Sector: An Overview', *Public Sector*, 18(4) December, pp.2-5.
- van Geenhuizen, M. (1999). How Small Biotechnology Firms Survive in the Dutch Pharmaceutical Industry: An Exploratory Analysis, *New Technology-based Firms in the 1990s* (Vol. Volume VI,). Amsterdam: Pergamon.
- Walker, P. and J. Liu (1998) *Baseline Indicators for Measuring Progress Towards the Goals of RS&T: 2010*, Ministry of Research Science and Technology,, Wellington.
- Winsley, P., P. Couchman and D. Gilbertson (1998) 'Future Developments for New Zealand's Science and Technology System', *Prometheus*, 16(1) pp.57-68.
- Winsley, P. and L. Hammond (1997) 'Policies for Transforming the Science and Technology System in New Zealand 1988-1997', *Prometheus*, 15(2) pp.267-278.
- Zucker, L. G. and M. R. Darby (1996) 'Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry', *Proceedings of the National Academy of Sciences*, 93(23) November 12, pp.12709-12716.