

**UNIVERSITY OF WAIKATO**

**Hamilton  
New Zealand**

**Does New Zealand have an  
Innovation System for Biotechnology?**

Dan Marsh

**Department of Economics  
Working Paper in Economics 3/02**

May 2002

**Dan Marsh**

Department of Economics  
University of Waikato  
Private Bag 3105  
Hamilton, New Zealand

Tel: +64 (07) 838-4950

Fax: +64 (07) 838-4331

Email [dmarsh@waikato.ac.nz](mailto:dmarsh@waikato.ac.nz)

<http://www.mngt.waikato.ac.nz>

## **Abstract**

While there is a large and growing international literature on economic aspects of biotechnology innovation (for example, work by Carlsson, McKelvey, Orsenigo, Zucker and Darby) these studies concentrate on the United States and Europe. The New Zealand biotechnology industry may be expected to develop along a different trajectory as a consequence of a markedly different set of initial and framework conditions. This paper presents the 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 size and structure of modern biotech activity in New Zealand is described and compared to other OECD countries using biotech patent data and results from the New Zealand and Canadian biotechnology surveys. The paper then focuses on factors affecting innovation in biotechnology; framework conditions, government policy R&D funding and the role of networks and other linkages.

## **Keywords**

Biotechnology; Innovation System; Survey Data; New Zealand

## **JEL Classification**

L65, L66, O31, O32, O38

## **Acknowledgements**

Access to the 1998/99 Biotechnology Survey data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the author not Statistics New Zealand.



## **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 biotechnology revolution. There is a large and growing international literature on economic aspects of biotechnology innovation which McKelvey (2000) has characterised as “an area of research which attempts to explain how and why the new techniques and knowledge of modern biotechnology can have economic impacts”. This paper describes some of the results of an ongoing study that will describe and analyse the innovation system for biotechnology in New Zealand focussing on the major actors and the linkages among them.

The first part of this paper outlines a theoretical framework based on the systems of innovation literature and reviews some key indicators of the effectiveness of New Zealand’s national system of innovation (NIS). The size and competitive position of biotech activity in New Zealand is then described based on data from a variety of sources including the recently completed biotechnology survey and an analysis of biotech patent data. Part 3 presents and analyses data on various factors affecting biotech innovation based on the OECD’s Oslo Manual framework. Part 4 draws some conclusions on the state of New Zealand’s innovation system for biotechnology.

### *Definition of Biotechnology*

The term biotechnology was coined in 1919 by Karl Ereky, a Hungarian agricultural economist to refer to “all the lines of work by which products are produced from raw materials with the aid of living organisms”(Bud, 1989, p. 10). Since then “the word biotechnology has been re-developed at least four times and its definition changed on each occasion” (Kennedy, 1991, p. 218) and in recent years has become increasingly synonymous with genetic modification (GM). For reasons explained above, the economics literature has tended to focus on *modern* biotechnology defined in this paper to include GM and modern biotech processes; namely (1) recombinant DNA technology, (2) use of antibodies (3) protein engineering (4) novel bioprocessing techniques (Eliasson and Eliasson, 1997, p. 145, U.S. Congress, 1991, p. 5). The term “modern” is used to distinguish processes that have been developed in the last 30 years or so, from traditional biotech areas such as fermentation and extraction.

### *The Systems of Innovation Framework*

This 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 sectoral and enterprise specific innovation systems, to local, national, regional and global systems of innovation.

Modern biotechnology requires a multi-sectoral approach since it’s techniques are used in a number of different “biotechnology-based sectors”(Saviotti, 1998, p. 19) as such, Carlsson and Stankiewicz’s notion of a technological system (TS) is perhaps best suited to model the

interaction of the various actors. Carlsson recently defined a TS as: "a network of agents interacting in a specific *technology* under a particular *institutional infrastructure* or set of infrastructures and involved in the generation, diffusion, and utilization of technology" (1999, p. 12).

Bartholomew (1997) was perhaps the first author to refer to a *national system of biotechnology innovation* which she defined as "the specific institutional arrangements within a country which affect the generation of scientific knowledge relevant to biotechnology, and the diffusion of that knowledge throughout industry".

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 (Arundel and Rose, 1999, Fransman and Tanaka, 1995, 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.

#### *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 wire. 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. 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 graduates of the 18 sample countries and was ranked lowest on indicators of whether diffusion had actually taken place. Overall they concluded that “New Zealand continues to have a weak National Innovation System, despite the major changes to its research, science and technology sector since the late 1980s, and despite its openness to foreign direct investment”. This finding is supported by another empirical investigation into the national innovative capacity of a sample of 17 OECD countries from 1973 to 1996, which found that “a .. group, including Italy, New Zealand and Spain, lags behind the rest of the OECD over the full time period” (Stern et al., 2000, p. 31).

The strength of New Zealand’s science base is an important determinant of the effectiveness of the National Innovation System and should also provide a strong indication of the degree (if any) of New Zealand’s advantage in the area of biotechnology. Cole and Phelan’s (1999) investigation into the scientific productivity of nations found that New Zealand had 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 papers<sup>1</sup> 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.

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 impact of New Zealand papers in these areas was within 10% of the world average.

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.

## **2. 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 born

---

<sup>1</sup> Based on the number of papers published in 1987 which received 40 or more citations by the Science Citation Index between 1987 and 1991.

biophysicist, Dr Maurice Wilkins who was later jointly awarded the Nobel Prize with Crick and Watson.

Much of New Zealand's work builds on traditional 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 the industry organisation BIOTENZ (1998) include: breeding of transgenic crops; clonal afforestation; genetic manipulation of flower colour; the world's first enteric bacteria-based bio insecticide; a project to map the sheep genome; the world's first sheep genetically engineered for increased wool production; and the world's first recombinant livestock vaccine to combat sheep measles.

Most modern biotechnology activities in New Zealand are concentrated in universities and Crown Research Institutes (CRI) and a small number of private sector companies e.g. Genesis, Probe, ViaLactia. The government has been estimated to spend around NZ\$100m a year on biotechnology-related research ranging from genomics to processing of natural products (Rolleston, 1999, p. 46), of this around NZ\$18 million is spent on research involving genetic modification (Wright, 2000, p.7). Biotechnology-related research comprises around 17% of total spending on 'the Science Envelope' (NZ\$586 million in 1999/2000, NZ\$1 = US\$0.42). 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.

Few innovations or processes in modern biotechnology have reached the stage of being commercialised. Genesis Research and Development is perhaps one of the closest to achieving income from a new biotechnology product; it announced the results of US phase II clinical trials of its PVAC Psoriasis treatment in February 2001; one of over 300 biotech products now in phase II or phase III trials (Ernst & Young, 1999, p. 35).

In 2000 Statistics New Zealand undertook the first comprehensive survey on the use of biotechnology in New Zealand. The main objectives were to describe the present structure of the 'industry' in order to assist planning and to provide a baseline against which progress could be measured at a future date. The survey was sent to 426 enterprises that had been identified as possible users of a list of 54 biotechnology processes and achieved a 98% response rate with 180 respondents identified as users of at least one process. The high response rate and wide ranging methods used to identify possible users of modern biotechnology suggest that the survey is likely to have captured almost all significant users of modern biotech over the survey period (1998/99).

Respondents were divided into four categories (see Figure 1) based on whether they used modern or traditional processes and whether they were creators (engaged in R&D) or simply users of biotechnology processes.

(Figure 1: Classification of Biotech Respondents, about here)

The term Modern Biotech Enterprise (MBE) is used to describe respondents that are engaged in R&D into at least one modern biotech process. Academics and policy makers have a

particular interest in this group, since their innovative performance will be crucial in determining New Zealand's overall performance in the biotech area. Some of their key characteristics are presented as Table 1.

(Table 1: Key Characteristics of Modern Biotech Enterprises, about here)

It may be seen that modern biotechnology R&D was carried out by approximately 57 enterprises (15 primary product and manufacturing firms, 24 research organisations and 6 universities) employing around 1700 people. MBEs were split fairly evenly between the private sector (30) and the public sector (27). They reported expenditure on biotech of NZ\$202 million and income from biotech of NZ\$236 million. This compares to MBE income from all sources of NZ\$2.1 billion i.e. biotech provided around 11% of income for the 57 MBEs; twelve firms reported that they received all of their income from biotech and so might be referred to as dedicated biotech firms. A further 36 enterprises used modern biotech processes (but were not engaged in R&D) and employed around 950 people in 'biotech based activities', which provided income of NZ\$112 million.

The Statistics New Zealand biotech survey was closely modelled on work carried out by Statistics Canada thus enabling some comparisons to be made. However there are some important differences; the New Zealand definition of biotech included several additional processes and so was somewhat wider than that used in Canada; the number of biotech firms is also not directly comparable since the Canadian survey excluded firms that had less than five employees and less than C\$100,000 R&D expenditure.

An approximate comparison between the two data sets is included as Table 2. It is based on application of the Statistics Canada definition of a biotech enterprise to the New Zealand data set; namely enterprises which conduct R&D, have a minimum of five employees and biotech expenditure of at least NZ\$150,000. Data for Australia is also included although based on a narrower definition.

(Table 2: Comparison of Biotech in New Zealand, Canada and Australia about here)

New Zealand's biotech revenue per million population (NZ\$54 million) is rather lower than Canada's (NZ\$94 million), but the difference is fairly small considering Canada's higher per capita income and proximity to the United States. New Zealand has a rather lower mean revenue per biotech firm (NZ\$5.3m vs. NZ\$8.0m); consistent with the predominance of small firms in the New Zealand economy. New Zealand appears to have a significantly higher rate of biotech employment. There is some evidence that use of biotech processes in New Zealand is at an earlier stage with 72% being at the R&D stage against 49% in Canada.

#### *Data from Patenting*

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

Analysis of New Zealand patenting activity in biotechnology was carried out using international applications published in the Patent Cooperation Treaty (PCT) Electronic Gazette. 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 granted. Methodology based on Engelbrecht and Darroch (1999) was used to compare New Zealand's rate of patenting with G7 and a reference group of small high-income OECD countries (see Table 3). 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 below<sup>2</sup>.

(Table 3: New Zealand and OECD Patenting Rates in Biotechnology, about here)

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).

A breakdown of New Zealand patent applications by organisational type indicates 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.

### **3. Factors Affecting Innovation**

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; the *science and engineering base*; *transfer factors* which influence linkages and flows of information; and the *innovation dynamo* of 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.

---

<sup>2</sup> Includes A01G, A01H, A01N, C12M, C12N, C12P, C12Q – defined as 'General Biotechnology' by Joly and de Looze (1996).

The title of this paper asks whether New Zealand has a network of institutions firms and organisations - *an innovation system for biotechnology*. 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 Institutes. 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 et al., 1999, p. 6).

Some private firms placed little emphasis on linkages in development of biotechnology innovation; others found few organisations worth linking with (perhaps because the use of modern biotechnology in New Zealand is so limited) 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).

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 sector or the private sector which has a limited ability to apply the results of publicly funded R&D or to evaluate opportunities (Winsley et al., 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’. 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. A New Zealand company was 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 Canada (interview D). 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 companies (International Paper and Westvaco Corporation) and three New Zealand companies (Fletcher Challenge Forests, Genesis and Carter Holt Harvey).

Similarly Genesis was founded using intellectual property from the University of Auckland and has strong partnerships with two CRIs, 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.

#### *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 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 biotechnology.

Increasing levels of popular concern over the safety of some modern biotechnologies culminated in the setting up of the Royal Commission on Genetic Modification to inquire “into and report on the strategic options available to enable New Zealand to address genetic information now and in the future” (Royal Society of New Zealand, 2000). The Commission spent over NZ\$6 million and 14 months listening to all sides of the debate before concluding “that New Zealand should keep its options open. It would be unwise to turn our back on the potential advantages on offer, but we should proceed carefully, minimising and managing risks” (Royal Commission on Genetic Modification, 2001, p. 2). In October 2001 the government announced its response to the Royal Commission report, including permission for field trials to restart and a two-year ban on commercial release of genetically modified products.

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”(interview A). 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). There are concerns that implementation of recommendations from the Royal Commission will make New Zealand’s regulatory regime even tighter.

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 quote from 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 et al., 1999, p. 5).

### *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). 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 four to five years (interview F).

The present government is taking 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 the 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 include: the need for a targeted, rapid and flexible investment system by Government; the development of an entrepreneurial spirit; partnerships and linkages between stakeholders; increased 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" (Biotechnology Australia, 2000). The 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. Indeed Sommer (2001, p. 7) found that the 1996 and 2000 surveys of New Zealand scientists and technologists "indicate a stunning level of dissonance over New Zealand science and technology policy reforms". The statement "The management systems now in place are appropriate for the effective advancement of research," evoked 69.8% disagreement in 1996 and 70.9% in 2000. Similarly, the statement "The changes in the organization of New Zealand science over the past four years have enhanced my situation/conditions for performing innovative research," was disagreed with by 70% of panellists in 2000.

More specific criticisms are 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); and a "focus on small projects focussed on individuals has taken away the ability of CRI's to build future science capabilities"(interview A). 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".

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 were excessive (Mazoyer, 1999, p. 10).

### *R&D Funding*

It has been 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, 1999, 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" (interview B).

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 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 came bottom

of an OECD league table of the amount of tax subsidy for R&D (OECD, 1999, p. 135). In New Zealand, private sector expenditure of one dollar cost companies \$1.13 after tax and compliance were included. This compared 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-reporting 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” (interview B). Others were more sceptical: “I have not seen results that suggest support of R&D delivers real commercial benefits” (interview C).

Difficulties in obtaining venture capital may also constrain start-up or expanding biotech firms in New Zealand, although some suggest “the lack of entrepreneurs who can build companies, rather than a shortage of money, is curtailing the development of new companies” (Springall, 2000). Until recently no venture capital appeared to be available for biotechnology and companies relied on traditional methods of funding. However there has recently been a marked increase in private sector funding. At a 1999 venture capital conference in Auckland one speaker concluded “New Zealand does not yet have a venture capital market. But we do have

up to NZ\$800 million in venture capital available for high-tech firms and another NZ\$900 million already committed by 30 venture capital companies (Caragata, 2000)". Overall venture capital investment in Australia and New Zealand combined has increased sharply over the last three years with the health/bioscience category showing a huge increase from A\$7.9 million in 1998 to A\$81 million in 1999 (Australian Venture Capital Journal, 2000).

#### **4. 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. The modern biotechnology 'sector' is small; consisting of around 60 organisations employing approximately 1700 people, receiving biotech income of NZ\$236 million. A further 36 enterprises use modern biotech processes and employ around 950 people in 'biotech based activities', which provide income of NZ\$112 million. 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. New Zealand's biotech revenue per million population (NZ\$54 million) is rather lower than Canada's (NZ\$94 million), but the difference is fairly small considering Canada's higher per capita income and proximity to the United States.

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.

The New Zealand Government has not taken leadership in fostering innovation in modern biotechnology. Indeed government and industry only seem to have taken a close interest in biotechnology in the last four to five 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.

### **Acknowledgements**

Earlier versions of this paper were presented at the R&D Management Conference in 2001 and at the Eighth International Schumpeter Society Conference, Manchester, UK in June, 2000. I would like to acknowledge the generous support and assistance provided by my supervisors Dr Frank Scrimgeour and Professor Les Oxley. Any errors or omissions are entirely my own. Thanks also to Pamela Mazoyer and Junjia Liu at MoRST and various members of the biotechnology industry who found time to answer my many questions.

## References

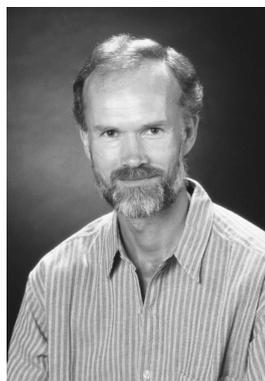
- Arundel, A. and Rose, A., 1999. The Diffusion of Environmental Biotechnology in Canada: Adoption Strategies and Cost Offsets. *Technovation*, 19(9), 551-560.
- Australian Venture Capital Journal, 2000. Almost \$1 billion Invested in 1999. *Australian Venture Capital Journal*, 9(85), 6-14.
- Bartholomew, S., 1997. National Systems of Biotechnology Innovation: Complex Interdependence in the Global System. *Journal of International Business Studies*, 28(2), 241-266.
- BIOTENZ, 1998. BIOTENZ Promotional Brochure (Promotional Brochure ). Auckland.
- Bud, R., 1989. History of 'Biotechnology'. *Nature*, 337(6202), 10.
- Caragata, P., 2000. Could you Sell your Great Ideas to a Venture Capitalist? *The Independent Business Weekly*, 8 March, 12.
- Carlsson, B., Jacobsson, S., Holmén, M. and Rickne, A., 1999. Innovation Systems: Analytical and Methodological Issues. Paper presented at the DRUID's Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, Rebild, Denmark.
- Cassie, F., 2000. University GM Research 'Can of Worms'. In *NZ Education Review*, Vol. 4(48), pp. 1.
- Clark, D. N., Pavlovich, K. and Simpson, B., 1999. The Horticulture and Food Research Institute of New Zealand Ltd. Waikato Management School, Department of Strategic Management and Leadership.
- Cole, S. and Phelan, T. J., 1999. The Scientific Productivity of Nations. *Minerva*, 37, 1-23.
- Eliasson, G. and Eliasson, Å., 1997. The Pharmaceutical and Biotechnological Competence Bloc and the Development of Losec. In *Technological Systems and Industrial Dynamics*, Vol. 10 (ed. Carlsson, B.) Kluwer, Dordrecht.
- Engelbrecht, H.-J. and Darroch, J., 1999. A Comparative Macro-Level Assessment of New Zealand's National Innovation System. *Prometheus*, 17(3), 283-298.
- Environmental Risk Management Authority, 1999. Briefing for the Incoming Government ( ER-BR-01-1 11/99). Wellington: Environmental Risk Management Authority.
- Ernst & Young, 1999. Bridging the Gap: Ernst & Young's 13th Biotechnology Industry Annual Report. Palo Alto, California: Ernst & Young.
- Foltz, J., Barham, B. and Kim, K., 2000. Universities and Agricultural Biotechnology Patents Production. *Agribusiness*, 16(1), 82-95.
- Fontes, M. and Novais, A. Q., 1998. The Conditions for the Development of a Biotechnology Industry in Portugal: The impact of Country Specific Factors. *Technology Analysis & Strategic Management*, 10(4).
- Foundation For Research Science and Technology, 2000. Strategic Portfolio Outline: Advance Biological Enterprises. Wellington: Foundation for Research, Science and Technology.
- Fransman, M. and Tanaka, S., 1995. The Strengths and Weaknesses of the Japanese Innovation System in Biotechnology. In *The Biotechnology Revolution?*, (eds, Fransman, M., Junne, G. and Roobeek, A.) Blackwell, Oxford, pp. 431-483.
- Freeman, C., 1987. *Technology and Economic Performance: Lessons from Japan*, Pinter.
- Hall, B. H. and Reenen, J. V., 2000. How Effective are Fiscal Incentives for R&D? A Review of the Evidence. *Research Policy*, 29(4-5), 449-469.

- Hazledine, T., 1998. *Taking New Zealand Seriously: The Economics of Decency*, Harper Collins.
- Institute for Scientific Information, 2000. *National Science Indicators on Diskette, 1981-98.*: Institute for Scientific Information.
- Janszen, F. H. A. and Deganaars, G. H., 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), 37-54.
- Joly, P.-B. and de Looze, M.-A., 1996. An Analysis of Innovation Strategies and Industrial Differentiation Through Patent Applications: The Case of Plant Biotechnology. *Research Policy*, 25(7), 1027-1045.
- Kennedy, M. J., 1991. The Evolution of the Word Biotechnology. *Trends in Biotechnology*, 9(7), 218-220.
- Lundvall, B. (ed.) 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London.
- Malo, S. and Geuna, A., 1999. Science-Technology Linkages in an Emerging Research Platform: The Case of Combinatorial Chemistry and Biology. SPRU. (SPRU Electronic Working Paper No. 37)
- Massey, P., 1995. *New Zealand: Market Liberalization in a Developed Economy*, Macmillan, London.
- Mazoyer, P., 1999. A Study of the Innovation System for Biotechnology in New Zealand ( Report No. 1072). Wellington: Ministry of Research, Science and Technology.
- McKelvey, M., 2000. Economics of Biotechnology. In *The Handbook of Economics (In Press)*, International Thomson Business Press.
- McMillan, G. S., Narin, F. and Deeds, D. L., 2000. An Analysis of the Critical Role of Public Science in Innovation: the Case of Biotechnology. *Research Policy*, 29(1), 1-8.
- McNiven, C., 2001. Biotechnology Use and Development 1999. Statistics Canada. (88F006XIE No. 7)
- Momma, S. and Sharp, M., 1999. Developments in New Biotechnology Firms in Germany. *Technovation*, 19(5), 267-282.
- Nelson, R. R. (ed.) 1993. *National Innovation Systems: A Comparative Analysis*, Oxford University Press, New York.
- New Zealand Trade Development Board, 2000. *Back to the Future New Zealand's Biotechnology Industry*. Auckland: New Zealand Trade Development Board.
- OECD, 1994. *The Measurement of Scientific and Technological Activities. Using Patent Data as Science and Technology Indicators: Patent Manual 1994*. Paris: OECD.
- OECD, 1997. *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data ( Revised Edition (1997))*. Paris: OECD.
- OECD, 1999. *OECD Science, Technology and Industry Scoreboard 1999 Benchmarking Knowledge-Based Economies*. Paris: OECD.
- Orsenigo, L., 1989. *The Emergence of Biotechnology*, St Martin's Press, New York.
- Petersen, G., 1998. Science in New Zealand Beyond 2000. Have we Lost the Plot? *NZ Science Review*, 55(3), 4-10.
- Rickne, A., 1999. The Growth of New Technology-Based Firms: The Case of Biomaterials in Sweden, Massachusetts and Ohio. In *New Technological Systems in the Bio Industries: An International Study*, (ed. Carlsson, B.).
- Rolleston, W., 1999. *Leveraging the Biology Revolution*. Paper presented at the Conference:

- Opportunities for Collaboration between Business, CRI's and Tertiary Institutions, Auckland.
- Royal Commission on Genetic Modification, 2001. Report of the Royal Commission on Genetic Modification. Wellington.
- Royal Society of New Zealand, 2000. Royal Commission on Genetic Modification. Royal Society Alert, 122, 1-14.
- Saviotti, P. P., 1998. Industrial Structure and the Dynamics of Knowledge Generation in Biotechnology. In *Biotechnology and Competitive Advantage : Europe's Firms and the US Challenge*, (ed. Senker, J.) Edward Elgar, Cheltenham, UK, pp. 19-43.
- Sommer, J., 2001. Voices from the Grassroots of Science: Tales of Hope and Woe. Paper presented at the The R&D Management Conference 2001: Levering Research and Technology, Wellington, NZ.
- Springall, L., 2000. Where are the Great Ideas? Say Venture Capitalists. *The Independent Business Weekly*, 5 July.
- Stern, S., Porter, M. E. and Furman, J. L., 2000. The Determinants of National Innovative Capacity. National Bureau of Economic Research. (Working Paper W7876)
- U.S. Congress, 1991. *Biotechnology in a Global Economy* ( OTA-BA-494). Washington, DC: Office of Technology Assessment.
- van Geenhuizen, M., 1999. How Small Biotechnology Firms Survive in the Dutch Pharmaceutical Industry: An Exploratory Analysis. In *New Technology-based Firms in the 1990s*, Vol. VI (eds, Oakey, R., During, W. and Mukhtar, S.-M.) Pergamon, Amsterdam.
- Winsley, P., Couchman, P. and Gilbertson, D., 1998. Future Developments for New Zealand's Science and Technology System. *Prometheus*, 16(1), 57-68.
- Wright, J. C., 2000. *The Economics of Genetic Modification* ( Background paper prepared for the Royal Commission on Genetic Modification).

### **Biography**

Dan Marsh is a lecturer in economics at the University of Waikato. This paper is part of a wider study that aims to fill some of the gaps in our knowledge of innovation processes in New Zealand. The study will describe and analyse the innovation system for biotechnology in New Zealand focussing on the major actors and the linkages among them.



## Tables and Figures

<b>Creators</b>	<b>Modern ! ! ! ! ! Traditional</b>	
	↓ ↓ ↓ ↓ <b>Users</b>	Modern Biotech Enterprises (MBEs)
	Modern Biotech Users (MBUs)	Traditional Biotech Users (TBUs)

**Figure 1: Classification of Biotech Respondents**

Industrial Group	No. of Enterprises	No. of Biotech Employees	Biotech Income (NZ\$ millions)
Primary Products and Manufacturing	15	214	106
Scientific Research	24	540	83
Tertiary Education	6	625	c
Health Services and Other	9	288	c
<b>Total for Modern Biotech Enterprises</b>	<b>57</b>	<b>1,667</b>	<b>236</b>
Modern Biotech Users	36	944	112

Note: Data in cells marked c are not presented and count data are subject to random rounding to base three in order to meet the confidentiality provisions of the Statistics Act 1975.

**Table 1: Key Characteristics of Modern Biotech Enterprises**

	Canada 1999	Australia 1998/99	NZ 1998/99
Population (1997)	30.3	18.5	3.8
No. of biotech enterprises	358	120	39
Total biotech revenue <sup>1</sup> (NZ\$ m)	2850	1077	205
Biotech revenue per million population (NZ\$ m)	94	58	54
Revenue per firm (NZ\$ m)	8.0	9.0	5.3
Biotech related employees (Headcount)	7695	3801	1708
Biotech related employees per million population	254	205	449
% of products and processes in R&D stage	49%	47%	72%

Data for Canada is extracted from McNiven (2001)

**Table 2: Comparison of Biotech in New Zealand, Canada and Australia**

PCT Patent Applications  
(1 Jan 1997 – 15 May, 2000) per million population

	C12N Modern Biotechnology	Broad Definition
All 18 Countries	13.8	22.5
G7	13.6	22.2
Small Countries <sup>2</sup>	15.4	25.7
Australia	12.1	19.1
New Zealand	8.0	15.7

**Table 3: New Zealand and OECD Patenting Rates in Biotechnology**

<sup>1</sup> Based on an exchange rate of NZ\$1.5= C\$1

<sup>2</sup> Austria, Belgium, Denmark, Finland, Ireland, Netherlands, NZ, Norway, Sweden, Switzerland.