Achieving innovative science

Jacqueline S. Rowarth[1] and Stephen L. Goldson[2]
[1]Institute of Natural Resources, Massey University, PB 11222, Palmerston North
[2]AgResearch Lincoln, Private Bag 4749, Christchurch 8140

In common with many other countries, New Zealand is investing in science as a driver for advancement. However, investment is not on a par with other developed countries, and the science system in which New Zealand's researchers operate is substantially different from that typically found in other countries. In New Zealand the degree of contestability for research providers, whether Crown research institute (CRI), university or private research provider, is extremely high. With this there are similarly stringent levels of accountability such that the research has largely become driven by pre-determined outcomes, rather than by discovery and/or the exploitation of the unexpected. Of further concern is that the CRIs are now supposed to make a 9% return on assets, which drives an intensive search for commercial income, diverting hard-pressed scientists into consultancy and attempts at the commercialisation of products. The research system is thus now antithetical to the very thing that it is trying to achieve – creative research leading to innovation, economic development and high environmental integrity. This paper outlines the problems and makes suggestions for an improved future for New Zealand's science.

Introduction

The current science system is the result of restructuring in the 1990s. The Ministry of Research, Science and Technology (MoRST), responsible for developing science priorities and policies, was established in 1990. The Foundation for Research, Science and Technology (FRST) was established independently to purchase outputs on behalf of Government. Ten sector-based CRIs were created from what had been the Department of Scientific and Industrial Research (DSIR) and Ministry of Agriculture and Fisheries (MAF) in 1992. At the same time, two new Ministerial portfolios were created, one for the CRIs and the other for Research, Science and Technology (RS&T). Funding was very short-term and 100% competitive. A pool of $10 million was ring-fenced for use by the universities.

The aim of the competitive system was to improve the quality of research, decrease overlap and duplication in research activities, improve links to industry and sectors, and remove what had been described as the moribund bureaucracy extant in the previous DSIR and MAF research systems (Palmer 1994).

This paper considers published information on the link between creativity, innovation and economic development and urges action in New Zealand to ensure that research areas of current and future value are appropriately supported and managed. In doing so, this paper builds directly on the points made in the Science Manifesto and released by the National Science Panel in April 2008.

Background information

The CRI Act (1992) states that the role of CRIs is to:

- undertake research for the benefit of New Zealand,
- pursue excellence in all their activities,
- comply with applicable ethical standards,
- promote and facilitate the application of the results of research and technological developments,
- be a good employer, and
- exhibit a sense of social responsibility by having regard to the interests of the community.

Financial principles stated that CRIs should:

- operate in a financially responsible manner,

Jacqueline Rowarth CNZM is Professor of Pastoral Agriculture and Director of Massey Agriculture at Massey University. After completing her PhD at Massey, Jacqueline initially took up a research position at DSIR Grasslands, which became AgResearch in 1992. In 1994 she was appointed Senior Lecturer in Plant Physiology at Lincoln University, then from 2000 to 2004 she was Director of Research and Dean of the Graduate School at Unitec New Zealand, becoming Vice-President of Research and Development. She became Associate Professor and Director of the Office for Environmental Programs at Melbourne University in 2005, returning to New Zealand in 2007 to take up the Foundation Chair at her alma mater. Professor Rowarth is a Companion of the Royal Society of New Zealand, and a Fellow and Honorary Member of the New Zealand Institute of Agricultural and Horticultural Science. In 2008 she was appointed a Companion of the New Zealand Order of Merit. She may be contacted at J.S.Rowarth@massey.ac.nz

Stephen Goldson has been actively involved in pest management and biosecurity research for thirty years. He has worked as AgResearch's Chief Science Strategist and most recently as its Chief Scientist. For ten years prior to this, he was the Science Leader of the Biocontrol and Biosecurity Group, focusing on pest management. He is also Biosecurity Theme Co-leader at the Bio-Protection Research Centre (one of the Centres of Research Excellence) and a Professorial Fellow at Lincoln University. He has been a member of several national science policy advisory groups over the last two decades. In 2005 he was appointed to the Biosecurity Ministerial Advisory Committee and in 2006 joined the National Science Panel. Dr Goldson is a Fellow of the New Zealand Institute of Agricultural Science and was the recipient of the Institute's Jubilee Medal in 2007. He is a Fellow of the Royal Entomological Society of London and a Fellow of the Royal Society of New Zealand. In 2009 he was elected to the Council of the Royal Society of New Zealand as Vice-President, Biological and Life Sciences.

- maintain financial viability, defined as providing an adequate rate of return on shareholders' funds (irrespective of whether or not a dividend is paid) and operate as a successful going concern (section 5(2) and 5(3)).

The intent of the CRI legislation was science excellence in the pursuit of industry and New Zealand good. The secondary component, commercialisation, reflected the expectation that the CRIs should maintain their fabric as attractive going concerns for science. The Rt Hon Simon Upton, then Minister of RS&T, referred to the return on shareholder funds as 'retained earnings' (as opposed to profit) to be reinvested in science itself, frequently by the organisation that created them. The concept behind the pseudo-commercial structure of the CRIs was to achieve a degree of efficiency under the direction of commercially aware and science-savvy, government-appointed boards. Thus directors on the boards were supposed to understand the focus of the CRIs (scientific excellence) as well as commerce rigour.

Seventeen years on and the science system is in need of another change. Exhaustive and exhausting competition has led to ever-increasing requirements in terms of bidding and reporting. This in turn has created a negative impression of research as a job and of the rewards associated with an insecure career in science. As a result there has been a severe downturn in recruitment in an era when most countries are increasing investment in science education in an attempt to increase scientific literacy in society. Other countries are similarly increasing investment in their research budgets in order to drive economic development, as well as provide science careers, as science is the key to new knowledge (Tallon 2008).

President Barack Obama has promised to 'return science to its rightful place'. In America there is now concern that the science budget over the past five years has been steadily losing buying power such that the science agencies can support only one in five of the proposals they receive. This means that scientists are less likely to pursue 'the ambitious, but often risky, research that often leads to the most important breakthroughs'. In New Zealand it has been estimated that only one in ten proposals get funded, and the need to bid for funding almost continuously has also resulted in severe fracturing of top scientists' time and excessively fragmented research portfolios.

The National Party's pre-election science policy acknowledged these problems with the comments that the current system is one that seeks 'instant gratification' and that 'scientists seem to spend more time applying for funding and reporting on it than actually doing science'. The policy went on to state that a National-led government 'would ensure that excellent science is performed in stable, high-quality institutions, properly resourced and financially viable'. It also stated that 'bureaucracy and compliance costs would be minimised, resources would be directed towards areas of importance to New Zealand, and a good supply of research-trained scientists, engineers and technologists would be created'. Speaking at the NZBio Annual Excellence Awards on 10 March, Minister for RS&T Wayne Mapp stated (Mapp 2009) that the science system would be examined over the next 12 months with a view to reducing transaction costs faced by researchers and research organisations and finding ways to strengthen links between RS&T, tertiary education and economic development. Furthermore, he indicated that the Prime Minister's Chief Scientific Adviser will provide a focus and expertise in this assessment. In short, the aim of these proposed changes is to deliver greater value for money for the Government's investment.

Economic development, innovation and creativity

Tom Nicholas (2008) has shown that, in an economic downturn, benefits exist for companies prepared to invest in innovation through good people and research. Underperforming companies die and, with this, there is a release of capital to new areas, leading to the movement of high-quality, skilled workers toward stronger employers. For companies with cash and ideas, downturns can indeed prove to be positive.

Looking towards the future, New Zealand can capitalise on past experience and current knowledge by investing appropriately in research to achieve value from its industries. Innovation is the key. Gary Hamel, business strategist and author on competitive innovation (e.g. Hamel & Prahalad 1996), has demonstrated that innovation is the life-blood of business. For a business to remain resilient, regular and frequent innovation is fundamental. Indeed, Porter and Stern (2001) have shown that the ability to create wealth from innovation is closely and positively linked to the proportion of scientists and engineers in the work force ($R^2 = 0.80$): more creative people in the workforce leads to more innovation and wealth.

Regression analysis (Table 1) shows a strong relationship between innovation, global competitiveness and expenditure on R&D (greater than $R^2 = 0.65$ in all cases).

Table 1. Relationship between R&D expenditure and indices of national competitiveness (World Economic Forum 2008).

Relationship	
Gross domestic expenditure on R&D (%GDP) and innovation	$R^2 = 0.66$
Gross domestic expenditure on R&D (%GDP) and global competitiveness	$R^2 = 0.67$
Gross domestic expenditure on R&D (as % of GDP) per capita and global competitiveness	$R^2 = 0.72$

Notably, New Zealand ranks at 28th in the world in innovation in the Global Competitive Index (2008/09) of 134 countries, falling from 25th in the 2006/07 survey. In the same survey, the United States was considered to be the most competitive country in the world, based on efficient use of resources and excellent infrastructure. Switzerland was second, reflecting a combination of a world-class capacity for innovation and the presence of a highly sophisticated business culture. In both countries, high spending on research and development, excellent research institutions, and strong collaboration between the academic and business sectors were also noted.

New Zealand spends only $290 per capita on research and development – the United States, the most competitive country in the world, spends four times this amount, and Denmark, the world's third most competitive country, three times as much (Table 2).

The Global Competitiveness Report (World Economic Forum 2008) also ranks New Zealand as:

- 19th in terms of quality of its research institutions,

Table 2. Global competitiveness rank and gross domestic expenditure on R&D per capita.

Country	Global competitiveness rank	R&D dollars per capita (US)
United States	1	1146
Switzerland	2	1003
Denmark	3	856
Sweden	4	1301
Finland	6	1129
United Kingdom	12	588
Australia	18	578
New Zealand	24	290

- 36th on company spending on R&D,
- 24th in university–industry research collaboration,
- 64th in Government procurement of advanced technology products, and
- 76th in availability of scientists and engineers.

The last point is a clear statement on the unattractiveness of science and engineering as a career in New Zealand and has been discussed by Rowarth *et al.* (2006a, b, c) and Rowarth and Goldblatt (2006). In support of this, the latest (2008) Ministry of Education data indicate that of the Bachelors degree cohort of approximately 19 600 domestic students, only 9% were in the natural and physical sciences, and only 1.7% were in engineering, with another 0.9% in 'agriculture, environment and related studies'. In contrast the performing and creative arts graduates have increased to over 12% of the cohort. Perhaps of even more concern is that numbers of PhD graduates in science and engineering (including agriculture, environment and related studies) has decreased from 210 in 2002, to 138 by 2008 – a 34% decrease.

The *status quo*

As discussed above, the current New Zealand science system has been designed to ensure that 'process is followed' in the belief that 'efficiency 'will increase when there is conformity to policy. Such thinking is also heavily based on belief in competition, which is thought to encourage excellence (as it does in sport). This position has evolved into a high-accountability, managerialist approach that is now excessively focused on funding success and not the science itself. It is true that stringent competition is a legitimate business model that aligns well with efficiency concepts formulated last century (Hamel 2009). Although a conformity to policy still remains a critical prerequisite to increasing greater efficiency in business (and has now largely been achieved in many industries), it is now recognised that there is also a fundamental requirement for innovation that is necessarily based on diversity in thought and action (Hamel 2009). A recent paper in the *Journal of Theoretical Biology* (Nettle 2009) makes the same point: in times of stress, it is important to have risk-takers and innovation to lead to adaptation and survival.

Of concern is that pure business systems are not appropriate to science. At worst they are able to engender group mind-sets where those people who get ahead are those that understand the process and appear to be efficient. The danger is that such conformist models are able to remove 'interesting and imaginative people' (Charlton 2009). With managers rather than creative scientists in charge in New Zealand, the drivers have become process-orientated rather than innovation-based. This has been greatly accentuated by (a) the need to report to boards of directors dominated by commercially savvy rather than scientifically literate members, and (b) the requirement for end-user support/approbation in some areas of research. The latter has led to industry sometimes demanding not only short-term science outcomes, but worse, how the outcomes may be achieved. This is effectively commissioned research that is sometimes little more than developmental activity or extension.

Commissioned art and literary works have been shown to contain less creativity and innovation than works that arise spontaneously (Amabile *et al*. 1986). From a study involving research and development scientists and technicians, specific enhancers of creativity were identified (Amabile *et al*. 2005). These included organisational, supervisory and work group encouragement, freedom and autonomy, allocation of resources to innovative projects, and challenging work without pressure of budget/deadlines (Amabile *et al*. 1996, 2005). Encouragement and freedom mitigate the effects of time pressure: whereas high time pressure always has a negative impact on creativity, medium pressure in a supportive environment can enhance creativity (Baer & Oldham 2006).

Concerns about the negative effect on innovation of the current science management regime have been borne out by the OECD Review of Innovation Policy: New Zealand (OECD 2007). The report further observed that a number of factors are leading to major threats to the science system. Most notably these include:

- the 'fragmented system of government support for R&D and innovation',
- the 'inappropriate incentives for public-sector research institutions with respect to building long-term capabilities, financing research infrastructures and transferring research results to business',
- 'shortcomings in the process of technology diffusion', and
- 'deterioration in the long-term capabilities of public research institutions, including through failure to pay internationally competitive salaries for professors and scientists'.

Conversely, opportunities were identified via New Zealand's 'strengths in science and technology in resource-based industries and related value-added services' and 'more efficient exploitation of New Zealand's environmental advantage'.

Related to the above, the latest OECD Economic Survey (OECD 2009) has pointed out that the central determinant of labour productivity growth is the rate of innovation. It is new ideas and technologies that improve the efficiency with which firms and workers use the capital at their disposal. Furthermore, higher skill levels in the workforce foster greater innovation and entrepreneurship and increase ability of economies to absorb, implement and adapt ideas generated by others.

Innovation is considered to be supported and stimulated by government-funded 'public good' research, whereas economic growth is driven by business expenditure on research (OECD 2003; Johnson *et al*. 2007). In New Zealand, gross domestic expenditure on research and development (GERD) is well below the OECD average (1.16% GDP cf. 2.26% GDP) and business expenditure on research and development (BERD) is very low indeed (Table 3).

Table 3. Expenditure on research (OECD 2008).

Country	GERD (GDP%)	BERD (% of GERD)
United States	2.62	70.3
Switzerland	2.90	73.7
Denmark	2.43	66.6
United Kingdom	1.78	61.7
Australia	1.78	54.1
New Zealand	1.16	41.8

When GDP is considered, the OECD average for BERD is three times that of New Zealand, and per capita it is 3.7 times that of New Zealand (OECD 2008).

These low investment figures have resulted in increasing effort to change New Zealand's research investment profile. Suggestions from the OECD report included fostering business–research links to facilitate commercialisation of new ideas and hence improve the rate of return on public sector R&D, by (a) encouraging co-funding for research between government and industry, and (b) re-jigging the current contestable funding models to weight bidding success towards projects with industry involvement.

Interest in public–private partnerships has been stimulated with the launch of the Primary Growth Partnership by the Minister of Agriculture, Hon David Carter, and this received considerable attention at the NZIAHS Forum* 'New Initiatives to Improve the New Zealand Science System' in June 2009. Speaking for the Minister of RS&T, Dr Paul Hutchinson stated that science and innovation need connection with New Zealand Trade and Enterprise and business, perhaps along the lines of the 'Singapore Model'. FRST funding will be moved to strengthen business links with increased technology transfer to end-users, and encourage entrepreneurs to work alongside scientists to create more 'market pull' (Murray Bain, pers. comm. June 2009).

Furthermore, four steps are under consideration by the New Zealand Treasury to achieve excellence in innovation (Struan Little, pers. comm. June 2009): These are:

- a statement of innovation priorities issued by the Government,
- reduction of business concerns around support for assistance with R&D – reduce fragmentation and complexity; provide single entry,
- tighter direction of the funding of CRIs and universities into business, and decrease in transaction costs – research priorities to be affirmed by business, with increased incentives to bring industry on board, and refine the PBRF to allow industry links to be of value,
- an increase in financial incentives for business R&D, e.g. tax credit, innovation vouchers, prizes, new grants schemes.

It thus appears that Treasury is focused on stimulating innovation in business research by involving CRI and university researchers, and hence, potentially, their funding.

* New Zealand Institute of Agricultural & Horticultural Science Forum, Lincoln University, 2009, http://www.agscience.org.nz/index.html

Business research

Although business research is important in driving economic growth (Johnson *et al.* 2007), it is fraught with difficulties in management, as are public–private partnerships. Such difficulties include an understandable focus on short-term goals to ensure a return on investment to shareholders, and a similarly understandable focus on ownership of intellectual property (IP). Consortia established on the CRI-business partnership model took longer than expected to settle, apparently because of IP concerns. Likewise, they have not produced the outcomes expected because of an emphasis on short-term delivery of benefits.

Of further concern is that New Zealand already has very high end-user input in deciding on research direction. The bulk of FRST funding requires end-user support. This has prompted the suggestion by some that in New Zealand the funding system is not 'investing in science' but merely 'contracting itinerants to do pre-determined jobs'. The necessity for industry co-funding in some areas has put research teams at the disposal of industrial entities seeking to create intellectual property for their own shareholders. A further comment is that, in order to achieve business support, researchers spend more time in consultation than they do collecting and analysing data. Increasingly, New Zealand scientists feel that they are 'jobbing researchers rather than serious contributors to international science'.

New Zealand's plan

New Zealand's science system does not need the sort of review that calls for deconstruction and re-creation. The spirit of the original intention can be restored by realigning its components, and by turning back what has been ideological application of its legislative framework. This includes ensuring a balance of commercial and scientifically experienced board members to ensure appropriate governance. At the same time, competition needs to be set and maintained at a level similar to that found in other small OECD economies.

Discussion and Conclusions

As a small OECD country, uniquely dependent on its primary industries, New Zealand faces rapidly changing social, environmental and trading challenges. The country is in the process of accommodating accelerating demographic shifts, arising in part from its proximity to Asia. Cutting across such socio-economic considerations (with their corresponding threats and opportunities) is the imperative to achieve such things as:

- maintaining environmental quality in the face of challenges such as the intensification of agriculture (including dairying),
- responding to climate change and the implications of the 'carbon economy',
- understanding and managing the public health consequences of 'Westernisation', and
- facing the prospect of potential catastrophe of sudden and severe biosecurity failure (including the arrival of realised and potential zoonoses, such as SARS, and zoonotic influenzas).

The ability to handle such circumstances depends heavily upon science-based understanding, solutions, discovery and invention. New Zealand will not progress as a distant follower in a competitive knowledge-based world. Another consideration is that, because of what New Zealand does and where it is, many science problems and opportunities cannot be fulfilled by systems developed elsewhere. It is essential that this country punches above its weight scientifically and exercises good judgment about how to use, protect, and administer scientific capability.

Such undertaking must involve recognition that New Zealand needs a science system with which to identify and promote areas of competitive advantage. Often these areas emerge 'spontaneously', rather than arising from foresight-based planning, which generally is not a useful way to manage a science system. Such consideration, coupled with the need for engagement with international research, means that science leadership is best undertaken by experienced researchers rather than generalist administrators, irrespective of levels of goodwill and motivation. Similarly, good governance requires that the boards have an understanding of science culture.

Basic entrepreneurial economics state that creating a sustainable competitive advantage requires access to excellent scientific research, skilled and creative product development teams, strong sales teams able to sell the concept or product, and a superb reputation for innovation and quality. For New Zealand to profit from research and development, funding needs to be increased to approach the OECD average and be inflation-adjusted and, perhaps of more importance, creative capability needs to be realised. How to do the latter is clear: encourage and value the incremental steps associated with science that coalesce to allow the sporadic 'breakthroughs'. Such gradual but inexorable progress can often be overlooked in pursuit of aspirational, and sometimes externally imposed, milestones and goals.

In order to achieve its goal of OECD-competitive economic development, New Zealand needs leadership rather than management. Vision and inspiration will encourage and liberate current employees, and attract future talent. Both of these attributes can be found at many levels in New Zealand, but such opportunity is hobbled by a managerialist science system where the demand for continual reporting and rebidding for small amounts of funding (both Crown and commercial) are the rule. Problems are now distinctly exacerbated by the requirement for 9% return on assets. This is made worse by the fact that, despite best intentions, research funding is sliding inexorably backwards in the face of inflation; this is in contrast to other countries' increased investment as they, too, seek economic development.

Further points to consider and address relate to the existing confusion in the setting of research direction. Is it industry, FRST, government, the boards, or the scientists who are in the best position to know what should or could be done to advance understanding?

With the innovation and business research initiatives currently being discussed at high level as part of the Government's six policies to improve productivity in the future, are there ways that scientists can work more closely with industry that don't result in industry dictating direction? Not least of these six is the idea that New Zealand industry must become more effectively innovative. It is notable that this is not the same thing as seeking ever-increasing efficiency.

Recommendations in the National Science Panel's Science Manifesto (2008) laid the groundwork for the suggestions and focus presented in this paper. The Chief Scientific Adviser to the Prime Minster has been appointed. Much consideration must now be given by all parties to the conundrum of productivity and commercialisation while preserving creativity and discovery.

Scientists need time to think, read, reason and talk. They need time to be creative and experience the satisfaction of following a scientific lead. Unless they are given a proper science environment there will be no pipeline of creative ideas to commercialise. Achieving innovative science is not a matter of managing workers for ever-greater efficiencies, but of trusting the professionalism of highly educated and creative people to do great work for New Zealand's future.

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